European Decapod Fisheries : Assessment and Management (EDFAM)

Concerted Action

Contract number QLRT 1999 01272

Draft Final Report

EDFAM participants

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Workpackage 1: Draft Final Report

I. Monitoring and Research of European Crustacean Fisheries
II. The European Crustacean Fisheries Metadatabase (ECFM)

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Workpackage 1 of EDFAM

The draft final report of EDFAM describes 3 principal deliverables of Work Package (WP) 1 of EDFAM

1. The current monitoring and research activities for Crustacean Fisheries in Europe (this document)
2. A newly developed metadatabase which holds metadata relevant to the biology and fisheries for crustaceans in Europe. This is hosted on the www and available to the public (this document)
3. A series of papers reviewing the biology and fisheries for each of the commercially important decapod crustaceans in Europe (report of WP1, Part III)

1. Biological Data on Decapods held by Participants

1. *Trinity College Dublin, Marine Institute and Irish Sea Fisheries Board*

The description below represents the data available in Ireland rather than in Trinity College only (data by TCD, BIM and MI)

The fisheries

In Ireland the following species of crustacean, listed in order of economic importance, are fished commercially

- *Nephrops norvegicus, Cancer pagurus, Homarus gammarus, Palaemon serratus, Maja squinado, Palinurus elephas, Necora puber, Carcinus meanas, Chaceon affinis*

These species are to some degree the subject of mixed species fisheries. For instance *Homarus, Cancer*, *Palinurus* and *Necora* can be captured by the same trap on the same fishing day on the same fishing ground. These species are captured both inshore in very shallow water and in the case of *Cancer* and *Chaceon* to the edge of the continental shelf at 200 and up to 800 m depth respectively. *Nephrops* is the subject of a trawl fishery in the Irish Sea, Celtic Sea and west coasts although trap fishing for this species has previously taken place on the south coast. *Palaemon* is captured by specialised traps in shallow water in embayments on the south and west coast. There is a single fishery for *Maja*, on the south west coast, although fisheries in other areas on the west coast are being developed. This species is at the northern end of it's range in Irish waters.

Monitoring

Catch and effort : Landings data are compiled by the Department of Commications, Marine and Natural Resources. Fishing effort and CPUE by ICES statistical square can be estimated from log book data for *Nephrops*. Effort and landings data by average daily GPS position are also available for the offshore component of the *Cancer* fishery on the north west coast. This has been generated through specific research projects rather than a long term monitoring programme operated by the state. More recently voluntary logbooks have been introduced to the inshore crustacean fishery and approximately 2000 fishing days are currently reported.

Size distributions: Size distribution data for Nephrops have been collected on a monthly basis for a number of years from the different ICES management units. More recently size distribution data for lobster by region and for the main *Cancer* fisheries have been collected. A new program for shrimp (*Palaemon*) began in 2003. Fishers collect random samples from the catch on alternate weeks during the fishing season and freeze and store these samples for collection by BIM. Age, growth, mortality and yield per recruit estimates will be obtained.

Research: The majority of data on crustacean fisheries have arisen as a result of particular research projects. These projects are funded either by national government or under the EU research programmes and are not designed for long term monitoring of the fisheries.

Nephrops norvegicus :

Annual or bi-annual research surveys were undertaken in the Irish Sea between 1986-2000. The objectives were to detect changes in stock abundance using the CPUE from standardised 30 minute trawls. Because of short term changes in catchability however it is difficult to standardise the CPUE and it is unclear how changes in stock are reflected in the survey data. Numerous factors such as time of day, tide and reproductive status affect catchability of *Nephrops*.

Size distribution data are collected on the surveys. Spatial variability in the shape of the distributions were described in 1989 and 1990 and correlations between growth and mortality and sediments, temperature and fishing effort have been estimated. Estimates of Z and spatial distribution of fishing effort are correlated.

Extensive analysis of size distribution data has been undertaken in order to derive growth and mortality estimates

Studies on size at morphometric and physiological maturity of males and females have been carried out in the Irish Sea.

Population structures have been preliminarily defined using isozyme data.

The use of age pigments (lipofuscin) to estimate the age structure of *Nephrops* in the Irish Sea has been investigated with limited success.

Spawning stock biomass of *Nephrops* in the Irish Sea has been investigated on a number of occasions from egg and larval production estimates

The size (growth rate) and metabolic condition of *Nephrops* larvae in relation to physical oceanographic conditions have been studied in the western Irish Sea gyre.

Stock Assessment : This species is assessed by the ICES Nephrops WG who use a pseudo-age based VPA technique to estimate population size and fishing mortality.

Management : This species is managed by a TAC and an MLS that varies geographically.

Homarus gammarus :
Catch and effort : On the south east coast monitoring of catch and effort has been in place since 1995 as part of an assessment of the impact of adjustments to technical conservation measures in the area. Daily catch of legal, undersized and v-notched lobster are recorded on a daily basis by between 10 and 25 vessels depending on year. Soak time for traps is recorded. Older data from the 1950s and 1960s are available for the south east coast fishery. A small amount of data on catch and effort is available for the south west coast for 1996-1999.

The size distribution of the landings has been recorded annually from 1995-2000 on the south east coast and during the 1998-1999 seasons on all other coasts. Data for the south east coast were collected also in the 1960s.

Biological characteristics : Data on size at maturity and the size fecundity relationship were obtained for all coasts in 1998 and 1999 as part of an EU biological studies programme. Some information on moult increments were obtained from tag returns in the 1960s and 1990s on the south east coast. Growth rates were estimated for the south east coast in the 1960s.

Larval distribution : Data on the distribution and abundance of larvae are sparse. Most of the data are for Galway Bay on the mid west coast from 1982-1985 and for the south east coast from 1995-1999. Vertical migratory behaviour of the larvae has been described.

Juvenile ecology : Despite numerous surveys no data are available for the early benthic phase. In fact the early juveniles have never been found.

Assessments : Yield and egg per recruit models have been developed and have been used to make recommendations to industry on technical conservation measures and effort control. Mark recapture data have been used to estimate stock size and exploitation rate on the south east coast from repeated Petersen estimates.

Regulation : Lobster fisheries are managed by minimum landing size which is currently 87 mm. Legislation to protect v-notched females (females with a v-notched mark on the tail fan) is also in place since 1994. Release of hatchery reared juveniles has been practised in some areas during the 1990s. Discussions are underway to restrict entry into this open access fishery through a licensing scheme.

Cancer pagurus :
The major fishery, representing 80% of national landings, is on the north west coast. The fleet is mainly artisanal making daily trips usually within 10 km of the coast. A small fleet of larger vivier vessels fish offshore to the edge of the continental shelf. Effort is increasing in the offshore sector.

Catch and effort : Data has been collated from the private diaries of the offshore vessels since this fishery began in 1990. For each 'string' of 125 traps deployed the GPS position at the start and end of the string, the total number of traps on the string, the soak time and the resulting catch is available. Catch and effort for the inshore fishery has been collated indirectly by reviewing purchase records of local co-operatives and processing plants that buy crab from the inshore fleet. These data give the boat name and the total weight of crab landed on a daily basis. Effort has been associated with this catch by interviewing skippers to find out the total number of traps used by each boat.

Size distribution of the landings : Available for 1997-1998 and for 2001-2003 for the north west coast fishery. These data have been collected at fine spatial scales and have associated GPS data.

Biological characteristics : Data on size at physiological maturity of females and morphometric maturity of males was collected in 1997-1998 and again in 2003 on a regional basis. Fecundity data are also available for 1997-1998. Moult increment data of juveniles are available from individuals held in re-circulation systems and from modal analysis of size distributions collected by suction samples from the seabed. Growth data are also available from mark recapture studies. Tagging has been used to monitor migration of males and females.

Larval and juvenile ecology : Some data on the seasonal occurrence of larvae is available for the south east coast and for Galway Bay. A dedicated survey was completed in 2002 off the north west coast to the edge of the continental shelf to describe vertical and horizontal distribution using Longhurst Hardy Plankton Recorder, Gulf VII and Neuston samplers. Densities of early juvenile stages on the seabed have been quantified on the south east coast by SCUBA operated suction sampling. Seabed mapping has been undertaken in a number of coastal areas with a view to describing Cancer-substrate associations and variability in sex ratio and size distributions on different substrates.

Interactions with other fisheries : Soft shell and white faced (recently moulted) crab are used as bait in the whelk fishery on the south east and east coasts. Data on the amount of crab going to this fishery have been evaluated.

Assessment : No formal assessments have been carried out. The catch and effort data may be suitable for production modelling or through a time series analyis forecasting of CPUE may be possible. The fine spatial scale data on catch and effort facilitates the application of depletion methods while minimising violation of the assumptions of the models. Movement of crab and short term changes in catchability, however, complicate a straightforward application of these methods. Incorporation of mark recapture data into the depletion has been evaluated in collaboration with CEFAS. Yield per recruit analysis is possible although construction of a representative size frequency distribution is difficult for this migratory stock. Yield per recruit analysis is important in this species because the yield or recoverable meat from a crab varies substantially during the moult cycle. Identifying individuals with high meat content is a problem in the species.

Management : The fishery is managed by a national minimum landing size of 130 mm carapace width. The market, however, which prefers crab greater than 140 mm has more effect on the size of crab landed from the offshore fishery. The fishery is in open access within the constraints set by MAGP IV.

Palinurus elephas :
This fishery has declined substantially and no longer exists in many coastal areas where this speceis was once common. Overfishing by tangle nets in the 19970s is thought to have been the main cause of the stock collapse. Possibly 20 vessels currently target this species on a seasonal basis nationally.

Sporadic data on size distributions are available from the 1960s and 1990s. Total landings data are collected by port.

A small amount of CPUE data are available for the south west coast.

No assessments have been carried out.

Recent EU legislation has set a minimum size of 110 mm carapace length.

Palaemon serratus :
Fishing for this species began in the 1970s on the mid west coast. Today the species is fished on the mid west and south west coast. It is shorter lived (3-4 years) that other decapod species fished in Ireland. The fishery is prone to local recruitment failure.

Landings and effort : Landings data are recorded by port and have increased substantially in the late 1990s but has declined since 2001. No effort data are available but it is increasing significantly.

Size distributions : Some size distribution data have been collected on the west and south west

Catch and effort data : CPUE has been estimated mainly from commercial data

Biological characteristics : Age and growth has been calculated from analysis of length frequency distributions. Maturity of females and the seasonal cycle of reproduction has been estimated from observations of ovigerous females and on the development of the gonad.

Larval distributions : Data on the seasonal occurrence of larvae are available for Galway Bay.

Assessments : No formal assessments have been carried out. Yield per recruit is an important consideration as the fishery may begin too early in the season to allow growth of juveniles. Protection of local spawning stock may be important, as dispersal of larvae may be restricted. Unknown patterns of migration and stock structure make it difficult to collect representative size and age frequency data.

Management : There are no management controls

Maja squinado
This species is fished in one location on the south west coast. The stock structure is unknown. New fisheries on the west coast are beginning.

Catch and effort : Total landings data are collected. Effort is unknown. Indices of CPUE have been developed although it is unclear if they are representative of stock changes

Size distributions : Size distribution of the landings for certain years are available and indicate a strong within season impact on size.

Assessments : None available

Necora puber
This species is common on all coasts. Only landings data are available. Some biological information was collected previously on the east coast fishery. Size at maturity and size fecundity relationship are currently being evaluated. No assessments have been undertaken.

Carcinus meanas
Since 2001 a fishery has developed for Carcinus meanas on the west coasts of Ireland. Data on catch rate have been collected.

2. Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK

The following are the data collection programmes for crustacean fisheries in the UK

Fisheries

The decapod crustacean fisheries around the coast of the United Kingdom are routinely monitored by three Government Agencies, the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in England and Wales, Fisheries Research Services (FRS) in Scotland, and the Department of Agriculture and Rural Development in Northern Ireland (DARDNI). The role of the agencies is to carry out monitoring and assessment of fish and shellfish stocks, and to provide advice on their management to the UK Government. All three organisations also carry out research activities, which include the collection of data that may be incorporated into stock assessments and fisheries management advice. In addition there are a number of regional bodies which have their own data collection programmes, for example the Sea Fisheries Committees in England and Wales, and to a lesser extent Universities and other academic institutions carry out research programmes that may produce important data in relation to stock assessment and fisheries management.

In general, data on crustacean fisheries in the UK are characterised by long time series of landings data on a relatively fine scale, in some places since the beginning of the 20th century, but because of the artisanal nature of the fisheries, the true landings may be significantly underestimated in some areas. Data on fishing effort are not well documented on a national basis for all species, although locally some fishers log book schemes provide good reliable information. Size distribution data have been collected on a regular basis since the early 1970s for most species on a reasonably fine spatial scale. The following paragraphs summarise the main data collection programmes for each species in the UK. The summaries are split into routine monitoring programmes and research projects which have collected large amounts of data which could be used in assessments. This is by no means an exhaustive list, but is meant purely to give the reader a flavour of the level of data that is available for the UK fisheries.

Nephrops norvegicus

Routine monitoring: *Nephrops* fisheries have been monitored routinely for the last 30 years by CEFAS, FRS and DARDNI. Landings data are collated by port, and effort data are compiled from obligatory EU log books. Size distribution data are also collected monthly at all the main ports. Landings of *Nephrops* have been relatively stable in the UK over recent years, and assessment of these stocks is carried out by the ICES *Nephrops* Working Group.

Research studies: In addition there has been a series of major research programmes which have collected data which are useful for stock assessment. Discard surveys of *Nephrops* are routinely carried out in many fisheries, independent trawl surveys are undertaken, and for many years Scottish scientists, and in more recent years, English scientists, have undertaken underwater TV surveys of *Nephrops* burrows, which are used to derive fishery-independent estimates of stock abundance. Larvae surveys have been carried out on numerous occasions for the various *Nephrops* stocks, and these have also been used to provide fishery-independent estimates of stock abundance. Fine scale effort mapping of the fishery, and growth studies in relation to the nature of the substrate are two facets of a major research programme on *Nephrops* carried out by FRS in Scotland over the last two decades.

Homarus gammarus

Routine monitoring: Landings of lobsters are routinely collected around the coast of the UK on a port basis and have been for most of this century. Currently landings are relatively stable, although they were higher at various times in the early part of the 20th century up to the

1960s. Effort data are recorded but generally they are of poor quality. In England and Wales size distribution data are collected by port by month. This data set extends back to 1972 and is extensive for many fishing areas, but is not complete for a number of less important fishing regions. Catch per unit effort (CPUE) data recorded on a daily basis have also been collected by CEFAS on an *ad hoc* basis since the 1960s, but more systematically for around 50 vessels since 1987. Similar data collection schemes for landings, effort and log book data exist in Scotland and Northern Ireland. In addition 8 of the 12 Sea Fisheries Committees (regional fisheries management bodies in England and Wales) have shellfish permit schemes which require the completion of daily catch rate information for the lobster and crab pot fishery. These data sets provide a comprehensive summary of fishing effort, fishing position and landings for all the lobster and crab vessels fishing within 6 miles of the coast in each area. Some permit schemes have been in operation for only a short period of time, but the scheme in South Wales has now been running for 23 years, and provides an excellent database with which to carry out assessments. In 2004 a restrictive licensing scheme for crustacean (pot and net) fisheries will be introduced. Licence holders will have to provide obligatory returns of catch and effort data on a daily basis, which should significantly improve assessment capability. Assessment of lobsters is carried out currently on a regional and national basis at present using local growth data, and maturity and fecundity data collected on a large regional scale.

Research studies: Three major research studies have been carried out by CEFAS which provide a range of data that may be useful for stock assessment. Firstly, a long term study of the Bridlington lobster fishery over 15 years has provided information on spatial and temporal variation in catch rates, in addition to pre-recruit indices which can be used to predict catch rates in the following year. Secondly a major programme of release of hatchery-reared juvenile lobsters has shown that they can survive to recruit to the fishery, and has provided important information on growth rates and survival and movement patterns within the fishery. In parallel hatchery-reared lobsters have been released in three other sites by the Sea Fish Industry Authority and North Western and North Wales Sea Fisheries Committee. Two lobster hatcheries, in Cornwall and Orkney, are in operation currently. Thirdly an ongoing programme on age determination by Leicester University in conjunction with CEFAS has produced a size-age relationship for lobsters based on accumulation of lipofuscin pigment. There have also been a number of programmes on lobsters around the UK which may have a bearing on assessments. For example, Southampton Oceanography Centre have been studying lobster behaviour on an artificial reef and investigating movement patterns in relation to habitat selection and catchability, various bodies have received PESCA funding to initiate V-notching programmes for lobsters, and a range of tagging programmes has been carried out. There have been two larvae surveys for lobsters on the east coast of England but little sound quantitative data are available.

Cancer pagurus

Routine monitoring: The fishery for brown crabs is routinely monitored in the same way as for lobsters described above, and indeed in most fishing areas, lobsters and crabs are caught in the same gear. Currently the status of stocks varies considerably around the UK, with fishing mortality rates very high in some of the traditional fishing areas, whereas some offshore areas are only lightly exploited. As with lobsters, local Sea Fisheries Committees also collect landings and effort data on a fine spatial and temporal scale, and the forthcoming introduction of the shellfish licensing scheme will provide more accurate data for assessments. Assessments are carried out for England and Wales, Scotland and Northern Ireland based on local growth data and fecundity and maturity data collected on a relatively large regional scale. A recent European Commission funded project considered both new and conventional approaches to crab stock assessment including the use of depletion methods.

Research studies: A major series of tagging studies was carried out by CEFAS in the 1960s and 1970s and this has provided considerable information on growth rates and migratory movements of female crabs between fishing areas. In recent years CEFAS has also undertaken very detailed catch monitoring on a fine spatial scale in both the North Sea and English Channel fisheries. This has provided important information on small scale movements of crabs which could have important consequences for assessments based on local size distribution. Three detailed larvae surveys have been carried out in the North Sea and one in the English Channel and the results of these surveys in conjunction with new hydrographic information are casting new light on stock definition of crabs. An ongoing programme on age determination by Leicester University in conjunction with CEFAS has produced a size-age relationship for *Cancer pagurus* based on accumulation of lipofuscin pigment. Genetics studies at Royal Holloway College, University of London and Hull University have identified microsatellite markers for *Cancer pagurus*. Studies have also been undertaken on the efficiency of various sizes of escape gaps at releasing juvenile undersized crabs and lobsters from pots.

Maja squinado
Routine monitoring: In the UK there is a low level of monitoring of landings, effort and size distribution data for spider crabs, but because this is a small fishery in the UK, it is not a priority species for data collection. Those Sea Fisheries Committee areas where spider crabs are caught will also have data recorded on their permit scheme return sheets. There have not been any major research studies on this species with the intent of providing parameters for stock assessment, except for some tagging work to study migration, but the forthcoming shellfish licensing scheme should provide much needed data on trends in catch and fishing effort.

Palinurus elephas
Routine monitoring: Crawfish landings are routinely recorded at ports but this is a small fishery in the UK with landings principally occurring in South Wales and Cornwall, where catches may occur in pots, nets and previously by diving. The most extensive fisheries statistics come from South Wales where over 20 years of catch data from pots and nets have been accumulated. No routine assessments are carried out because the UK fishery is at the northern end of the range of *P. elephas*, and the stock structure is unknown.

Research studies: A major study of the crawfish fishery and biology relating to assessment was carried out in the 1990s and this has been published in the peer reviewed literature (E. Hunter *et al*., 1996. Recent studies on the crawfish *Palinurus elephas* in South Wales and Cornwall. JMBA **76**, 963-983), but this is not a species which has been widely studied in the UK.

Crangon crangon
Routine monitoring: Landings and fishing effort for *Crangon crangon* are routinely collected in all the main fishing areas, and information on graded landings is available which can be converted to an index of size. The main fishery is in The Wash and adjacent areas, and detailed fishery information is available for this fishery since the mid-1980s when a major expansion of the fleet occurred.

Research studies: There have been major research studies on the catch, effort and size distribution for The Wash and Solway Firth fisheries. These studies collected detailed information on spatial and temporal variations in catch rates, size distribution and recruitment which can be used for stock assessment. In addition major studies have been carried out on gear selectivity and discard patterns of *Crangon* principally in The Wash fishery, and the biological and economic impacts of discarding by-catch of commercial fish species.

Pandalus spp.
Fisheries statistics are routinely collected for *Pandalus spp.* around the coast of the UK. There is a small fishery for *P. borealis* in Scotland, with very minor landings of *P. borealis*

and P. montagui in England. No major research studies are currently underway, although there are a wealth of previous studies from the 1970s and earlier on the biology and exploitation of *Pandalus spp.*

Palaemon serratus
The pot fishery for Palaemon has developed significantly in the UK over the last few years, and this expansion is being carefully monitored. The main fishery is in Wales, but to date little scientific work has been undertaken on this fishery.

Necora puber
Velvet crab is becoming increasingly important commercially, but the fisheries statistics for this species are still not recorded on a national basis across the UK, although landings information is available in a number of regions, and some size distribution data have been collected. There is some Scottish data for these fisheries but no major fisheries studies have been carried out in England and Wales. Most of the biological information can be found scattered amongst the marine literature and has been collected primarily by Universities.

Chaceon affinis
The fishery on the shelf edge for the deep water red crab, Chaceon affinis, has developed significantly in recent years and landings into many of the ports on the western coast of the UK are now monitored routinely. Relatively little scientific work has been carried out to date in relation to this fishery.

Munida, Galathea, Carcinus etc..
There are a number of other crustacean species which are occasionally landed commercially in the UK, but which are not subject to routine fisheries monitoring programmes, although landings may sometimes be recorded.

3. Institut Francais de Recherche pour l'exploitation de la Mer (IFREMER)

The fisheries

Respective importance of the crustacean fisheries in France can be seen through the following figures (indicative data) :

Nephrops norvegicus 7000 t, 9.2 euro/kg, value 64 Meuros,
Cancer pagurus 6500 t, 2.7 euros/kg, 18 Meuros,
Maja squinado 4500 t, 2.7 euros/kg, 12 Meuros,
Homarus gammarus 400 t, 20 euros/kg, 8 Meuros,
Palinurus elephas 100 t, 35 euros/kg, 3.5 Meuros,
Palaemon serratus 150 t, 25 euros/kg, 3.8Meuros,
Necora puber, 500 t, 4 euros/kg, 2.0 Meuros.

Nephrops is a trawl fishery, *Palinurus* a tangle net fishery, *Cancer, Homarus, Necora* and *Palaemon* trap fisheries. *Maja* is fished both by traps and tangle net. *Cancer* and *Homarus* are also by-catch of the tangle net fishery aimed at fish. It shall be noted that most of these fisheries are mixed fisheries insofar as a same trap can catch at a same time *Cancer, Homarus, Maja* and *Necora* ; in addition, a great proportion of the boats in the crabs and lobster fishery are fishing with pots and nets.

Monitoring
Since 2000, the **activity** of every professionnal fishing boat is monthly documented in term of "métier" defined as « a type of fishing gear operated to catch one or several targetted species

on a fishing area during a given period ». This continuous census is carried out by Ifremer which is also responsible for data storage and analysis.

Landings and effort data from, supposedly, every boat are collected through european logbooks (boats larger than 10 meters) and national logsheets (boats smaller than 10 meters). Those data completed with auction markets data are recorded in a national base under Ministry responsability. Unfortunatly the lack of reliability, (specially concerning fishing effort) prevents from using this data base except for Nephrops fished in area VII (see below). In addition, a (unfortunetly small) sample of european logbooks and/or fishermen personnal logbooks is collected by Ifremer to derive C.P.U.E. for *Cancer* and *Homarus*.

Nephrops landings are precisely known, since they are all recorded in the auctions. The quality of effort data depends on the fisheries. Effort is well documented for the Celtic Sea and the Porcupine Bank, since the EU logbook regulation is enforced. This is not the case for the Bay of Biscay where very few skippers fill in their logbooks regularly : only 15% of *Nephrops* auction sales from this area can be linked to logbook data.

Size distribution : sampling of landed *Cancer pagurus* and *Homarus gammarus* is carried out, since 2002, in the frame of a contract with EU. Data are recorded by IFREMER.

Table summarising landings, fishing and sampling activity for crustanceans in France

FRANCE	Landings	Boats	Gear	Auction	Logbooks	CPUE	Quay sampling	Sea sampling
Cancer pagurus	~ 6000 t	))	Pot	No	+ or -	Offshore fleet	1985-87 2002 +	Some
Maja squinado	~ 5000 t	)) ~800	Pot and Net	No	+ or -		no	Some
Necora puber	< 300 t	)	Pot	No	+ or -		no	Some
Homarus gammarus	~ 400 t	))	Pot	No	+ or -	some	2002	Some
Palinurus elephas	~ 150 t	> 200	Net	No	+ or -		no	Some
Palinurus mauritanicus	~ 10 t	?	Net and Trawl	No	+ or -		no	No
Nephrops norvegicus	~ 7000 t	~ 300	Trawl	Yes	+ (area VII) - (area VIII)	yes	Yes	Yes
Palaemon serratus	< 500 t	100 ?	Pot	Some	+ or -		no	No
Crangon crangon	~ 500 t	?	Trawl	?	+ or -		?	?

Nephrops norvegicus :

Assessments of the *Nephrops* stocks exploited by French vessels are carried out by the ICES *Nephrops* working group.

Porcupine bank

Landing and effort : this stock is exploited only in summer by French vessels. Twenty years of landing and effort data are available. Landings show fluctuations with low values in the late 1980s (300-600 t), higher values in the mid 1990s (1000-1200 t), and lower values again in the most recent years (300 t).
Sampling : Eight years of size distribution of landings are available.
Biological characteristics : very few studies have been performed. Female growth was studied in the 1980s, and other biological parameters used in assessment are based on values in other areas.

Regulation : this stock is managed by a TAC set for area VII and a MLS clearly above the EC one for market reasons (35 mm, instead 25 mm CL). 90 mm codend mesh size can be used (instead of 100 mm for finfish) provided that a minimum percentage of *Nephrops* in the catch is respected (70%).

Celtic sea

Landing and effort : French landings form the Celtic Sea have been slowly decreasing since the peak value of around 5000 t in 1977, to around 3500 t in 1993-95. From 1996 onwards, they have been fluctuating between 2000 and 3000 t. Twenty years of effort data are avalaible (‘000 hours fishing from logbooks).
Sampling : length composition data of the French landings are available since 1987, but discard data are available for 1985, 1991 and 1997 only. The numbers discarded at length for years without discard samples were derived from the ratios between the numbers discarded at length and the total numbers landed (all sizes combined) in the years when discard sampling actually took place. Discards are substancial in this fishery.
Biological parameters : they have been studied in the 1980s and have not been updated since then.
Regulation : this stock is managed by a TAC set for area VII and a MLS clearly above the EC one for market reasons (35 mm, instead 25 mm CL). Boats fishing for *Nephrops* are allowed to use a 90 mm codend mesh size, but they prefer to avoid problems with the minimum percentage of *Nephrops* that is required, and therefore generally use 100 mm meshes instead. The 100 mm mesh size also allows them to switch to finfish when *Nephrops* catch rates are low (during the night for example, or during periods of bad weather).

Bay of Biscay

Landing and effort : throughout the late 1960s and early 1970s, the landings by French trawlers steadily increased, to a peak value of 7100 t in 1974, then fell to 4700 t in 1978. During the 1980s and the early 1990s, landings fluctuated, typically between 4500 and 6100 t, but since 1995 they have shown a clear downward trend. In 1998, they fell to around 3200 t, and they remained at this record low level in the following two years. In 2001 and 2002, the landings increased again to around 3700 t, a recovery to the level of 1997. The logbook regulation is not particularly well enforced in the Bay of Biscay. Effort data are estimated from the available log-books and considered as representative of the whole fishery. This is likely to be biased since many vessels fill their log-books irregularly or not at all.
Sampling : length compositions of the French landings have been sampled since 1987. Discard data are available for 1987, 1991 and 1998 only, and the numbers discarded at length for the other years are derived (using ratios based on total number landed). Discards are substancial in this fishery.
Biological parameters : they have been studied in the 1980s and have not been updated since then.
Regulation : this stock is managed by a TAC and a MLS (25 mm CL). The minimum codend mesh size for *Nephrops* in the Bay of Biscay is 70 mm. There are no longer exemptions for the *Nephrops* trawlers, which previously could use a smaller mesh size than the finfish trawlers, provided that their catches contained at least 70% of *Nephrops*.

Homarus gammarus :

Catch and effort : despite improvement of data collection is on the way, official figures are still poor. Information on C.P.U.E. trend is deduced from a very limited number of fishermen personnal records. Not all area are documented and time serie is short.
Sampling : sex and size composition of landings are sampled since 2002 but the sampling rate remains low.
Biological characteristics : fecundity, female size at maturity, growth have been studied in the early 1980 and result published (ICES Communications).

Regulation : lobster fishing is managed through the EC MLS (87 mm) and the licencing scheme with pot limitation which, in France, applies to crab and lobster fisheries. Some small closed area are scattered along the coast.

Cancer pagurus :

Catch and effort : quality of data allow to derive correct C.P.U.E. for the offshore fleet since 1986, but not for inshore fleet.
Sampling : sex and size composition of landings are sampled since 2002. Similar data were previously got in 1985-1987.
Biological characteristics and ecology : female size at maturity, growth and migration have been studied and result published (ICES Communications).
Regulation : edible crab fishing is managed through the EC MLS and the licencing scheme with pot limitation which, in France, applies to crab and lobster fisheries.

Maja brachydactyla :

Catch and effort : catch data are improving but effort data remain poorly documented, partly because of difficulty in standardising effective fishing effort for spider net.
Sampling : size, sex and « age » composition of catches has been conducted at sea on western Channel potters and netters in 1984-1986. Size and sex composition of annual recruits before fishing season has been established yearly during the period 1986-1996.
Biological characteristics and ecology of spider crab in the Western Channel have been studied in the 1980'.
Regulation : spider fishing is managed through the EC MLS (12 cm) and the licencing scheme with pot and net limitation which, in France, applies to crab and lobster fisheries.

Palinurus elephas :

Catch and effort : catch data are improving but effort data are poorly documented. Spiny lobster is generally a by-catch in fish netting.
Sampling : sporadic data on size and sex composition are avalaible since 1990.
Regulation : spiny lobster is managed through the EC MLS (95 mm). The stock is currently at a very low level.

4. ***Universidade da Coruna (UDC), Spain***

Fisheries

Decapod fisheries are carried out all along the NW coast of Spain (Galicia, Asturias, Cantabria and Basque Country) , but they are especially important in Galicia due to its higher biological productivity and more extensive coastal areas. We have to differentiate the coastal fisheries (from the intertidal to 60-80 m) and trawl fisheries carried out in the continental shelf and upper slope (up to approx. 500 m).

In coastal waters, a diverse array of decapod species is exploited. The targets are spider crab (*Maja squinado*), velvet swimming crab (*Necora puber*), and prawns (*Palaemon serratus* and *P. elegans*), secondary (non target) species are edible crab (*Cancer pagurus*), lobster (*Homarus gammarus*), spiny lobster (*Palinurus elephas*) and slipper lobster (*Scyllarus arctus*). The three lobster fisheries are now overexploited and probably collapsed, showing only anecdotal catches (although some signs of recovery exist for the spiny lobster in deep waters). Many other species have a residual commercial value with some sporadic catches, such as swimming crabs (*Liocarcinus corrugatus* and *Liocarcinus depurator*) and green crabs (*Carcinus maenas*).

In the multispecies trawl fishery in the shelf and upper slope, the Norway lobster (*Nephrops norvegicus*) is only decapod species of commercial value (the second one after the hake). In the 90s some trap exploratory fishing was carried out in the slope for deep-water crabs (*Chaceon quinquedens* and *Cancer bellianus*).

Long-term monitoring programs using direct assessment methods are carried out only for demersal trawl resources (including Norway lobster in these multispecies resources). For coastal species only landing data are available, and routinely obtained, and no direct assessment methods are used. Different research programs, limited in their duration, have studied various aspects of the biology and population dynamics of different decapod species providing also some punctual stock assessments.

Sampling programs

Multispecies trawl fishery in the shelf and upper slope

Trawl surveys for demersal resources in the continental shelf and upper slope

The Spanish Institute of Oceanography (IEO, “Instituto Español de Oceanografía”) carries out annual demersal trawl surveys to assess demersal resources. The main objective is the estimation of recruitment indices for the hake (*Merluccius merluccius*, the species of greater economic value). Data on abundance and catch size structure are obtained, at least, for all the commercial species. The survey is carried out in autumn, covers from 100 to 500 m deep and covers the NW Spanish Atlantic coast and the Cantabrian Sea, and uses a random stratified design. The main results for the Norway lobsters are distribution patterns and relative abundance estimators (CPUE). These surveys started in 1979 in a restricted area and were expanded and adapted progressively.

Port-based samplings of size frequency distributions for demersal trawl fisheries

The IEO develop a program of sampling at port size frequency distribution of landings of the main species in the demersal trawl fisheries. The Norway lobster is included in this program and data obtained comprise size frequency distribution, sex and presence of egg-bearing females.

Landing statistics

Landing statistics (biomass and economic value per species) are recorded daily from all ports and first sale places. These data are available for the Norway lobster.

Exploratory fishery for deep-water crabs

In the 90s some trap exploratory fishing was carried out in the slope of Galician waters for deep-water crabs (*Chaceon quinquedens* and *Cancer bellianus*). Available data were collected by the "Consellería de Pesca, Marisqueo e Acuicultura" (Ministry of Fisheries and Aquaculture) of the autonomous government of Galicia ("Xunta de Galicia", XUGA), consisting in a few surveys monitoring catch rate and composition (sex, size, presence of eggs) in commercial vessels.

Statistical data corresponding to daily landings (biomass and economic value) are available from the "Servicio de Información Pesquera" (SIP, Fishery Information Service) of the XUGA from the different ports and first sale places were these species were landed. Now, there are almost no fishery for this species, although occasionally some catches are reported.

Coastal water fisheries

Coastal fisheries are carried out in Galicia by an artisanal fleet operating between the intertidal and approx. 60-80 m deep along almost 1300 km of coastline. There are more than 80 fishing communities along the coast and 65 first sale places were statistical data are collected. With respect to decapod crustaceans, the main gears used are traps (mostly for velvet swimming crabs and lobsters) and gill- and tangle-nets (for spider crabs). Some divers and intertidal harvesters also catch decapods, but these activities are in most cases illegal, and, although they could have an important impact in the resources, they are no included in the official statistics. Artisanal fisheries for these rsourcesin other NW Spain regions have minor importance, and only a few data of landings are recorded. The following description will be referred to the Galician fisheries.

Three different sources of fishery data are available for the decapod crustacean resources:

1. 1941-1993. Yearbook of Marine Fisheries (Ministry of Agriculture, Fisheries and Food, Spain). Monthly data of biomass and value of landings of each species. These data are aggregated for the complete region.

2. 1994 to present. The Xunta de Galicia, through its Fishery Information Service, compiled data for each Galician port of the biomass and value of each species landed. The data have a monthly periodicity although in some periods weekly or daily data are available. Now, the personnel of the fishers' associations introduce these data in an information system. The original data are disaggregated by vessel and day, although after that the information is aggregated by port and month. In the future, these disaggregated data could be available if they were needed for assessment purposes.

3. 1958-1993. The research group in biology and fisheries of marine resources of the Universidade da Coruña (UDC), participating in the EDFAM, compiled data from all the ports of Galicia using information available from Cofradías (fishers' associations), city councils, port authorities or other institutions that historically were in charge of the control of the landings of the fishing fleet. These data have a variable level of aggregation (monthly, weekly or daily) depending of the original source of data, but always included all the crustacean species and their biomass and value at least monthly. These data complement the series of the Xunta de Galicia that started in 1994 and have similar characteristics to this data set. Complimentary to these data the research group of the UDC has data sets of daily or weekly data of some ports (O Grove and Lira) from 1990 to the present including catch and value per fishing vessel and species. These data have been obtained form the Cofradías or people involved in the marketing of these products and have been used previously for assessment purposes.

Assessment

Multispecies trawl fishery in the shelf and upper slope
Direct assessments of exploitable biomass of *Nephrops norvegicus* have been made using the information from the research trawl surveys, These data have been analyzed using geostatistical methods to get yearly local and global estimators of abundance (Fariña et al. 1994).

Coastal water fisheries
No prospective or in-season stock assessments is made for the decapod species exploited in coastal waters. Only some punctual and retrospective analyses have been made for the velvet swimming crab and spider crab. Yield- and egg-per-recruit analysis of the velvet swimming crab stock has been carried out. Exploiation rate for the fishing season for the spider crab using stock depletion methods (based in fishery statistics and mark-recapture experiments) have been carried out. Modelling of yield- and egg-per recruit including the life history of the species, habitat changes and the effects of the legal and illegal fisheries are available. This last analysis compared the performance of fishing effort control and habitat protection regulations. These assessments have been made with a research purpose and have not been used yet in the management of the resources.

5. *Instituto Espanol de Oceanografia (IEO), Centro Oceanografico de Balaeres (COB), Spain*

Fisheries

Palinurus elephas
Fished in the western Mediterranean distributed from about 10 to 160 m depth

This species is the target of artisanal fisheries during the open season (March to August, both inclusive) all along the coast of the Spanish Mediterranean. Because it is in high demand and a high unit value species, it is suspected that fishing mortality rates have been increasing in all grounds, in particular since the introduction of trammel nets in the 1960s and 1970s. Trammel nets have replaced traps in most areas, as nets are able to catch more fish, which compensates for declining lobster yields.

P. elephas fisheries are subject to closed seasons during the egg bearing period, minimum landing sizes (at around the size at first maturity) and the prohibition of landing berried females.

Most lobster are caught with trammel nets set soaked an average of 48 hours preferably between 50-100 m. Trammel nets are some 600 m long and have a drop of 1.7 m. The mesh size of the inner and outer panels are about 80 mm and 300 mm respectively. A relict lobster trap fishery remains in the productive grounds off the island of Menorca (Balearic Is).

Sampling Programmes:
- No long term sampling programme exists for this species, as it is not included in the list of priorities for EU fisheries sampling programmes.
- A short-term sampling programme (LANGOSTA project) was initiated in 1998 on the fisheries around the marine reserve of Columbretes Islands as well as in the Balearic Islands (Western Mediterranean). A main objective of the study was also the study of the protected lobster population off Columbretes. The study will continue until 2002.

Official landing statistics: Official landing data come from fish markets in each harbour. However, for lobster these data are not reliable because it is common to sell all or part of the catch directly to restaurants.

Effort data: An unknown number of artisanal vessels engage every year in lobster fishing along the Mediterranean littoral. The total number of units engaged in the fishery is difficult to estimate because it varies from year to year and through the lobster-fishing season and depends on lobster yields and weather conditions.

Catches: In the framework the LANGOSTA project, we are trying to estimate a conversion factor from the few harbours where we have more than one source of catch data. Preliminary estimates of the factor (to convert official figures) range between 3-35 depending on the harbours, years and seasons.

CPUE: Series of CPUE (catch in weight per trip) are available for 3 harbours. Length of series varies from 3 to 14 years.

Size distributions: Onboard sampling of selected trips in three fisheries is ongoing since 1998.

Aristeus antennatus,

The red shrimp is caught between 450 and 850 metres on muddy bottom of the slope. Its distribution is restricted to the canyons and smooth areas of the slope. .It is the most important decapod in landed weights in the Spanish Mediterranean Sea. Its price is usually one of the highest among crustaceans.

Sampling programmes: The majority of data on *Aristeus antennatus* have arisen on the particular research projects funded by national governement and EU financial support. A national sampling programme conducted by the Spanish Oceanographic Institut undertaken the long term monitoring of the fisheries in the Spanish Mediterranean Sea.

Catch and effort data: has been compiled from the commercial data in different harbours during research projects.

Size distributions: From the on board observer commercial sampling programme are obtained commercial catch per species and category (weight and number) per vessel, haul and day, and size frequency distribution for the target species. Moreover, the information of the cast (geographical situation, depth, gear, haul duration, etc.) are recorded.

Biological parameters*:* on the monthly basis are collected size distribution by sex, size-weight relationship and maturity stages, growth and mortaliy estimates.

Stock assessments: This species is assessed for the GFCM (General Fishery Commission for the Mediterranean) organised in SAC (Scientific Advisory Committees) Working Groups: for assessment of demersal and pelagic target species.

Nephrops norvegicus

The Norway lobster is one of the main target species of mixed trawl fisheries in the Spanish Mediterranean Sea. This species has a depth distribution between 20 and 500 m in the Atlantic Ocean and between 300 and 600 m in the Western Mediterranean Sea. The statistic showed that it is the second crustacean in volume of catches after the red shrimp. However, the landings of Norway lobster are relatively low and its importance is mainly due to its high market price.

Catch and effort data, size and spatial distribution by means on board observer commercial sampling programme are compiled.

Stock assessments: This species is assessed for the GFCM (General Fishery Commission for the Mediterranean) organised in SAC (Scientific Advisory Committees) Working Groups: for assessment of demersal and pelagic target species.

Parapenaeus longirostris

The deep water shrimp is one of the most important commercial shrimps in the Mediterranean. It live on muddy or muddy-sandy bottoms, mostly at depths of 150-400 m (upper slope) although it is found on the end of the shelf but with lower yields. The distribution is extended in the Mediterranean Sea and the eastern north Atlantic Ocean.

Catch and effort data, size and spatial distribution by means on board observer commercial sampling programme are obtained. Biological parameters, growth and mortaliy estimates are obtained for assessment.

Stock assessments: This species is assessed for the GFCM (General Fishery Commission for the Mediterranean) organised in SAC (Scientific Advisory Committees) Working Groups: for assessment of demersal and pelagic target species.

Penaeus kerathurus
This species is fished by littoral trawls in winter (December-February) and by the artisan fisheries (Trammel nets) in spring summer (April to September). It lives in muddy-sandy bottoms, mostly at depths of 0 to 100 m. In the south western zone of the Spanish Peninsula (Golf of Cadiz) and in the Levant Spanish zone (Golf of Valencia) this species is in high demand.

Sea Surveys: Direct assessment surveys DEMERSAL MEDITERRANEAN SURVEYS collect size distribution and abundance index from 1994 to the present for the Mediterranean Spanish crustacean species. DEMERSAL ATLANTIC SURVEYS_ For *Parapenaeus longirostris* providing size dsitribution an abundance index from 1993 to the present

Table 1 : Summary of landing and sampmpling data for Aristeus antennatus, Nephrops norvegicus and Parapenaues longisrostris.

Species	Harbour	Landing	CPUE	Monthly catches (fleet)	Biological parameters	Surveys
A. antennatus	Balearic Islands Spanish coast	1976 1976	Yes Yes	Yes Yes	Yes Yes	Yes Yes
N. norvegicus	Balearic Islands Spanish coast	1976 1976--	Yes Yes	Yes Yes	Yes Yes	Yes Yes
P. longisrostris	Balearic Islands Spanish coast	1993 1993	Yes Yes	Yes Yes	Yes Yes	Yes Yes

6. *Instituto de Ciencias del Mar –Consejo Superior Investigaciones Cientificas (ICM-CSIC)*

Description of sampling methods

ICM-CSIC is not involved in routine assessment or monitoring of fisheries. Its primary role is to obtain information (population data, mathematical models, etc.) on the biology, ecology and fisheries of crustacean decapods for scientific purposes. This information has been obtained from short-term (1-3 years) research projects funded by regional (Autonomous Government of Catalonia), national (Spanish Scientific Research Agency) or European (DG XIV AIR an FAIR programmes) funding bodies. This information may be used by the official fisheries organism in Spain (IEO) for assessment or monitoring. However, in the Mediterranean there is no adaptive management of fisheries on an annual basis, so neither assessment nor monitoring are formally included in management.

The ICM-CSIC study area covers all Catalonia, but most research projects have been carried out in the Central (Barcelona) and Southern region (Tarragona). The Central region is characterised by a narrow shelf and a steep continental slope and the majority of crustaceans caught are form deep-water fisheries targeting *Nephrops norvegicus* and *Aristeus antennatus*. On the contrary, the Southern region is characterised by a wide continental shelf under the influence of a large river (Ebro) and the crustaceans targeted are shallow-water species, such as *Liocarcinus depurator* and *Squilla mantis*.

The research projects leaded by ICM-CSIC on crustacean decapods are the following:

*AQUDE trawl surveys (1981-83): Quarterly trawl surveys along the Catalan coast using commercial boats from different harbours to obtain basic population characteristics, parameters and distribution for commercial species from 3 to 800 m. All crustacean decapods were studied***.**

Research project "The fisheries of Catalonia and Valencia" (Dr. Jordi Lleonart, 1987-89, EU FAIR programme): Data collection of population biology, landings and effort for the period 1988-89 for demersal fisheries. The biological parameters for the main commercial species (*Aristeus antennatus*, *Nephrops norvegicus*, *Liocarcinus depurator* and *Squilla mantis*) were obtained for the Catalan sea area. Also, the technical characteristics of the fleet were obtained and the routine collection of monthly data series was started.

Research project "ARRASTRILLOS" (Dra. Pilar Sánchez, 1989-91, Autonomous Government of Catalonia): Trawl surveys in three localities of the Catalan coast using commercial fishing boats. Quarterly samplings in each area to obtain basic biological parameters for *Liocarcinus depurator* and *Squilla mantis*, on the continental shelf and upper slope.

Research project "RASTELLS" (Dra. Pilar Sánchez, 1992-93, Autonomous Government of Catalonia):
Monthly beam-trawl surveys in two localities of the Catalan coast using commercial fishing boats. Monthly samplings in each area to obtain basic biological parameters for *Liocarcinus depurator* and *Squilla mantis*.

Monthly on board sampling of deep-sea trawlers in the port of Barcelona (1992-93, Dr. Joan B. Company) between 250 and 800 m depth. The crustacean target species of this fishery are *Nephrops norvegicus* and *Aristeus antennatus*. All the by-catch species were sampled also: *Pasiphaea sivado* and *P. multidentata, Solenocera membranacea, Plesionika edwardsii*, *P. gigliolii*, and *P. martia*. This sampling allowed to obtain a data for biological parameters of the species considered.

Research project "MEDITS" (Dr. Luis Gil de Sola, 1994-2000, EU DG XIV): Annual spring trawl surveys along the Iberian Peninsula Mediterranean coast (Spanish Mediterranean from Gibraltar to Cape Creus, excluding most of the Balearic islands) using the research ship: "Cornide de Saavedra". Data are mainly used to establish species distribution, annual trends and direct assessment. Biological data (such as sex, size, etc.) on *Nephrops norvegicus*, *Aristeus antennatus*, *Parapenaeus longirostris* and *Liocarcinus depurator* are collected regularly: Around 120 stations are sampled each year throughout the study area. Depths: 30-800 m.

Research projects "Nephrops norvegicus: resource assessment in the Catalan sea" (Dr. Francesc Sardà, 1991-92, EU DG XIV) and "Nephrops norvegicus: Comparative biology and fisheries in the Mediterranean, NEMED" (Dr. Francesc Sardà 1992-96, EU DG XIV): 3 trawl surveys on an oceanographic vessel for the estimation of biological parameters and stock assessment by means of geostatistical methods of the Nephrops norvegicus resource in the Central and Southern areas of the Catalan coast. A monthly sampling aboard commercial vessels was also conducted between 1994-1995 (NEMED project) to obtain biological parameters of this species and size frequency analysis of landings for the Port of Barcelona, 1994-1995 completed the project

The research project DEEP-FISHERIES (co-ordinated by John Gordon in Oban, and under the direction of Dr. Beatriz Morales in CSIC) allowed for the construction of a database including all the information gathered during the deep-sea surveys carried out in CSIC during the 1980s and 1990s.

Landings data series :
Due to special agreements with the Autonomous Government of Catalonia (Directorate of Agriculture and Fisheries) the monthly official landings and effort from 1988 to 2000 for all ports is available. This data series allow to analyse CPUE trends over time.

At a finer time scale, the daily landings and effort recorded at the Barcelona port auction is available from 1992-2000. The same data series is available for the port of Blanes from 1997-2000. These two ports are major landing sites for *Nephrops norvegicus* and *Aristeus antennatus*.

7. Instituto de Investigacao das Pescas e do Mar (IPIMAR)

The Crustacean Fisheries

The most important crustacean fishery in Portugal is a multispecies deepwater trawl fishery targeting mainly Norway lobster (*Nephrops norvegicus*), pink shrimp (*Parapenaeus longirostris*) and red shrimp (*Aristeus antennatus*). The main fishing grounds are located off the Southwest coast (Alentejo) and South coast (Algarve) of Portugal, from 100 to 700 m deep. The three species have an overlapping distribution, although Norway lobster and red shrimp are more abundant in deeper waters (300-600 m) and pink shrimp in shallower waters (100-300 m). *Aristaeomorpha foliacea, Aristaeopsis edwardsiana* and *Plesionika* sp. are also caught in the trawl fishery in minor quantities. This fishery contributes with 90% of total crustacean landings.

Other decapod species (*Palaemon serratus*, *Melicertus kerathurus*, *Palinurus elephas*, *Scyllarides latus*, *Hommarus gammarus*, *Cancer Pagurus*, *Maja squinado* and *Carcinus maenas*) are caught by local fisheries with different gear.

Sampling of the Landings

The Biological National Sampling Program (PNAB) started in 1979, being its main objective to collect data for fisheries assessment purposes. The sampling for crustaceans was conducted in the main landing harbours, namely Matosinhos in north Portugal, and Olhão, Portimão and Vila Real de Santo António in the south.

Presently, in the southern area, sampling is carried out just in Vila Real de Santo António, since almost all the crustaceans are landed in this harbour or, if landed in other harbours, the product is redirected to this landing site where it is auctioned. The species sampled are *Nephrops norvegicus* (Norway lobster), *Parapenaeus longirostris* (pink shrimp) and *Aristeus antennatus* (red shrimp). The samples for each species are taken weekly under a stratified multistage random sampling scheme, by fishing harbour, month and vessel, and the carapace length frequencies are recorded by sex. To get the monthly length distribution of the landings, the samples are raised in three steps: first, to the total weight landed by the selected vessels, then to the total landings of the sampled harbours and at last to the total landings of the month. In the specific case of crustaceans sampling, as there is just one landing place sampled in each area, the second step is skipped. These length distributions and the corresponding age compositions are used to run length and age based assessment models (LCA, VPA).

Sampling of catches onboard of commercial trawlers.

In March 1999, a new sampling program on board of the commercial vessels was started to collect the length composition of the catches for the 3 most important crustacean species in the trawl fishery. The main objective of this sampling program is to get the length distribution of the catches to compare with the landings length composition and to get a measure of discards if they exist. The sampling procedure is again a stratified random scheme. Each month, four one-day fishing trips are randomly selected and a technician on board collects the information of all trawling operations. From each haul, samples are taken by species and commercial categories, and the carapace length and sex are recorded for each individual. The total catch of the haul by species and commercial categories is also recorded.

The samples are raised to the total catch of the haul, by size categories, and added, to estimate the total catch of the sampled vessel. The second step is to raise the catch of the sampled vessels to the total monthly catch landed in the considered harbour. As, according to the observations, there are no discards of the commercial species of crustaceans, total landings and total catches are used as equivalents.

Biological sampling

For biological studies, a sample of the three main commercial species is taken twice a month from landings. From this sample the following characteristics are recorded for each individual: carapace length, total length, total weight, sex, maturity stage and any other observations (as moulting, gastroliths, presence of spermatophore in females, egg-bearing, etc). In the case of *Nephrops*, individual weights with and without the first pair of walking legs (the clawed legs) are also recorded. Although two samples per month were planned, this program is not yet running in a routine basis.

Crustacean Surveys : Period 1980-1994 :

A large number of trawl surveys for deepwater crustaceans were conducted in the two research vessels of IPIMAR (*Mestre Costeiro* and *Noruega*) in the period 1981-1994, covering mainly the south and southwest coasts of Portugal, between 100 and 800 m deep. However, the target objectives of these surveys were different (location of fishing grounds, abundance estimates, selectivity studies, etc.) and the sampling programmes designed accordingly.

Crustacean Surveys : Period 1997-2000 :

One trawl survey per year was carried out in the summer season (May-June) to estimate abundance indices for the main crustacean species in the traditional fishing areas. A stratified random sampling scheme was used, dividing the south and southwest coasts of Portugal in sub-areas, each of them splitted in four depth strata (less than 100m, 100-200, 200-500 and 500-750m). The number of stations in each stratum depends on the size of the stratum and the abundance variance of the two main species (*N. norvegicus* and *P. longirostris*).

Deepwater fish resources surveys

A series of trawl surveys have been carried out in the period 1994-2000 for deepwater fish resources, in the same area as for crustaceans and with the same gear (shrimp trawl). The depth range is 200-1000 m, but the strata are different from the crustacean surveys.

Groundfish surveys

Groundfish surveys may also be a source of information on crustaceans' abundance and biology. Although a different trawl net is used (with bobbins), the area covered includes the crustaceans fishing area and uses the same strata definition. There are 2 surveys per year since 1979, in summer and autumn.

8. *Dipartimento di Scienze dell'Uomo e dell'Ambiente dell'Università di Pisa, Pisa (DSUA) - Italy*

Long term monitoring programmes

With the approval of the Law 41/82, otter trawl surveys in all the Italian seas were performed starting from 1984-85. Within the framework of the first national plan (1985-88) research groups to assess demersal resources were organised. All the seas were covered, applying a stratified random sampling design. Five depth strata were chosen (0-50 m, 50-100 m, 100-200 m, 200-450 m and 450-700 m). The number of hauls was proportional to the surface area of each stratum; professional trawlers were hired for two surveys (spring and summer) per year.

During the second national plan (1990-93) the same spatial coverage was maintained. The transect design with three surveys per year (spring, summer, autumn) was use to improve the knowledge of biological parameters and population structure of ten target species: red mullet (*Mullus barbatus*), hake (*Merluccius merluccius*), greater forkbeard (*Phycis blennoides*), blue whiting (*Micromesistius poutassou*), Norway lobster (*Nephrops norvegicus*), red shrimp (*Aristaeomorpha foliacea*), blue shrimp (*Aristeus antennatus*), deep water rose shrimp (*Parapenaeus longirostris*), common octopus (*Octopus vulgaris*), horned octopus (*Eledone cirrhosa*). For each target species the following data were provided: length frequency distributions for each survey and stratum, sex ratio, growth parameters, length/weight relationship, sexual maturity and mortality. Moreover, for each species of fish, crustaceans and cephalopods, catch per hour (number of specimens and kg) was collected.

During the third national plan (1994-96) demersal resources of all the seas around Italy were assessed by means of two trawl surveys per year (spring and autumn). In this triennium, the sampling design was again random stratified. From this plan the research groups were joined in one national group (GRUND: Gruppo Nazionale Demersali).

In 1994 the first MEDITS (Mediterranean International Trawl Surveys) campaign was also carried out in late spring, beginning of summer. MEDITS is an international programme financed by the European Commission with the aim to produce demographic structure and biological data on the demersal resources along the coasts of the four Mediterranean countries of the European Union (Spain, France, Italy and Greece). Since 1996, the project covers almost all the Adriatic Sea, expanding the participation to the Balkan countries. MEDITS produces common data at large scale in the Mediterranean, covering all the trawlable areas on the shelves and the upper slopes (at depths from 10 to 800 m) and using the same standardised protocol and a common gear experimented and built by the IFREMER Institute of Sète. From 1994 to till now an annual campaign was carried out.

Starting from the fourth national plan (1996-99) the Italian surveys were co-ordinated by MEDITS: the two campaigns of the previous national plan are concentrated in an autumn campaign. The protocol has been adapted to the MEDITS protocol, in particular with regard to depth strata subdivisions. The hauls are the same for both surveys and not change from year to year. During this plan preliminary tests were also performed on selectivity (cod-end mesh size) and on inter-calibration among boats and nets used for national campaigns and between boats utilised for national campaigns and MEDITS boats utilised in Italy.

From the year 2000 the new national plan began. The same sampling protocol of the previous plan was adopted. The synthetic description of the trawl surveys carried out in Italy since 1985 is showed in Table 1.

Thus, from 1985 a lot of data were collected allowing to have a global picture of the status of demersal resources around Italy, comparing also the different fishing effort and the different catch per hour occurring in each sea. The available data were utilised by the Central

Administration in Fishery Policy to establish the period for stopping trawling activity, to establish protected areas of nurseries, to enforce measures to reduce fishing effort.

Regarding crustaceans Decapods many important data came from the experimental trawl surveys. For each species the depth distribution range and indices of abundance (number and kg/hour, number and kg/km^2) were obtained. For the four target species *N. norvegicus, P. longirostris, A. foliacea* and *A. antennatus* also the following information is available:

- size structure according to depth strata and depth-size relationship;
- length-weight relationship;
- sex-ratio and sexual maturity by size during the year;
- fecundity estimations;
- morphometric data;
- feeding ecology;
- growth and mortality parameters;
- estimations of the exploitation rate applying analytical models;
- population genetics.

Most of these data are available in the scientific papers or in the grey literature.

Table 1 – Trawl surveys carried out in Italy since 1985.

Period	**DEPTH RANGE**	**N° OF SURVEYS**	**SAMPLING DESIGN**
National survey			
1985-'87(summer and spring)	0-700 m	6	Random stratified
1990-'93 (spring, summer, autumn)	0-700 m	9	Transects
1994-'96 (spring, autumn)	0-700 m	4	Random stratified
1996-'99 (autumn)	10-800 m	3	Random stratified
1999-'01(autumn)	10-800 m	2	Random stratified
MEDITS project			
Period	DEPTH RANGE	N° OF SURVEYS	SAMPLING DESIGN
1994-'00(spring)	10-800 m	7	Random stratified

Short term projects

The Departimento di Scienze dell'Uomo e dell'Ambiente in collaboration with the Centro Interuniversitario di Biologia Marina of Livorno is involved in a project financed by the European Commission on the beam-trawl fishery (Study contract 99/051 – Study on the mixed-species catches of the rapido trawl fishery along the Italian coasts). This gear is largely used around the Italian coasts and especially in the Adriatic Sea, mainly to catch scallops and soles. The strong impact of beam trawl on the seabed as well as the lack of studies concerning the fishing technique and its possible impact on the fishing resources make urgent a detailed analysis of fishing regimes and catches. Therefore the aim of this study is to collect data on the fishing areas, the fishing effort and the catches obtained in the different seasons by professional fishing vessels.

Regarding crustaceans, the Decapod *Penaeus kerathurus* and the Stomatopod *Squilla mantis* are two important components of the commercial fraction in this activity. Although this last species isn't a Decapod, it was included in the EDFAM project because of it's economic importance in the Mediterranean fishery. The results expected by the project are to increase the actual knowledge on the quali-quantitative structure of the catches obtained with this gear. The estimation of the commercial and by-catch species will also allow to evaluate the importance of the various species on this activity during different seasons, the impact of this fishing technique on the living resources as well as its suitability to be employed. In addition, further information on the demographic structure and on various biological aspects will be obtained for *P. kerathurus* and *S. mantis*.

9. National Centre for Marine Research (NCRM) Greece

Current projects :

1. "Comparative Studies On The State Of Fishery Of The Native Shrimp Penaeus Kerathurus Population Of North Mediterranean".

The project, financed by the EC (Studies Project No 037/98), has as objectives:

- To study and analyze the state of the species stock in Amvrakikos Gulf and Lesina-Aquatina lagoons
- To assess the fishing effort and link it to the fishery productivity of the areas
- To provide an information system for the support of the administration, district authorities, producers, researchers and policy makers involved in local fisheries management.

The project was undertaken by NCMR, the University of Lecce (Italy) and the Navigator Development International Consulting Ltd., under the coordination of NCMR and its duration is from 1999 to 2001. The data were collected by means of fixed nets during two years (1999-2000) on a monthly basis from 15 stations in the species fishing grounds. The assessment will be based on Y/R analysis.

2. Study, Protection And Fishery Exploitation Of The Messolonghi-Etolikon Lagoon"
The project was financed by the Greek Ministry of Agriculture during 1982-1990. The scope was to study the biology of all the species of these lagoons in order to improve the management of these areas. In the framework of the project, the biology of *Palaemon adspersus* has been studied.

3. "Fisheries Investigation Of The Demersal Fish Stocks In The Evoikos And Pagasitikos Gulfs"
This program was carried out by NCMR and financed by the Greek Ministry of Agriculture during the period 1986-1989. The main objectives of the project was the study of the commercially important demersal stocks of the Evoikos and Pagasitikos Gulfs (Greece) and to estimate the parameters on which their rational management could be based. The data were collected by means of experimental trawl sampling during two years (1986-1988) on a seasonal basis from 34 stations using a random stratified sampling design. Assessment was based on Y/R method.

4. "Investigation Of The Abundance And Distribution Of Demersal Stocks Of Primary Importance To The Greek Fishery In The North Aegean Sea"
The project was undertaken by NCNR and the University of Bari under the coordination of NCMR, and financed by the EC (No MA-1-90). It had as objectives to study the commercially important demersal stocks in the North Aegean Sea (Greece) and to estimate the parameters on which their rational management could be based. The data were collected by means of experimental trawling during two years (1990-1992) on a seasonal basis from 33 stations using a random stratified sampling design. Assessment was based on Y/R analysis.

5. "International Bottom Trawl Survey In The Mediterranean" - Medits
This is an experimental survey program financed by the EC, in which all the Mediterranean EU countries, plus Albania, Croatia, Slovenia and Morocco participate. From Greece, 3 institutes participate (NCMR, IMBC, FRI) under the coordination of NCMR and they cover all the Greek seas. The main objectives of this project are to:

- Provide time series of abundance indices for 36 commercially important target species of fishes, cephalopods and decapods (*Aristeus antennatus, Aristaeomorpha foliacea, Nephrops norvegicus, Parapenaeus longirostris*).
- Provide size frequency distributions for the same species.

The data are collected on an annual basis from 1994 until now using standard fishing gears (MEDITS trawl) and common protocols. Consequently, the results produced are comparable between areas and between years. The assessment will be done by examining trends in the abundance indices

6. "Estimation Of The Demersal Stocks Of The Thermaikos Gulf And The Thracian Sea"
The project, undertaken by NCNR and financed by the Greek Ministry of Agriculture, had as objectives to study the commercially important demersal stocks in the Thermaikos Gulf and the Thracian Sea (Greece) and to estimate the parameters on which their rational management could be based. The data were collected, by means of experimental trawling for two years (1992-1994) on a seasonal basis from 68 stations using a random stratified sampling design.

7. "Development Of The Greek Fishery. Estimation Of The Demersal Stocks With Commercial Importance In The South Aegean Sea"
The project was undertaken by NCNR, during the period 1995-1998 and financed by the Greek Ministry of Agriculture. It had as objectives to study the commercially important demersal fish stocks in the Cyclades and Dodecanisa Islands (Greece) and to estimate the parameters on which their rational management could be based. The data were collected, by means of experimental trawling for two years (1995-1996) on a seasonal basis from 57 stations using a stratified random sampling design.

8. "Nephrops Norvegicus: Comparative Biology And Fishery In The Mediterranean And The Adjacent Seas" - Nemed
The program was undertaken by NCNR, ICM, the University of Pisa, the Univerity of Genova, the CNR and the University of Algarve under the coordination of ICM, and financed by the EC (Studies, MED 92/008) during the period 1993-1996. The objective was the comparative study of the biology and fisheries of the Norway lobster in the Mediterranean and the adjoining Atlantic areas. The main goal was to assess the conditions for a global regulation in the area and determine possible differences among exploited stocks. The data were collected, by means of a trawl, for two years (1993-1995) on a monthly basis, from 6 stations, in norway lobster grounds.
Assessment was based on Y/R analysis.

9. "Developing Deep Water Fisheries: Data For Their Assessment And For Understanding Their Interaction With And Impact In A Fragile Environment"
The program was undertaken by NCMR and many other European countries under the coordination of SAMS, and financed by the EC (Fair CT 95-655) during the period 1996-1999. The objectives were to investigate the stocks of fish, crustaceans and cephalopods extending in the depth zone 200-800 m and the possibility of development of a deep water fishery in the Greek waters of the south Ionian Sea. The data were collected by means of a trawl for two years (1996-1998) on a monthly basis using stratified random sampling design.

10. "Protection Of The Marine Environment. Distribution Of Renewable Marine Biological Resources In Deep Waters" - Interreg Ii
The program was undertaken by NCNR and the University of Bari, and financed by the Greek and Italian Ministries of Economic Affaires during the period 1999-2001. Its objectives were a) to investigate the spatial distribution and abundance of important renewable deep marine resources, focusing on the red shrimps and b) to set up useful information for management purposes and particularly for the development of a Greek and Italian red shrimp fishery. The data were collected by means of experimental trawling for two years (1999-2000) on a monthly basis using stratified random sampling design.

The results from all the above mentioned programs are transmitted to the EC by the Interim and Final Reports. These reports are also disseminated to the National Organisations participating in the financing of the projects, to the Ministry of Agriculture and to the Local Authorities, which are related to the subject and constitute management and policy organisms.

10. National Agricultural Research Foundation (NAGREF) – Fisheries Research Institute (FRI)

Activities

Our present knowledge on the decapods of the North Aegean Sea is focused on their systematics and distribution as well as on the biology of the species *Nephrops norvegicus* and on the fisheries of certain commercial species under the framework of the international project MEDITS.

Concerning the distribution of decapods, a comprehensive study of the Aegean species has been carried out. 231 of decapod crustacean species are known to date from the Aegean Sea.

Concerning the biology and the fisheries of the commercial decapods, the existing information is limited and is derived from two short term sampling programmes in North Aegean Sea.

The first is entitled “Growth and natural mortality of *Nephrops norvegicus* with an evaluation of creeling in Mediterranean waters, NEPHROPS”.
The aim of this project is:

1. the study of the species biology and gear technology, aiming at the better management of *Nephrops* Mediterranean populations
2. the assessment of growth and natural mortality using tagging techniques
3. the introduction of the creeling technique, carried out with lobster traps
4. evaluation of the creeling technique and comparison of the growth measurements taken with this method with those taken with the traditional techniques

This project is carried out in an enclosed bay, protected by law from commercial trawling, inhabited by a relatively undisturbed population. The particular tasks of this project concerning the biology of *Nephrops* are:

1. the study of the structure and dynamics of Nephrops population are investigated by size frequency measurements in a time series, individually for both males and females. Measurements are taken both from the animals captured by creeling and from seasonal experimental trawling
2. the growth of *Nephrops* is investigated by tagging and recapture. The large number of individuals collected by creeling is sexed and measured, then tagged before they are released. On recapture, each animal is identified by its tag and re-measured. Growth is also assessed by traditional analysis of the time series of length frequency measurements
3. The reproductive state of *Nephrops* is assessed from the female individuals and their gonads. Male maturity is much more difficult to assess but a recent morphometric technique is employed utilizing a comparison of various size relationships of the claws
4. A synthesis of the above biological parameters and an estimation of natural mortality will be made

The second project is entitled “International bottom trawl survey in the Mediterranean, MEDITS”.

This project is basically focused on fish stocks and its aims are the following:

1. Study of the dynamics and spatial distribution of the most important demersal fish populations
2. Assessment of fish abundance, density, age structure, growth and mortality juvenile recruitment and fecundity
3. Development of a model for appropriate management of each stock

The crustacean target species found in the North Aegean Sea are *Aristeus antennatus, Aristeomorpha foliacea*, *Nephrops norvegicus* and *Parapenaeus longirostris*. The parameters studied during the project are the geographic and depth zone distribution, biomass, sex ratio, carapace length and abundance. However, the populations of the above decapods are very restricted and so is the information for these species collected during this project.

11. Goeteburg University (UGOT)

The summary below applies to Sweden as a whole and not to the UGOT specifically.

Fisheries

Nephrops, Pandalus, Homarus, Cancer and *Carcinus* are the subject of fisheries in Sweden. In the latter 3 species a higher proportion of the total catch is taken by recreational fishermen rather than by the commercial fleet. Statistics therefore are very difficult to compile and the stated landings from commercial vessels greatly underestimate the catch. This is not the case with *Nephrops* and *Pandalus*.

Monitoring Data

Nephrops and Pandalus :

- Landings data is available from 1914-the present.
- Commercial logbook data has been collected since 1978 on a 30 x 30 nautical miles resolution.
- Size/age structure data has been collected since 1991. Samples are taken ever 14-30 days at 1 port from 3-5 boats
- Direct research trawl surveys were carried out between 1970-1990 2-3 times per year at 50 stations. These were terminated.

These data are used as input to stock assessment at the ICES Working Groups.

Homarus, Cancer and Carcinus

Commercial landings for these species are probably only 15-30% of the total catch. Commercial landings data is available since 1914 and commercial logbook data collected in a similar way as for Nephrops and Pandalus is available since 1978.

Private logbook data for *Homarus* especially is available from 1938 and may be used to indicate relative stock changes. Size structure of the landings of Homarus has been collected since 1996, once per year at one location.

12. University of Southampton (SOTON), UK

Activties

The activities of SOTON are not directly related to fisheries monitoring. Studies on the behaviour, colonisation and movement of lobster (*Homarus*) and crab (*Cancer, Necora*) in and around artificial reefs are conducted. This has resulted in a very substantial database on behaviour on fine spatial and temporal scales including repeat observations over time on individual decapods. Some of the data has application for the study of catchability in trap fisheries and it's seasonal variation. Other data on biometrics, laboratory based agonistic interactions and the energetic costs associated with these are collected. Video footage of aggregations of Maja and their formation is also available. The main techniques used were tagging including electromagnetic telemetry, underwater video footage and direct observations using SCUBA.

The work was conduncted between 1990-1997 in a number of bays and artificial reefs on the south coast of England. Three and a half thousand *Homarus* were tagged and approximately 0.5 million activity records of 52 lobsters were collected using electromagnetic telemetry.

2. The European Crustacean Fisheries Metadatabase (ECFM) (www.edfam.net)

The data held by participating organisations in EDFAM are summarised in (1) above. The results of this work are dispersed in the scientific literature, in reports, in databases etc. A metadatabase has been developed through the EDFAM project to host this and other European data on crustacean fisheries as a resource to researchers and managers in these fisheries. It has two main functions

- It allows registered users of the web site to enter their own metadata
- All users can search the database through the web application (www.edfam.net)

It is envisaged that this application will be an extremely useful focus for researchers and managers of crustacean fisheries in Europe and that it's value will increase over time as the database is populated and the number of registered user's loading their data to the site increases. It could then be a major source of up to date information on the fishery and biology for these species.

The functional specification written prior to development of the database application and description of the data model are presented below and are followed by a detailed description and navigation through the site. The functional specification describes the requirements of the site from a users perspective.

1. ECFM User Requirements Specification

Document No:		MDC/STI-M12-UR-1.0	
Distribution:			
Oliver Tully		TCD	
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Yvonne Mc Fadden		Marine Institute	
Issue No	**Date**	**Author**	**Changes**
0.1	25th July 2001	Yvonne Mc Fadden	First Draft based on RFT
1.0	1st August 2001	Yvonne Mc Fadden	Update to reflect discussions at first project meeting with Compass and TCD and to include database understanding

Sub-contractors for development of the ECFM Website : Gearoid O Riain, Compass Informatics, Nassau St., Dublin 2

I. Scope of the document

The main aim of this document is to clearly communicate the user requirements regarding the European Crustacean Fisheries Metadatabase (ECFM) Web site application. Any references in this document as to how this might be implemented are merely there to clarify the user requirements. An appropriate implementation should be fully described in a functional specification document with the technical details described in a technical specification.

A secondary aim of this document is to provide an overall insight into the database regarding the tables where information is stored and the relationships between different tables. Table names are included in the document when referring to information that is stored in the database and relationship diagrams are also included for the section on data entry.

This document for the most part contains relatively high-level user requirements. Very detailed information is not contained here (for example, the exact fields to be displayed to the user, display names for fields or indeed all permutations of data that can be returned from a database query). Also, the data entry section only includes details on entering new information to the database. It does not describe deletion, editing or adding to existing information that is also required of this application.

II. Aim of the Website

The main purpose of the website, initially at least, is to provide a mechanism for the project partners to enter information on their data holdings into a database. Additionally it must provide a mechanism for the information held in the database to be queried and displayed. Most data holdings are related to a **species** and **sea area**. Additionally, information may be supplied on laboratory work, which is related to a **species alone** (no location). A small amount of static content (e.g. project description) will also be available on the site.

The site will primarily be of interest to those scientists involved in the EDFAM project. The information will also be of interest to scientists involved in similar work in other organisations.

III. Summary of Requirements

The overall requirement is for a simple, low maintenance, easily navigable website. The following high-level functionality has been identified:

1. Provide a short description of the project, partners etc.
2. Facilitate data entry to an Access database for a restricted number of users
3. Facilitate a number of defined queries on the database by general and scientific users
4. Allow results sets to be downloaded onto the local PC
5. Provide the facility for the database administrator to edit/quality assure the content of the database

More detail on these requirements is provided below.

While the project is currently funded to run to the end of 2003, it is envisaged that the website will be maintained and possibly further developed in the long term.

An additional requirement is that the website is hosted and managed by a third party.

IV. The Database

Analysis has been conducted on the data to be managed as part of the project, resulting in development of a database in MS Access.

The database contains information on data holdings. ***A Data Holding has been identified as any data that a specific institute holds relating to a particular species for one specific sea location***. This definition covers most types of data with the sole exception of laboratory-based data. This type of data is related to a species and institute only and not to any specific location. In the database, we can cater for this by setting the sea location for such data holdings to a ‘dummy’ sea location record (e.g. “N/A”). The definition of a data holding must be very clearly communicated via the Website to the users.

The database has been populated with some sample data in order to test the relationships. Look-up tables have also been populated with predefined values, for use in dropdown lists. However, there is a requirement for the web user to populate some of the look up tables also.

It will be possible to modify the database to a limited extent, if adjustments are identified as necessary during development of a detailed design for the interface. These must be agreed in consultation with TCD (EDFAM Co-ordinator). It is expected that security information will be added to allow only the user (and the administrator) who enters the data holding details to further modify or delete that data and to allow only specified users to gain access to the data entry facility in the first place. It is also expected that the sea location design will have to be modified to cater for a hierarchy of sea locations to 2 levels (parent and child) rather than the single level that exists at the moment. Another modification may be required to facilitate the off-line administration of the database by the administrator, as the next date for 'down time' of the database (for data entry) must be dynamically communicated to the users via the Website.

V. Detailed Description of the Website Requirements

The website will include the following:

- Home Page
- Partner Organisations
- Data Entry
- Query the Database
- Administration of the Database Content
- "Contact Us" (opens up an email)
- Help – succinct information to help the user enter data or run a query on the database

The relatively static information on the Home and Partner pages may need to be updated periodically by the administrator using a very simple approach e.g. editing of html page content.

Home Page

The Home Page will have a brief description of the project with the following links available:

- Partners
- Data Entry page
- Query page
- "Contact Us"
- Help

The home page will also need to display various logos.

Partners

This page will give details on all the project partners, including names and contact information. A user will be able to link to the project partners respective web sites and send e-mail to the partners e-mail addresses. In time it may be expanded to include details on other relevant organisations.

Data Entry

- Access to this section of the site will be restricted initially to the partner organisations. However, provision needs to be made on-line to allow other institutes to contribute to the site (e.g. perhaps an e-mail request to the administrator for a username and password – need to consider security issues on supplying this type information to the users over the internet).
- Data Entry will be restricted in the first instance to those organisations that are partners in the project. However, as above, this will extend to those institutes that are not partners but have been granted access to the system.
- It was thought that initially that there may only be a need for a single username and password for each institute but there may be a need to cater for more than 1 user at each institute.

- In addition to adding new information on data holdings to the database, the user may wish to delete, edit or add to existing information (with the restriction that it is the user's own data holding information that they are changing).
- In general, a user shouldn't be able to delete or change the information in the look up tables. In addition, some of the look up tables may be pre-populated with a set list of items and therefore, the user cannot add to these tables. The addition, deletion and edit permissions are clarified for all look up tables below in the section on **Database Look up tables**. In some cases, the administrator should be notified when a new item is entered by a user in the look up tables (e.g. T_Parameters, T_Measures, T_Objectives, T_ManagementStructureTypes).
- A mechanism to deal with a hierarchy of sea areas is required. Data holdings can be related to large geographical areas e.g. Central Mediterranean or smaller subsets e.g. Tyrrhenian Sea. The website needs to flexibly cater for this hierarchy in entering and querying data (e.g. searching on Central Mediterranean will also return data for Tyrrhenian Sea.) The database model must be adjusted to cater for this in the most appropriate way.
- There must be both appropriate field (e.g. incorrect data types, required fields) and record level (e.g. duplicate records) validation with meaningful error messages displayed to the user.
- The required fields for each data entry page must be flagged to the user in an appropriate way.
- A lot of consideration needs to be given to how to make the data entry process as painless as possible for the user.

Addition of new data holdings

The sequence of general steps involved in entering a ***new*** data holding is described below followed by specific steps for entering laboratory data and sea location data. The application does not have to follow this sequence in obtaining the information from the user and careful consideration must be given to ease of use and performance when designing the application.

Note: The addition of a new data holding only is described here. In addition to adding new data holdings to the database, there must be the facility on the Website to delete, edit or add to existing data holding information

General steps

Step 1
User is prompted to enter high-level metadata on the data holding. The user must enter a species, an institute and a data holding type.

The user must also be able to add new institute details if the institute does not exist. If the institute does exist, the user must be able to change these details if necessary. The user must also be able to add new species as required. See **Figure 1** for database relationships.

Step 2
User is prompted to enter the remaining fields in the T_DataHoldings table (Figure 1)

If the user has selected 'Laboratory-based data' for the data holding type, the user does not have to enter a sea location (but the application must associate the 'dummy' sea location ("N/A) behind the scenes with that record).

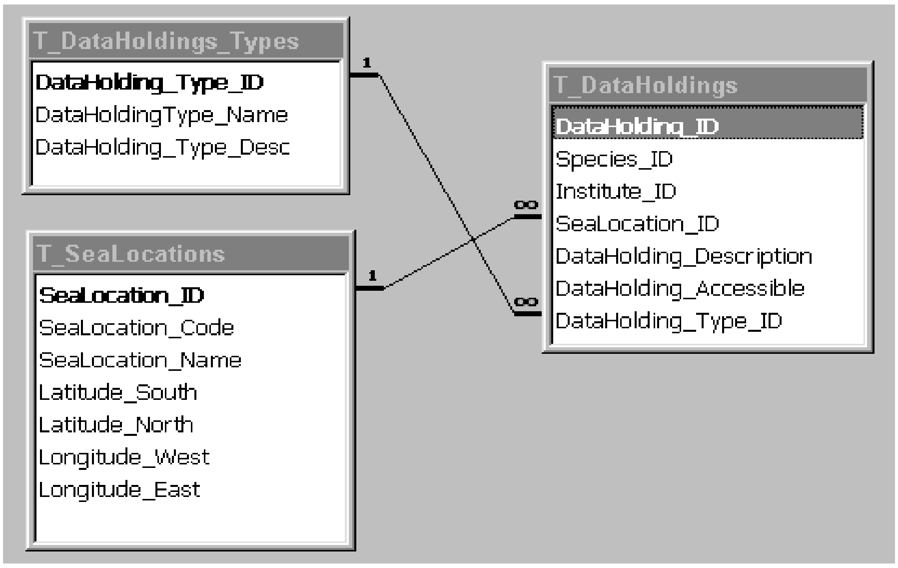


Figure 1 Relationships between data holdings (T_DataHoldings), sea locations (T_SeaLocations) and data holding types (T_DataHoldings_Types)

Step 3

The user enters any publications associated with the data holding. The user should be able to view the current list of publications. The publications related to the species associated with the data holding should be displayed first with the option to display the remaining publications. The user should be able to select 1 or more publications to associate with the data holding. Also, the user should be able to add new publications.

See **Figure 2** for database relationships. Note: Species_ID field has been removed from the publications table (T_Publications) and is now only associated with the data holding.

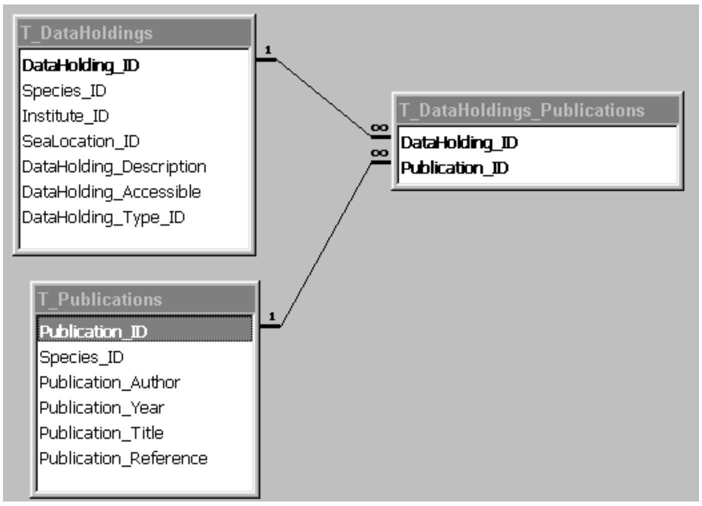


Figure 2 Relationships between publications (T_Publications) and data holdings (T_DataHoldings)

Specific steps for Laboratory-based data

Step 4

The user is prompted to enter the contact details for laboratory data and the application must update the table *T_DataHoldings_DataThemes*. If the contact does not already exist, the user must be able to enter these details and also new institute details for the contact if required.

The user should also be able to update the contact and institute details if there have been any changes to this information.

When the user is entering a new contact for laboratory data, the institute associated with the contact (T_Contacts.Institute_ID) should default to the institute for the data holding that is currently being entered (T_DataHoldings.Institute_ID). The user can change the institute if this is incorrect. Also, it is not necessary that a contact is associated with a data theme.

See **Figure 3** for database relationships. **Note:** extra fields for identifying the co-ordinating institute (T_Institutes) and the project co-ordinator (T_Contacts) are not shown in this relationship diagram.

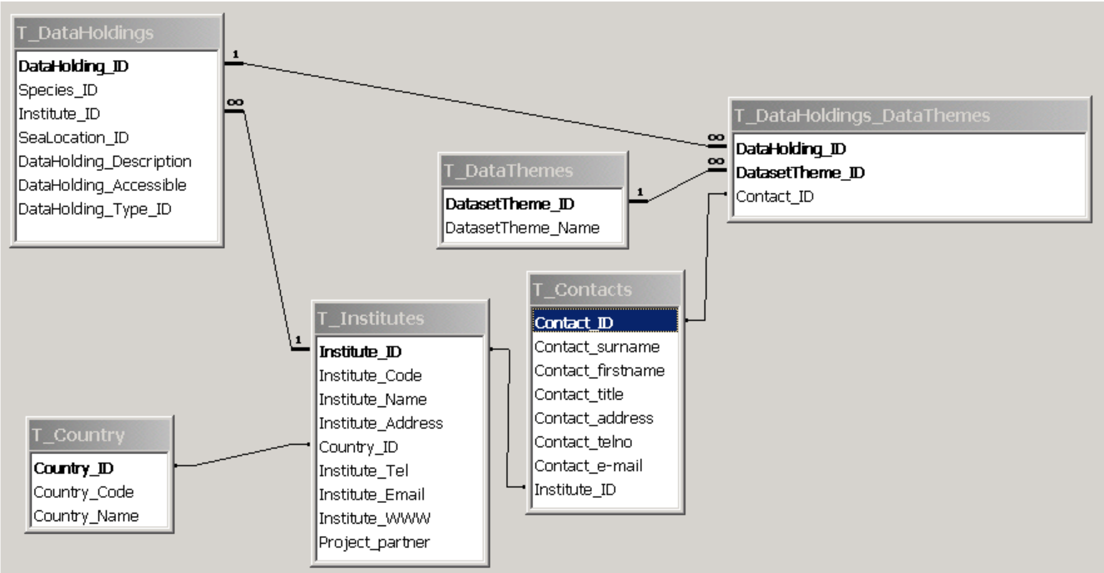


Figure 3 Relationships between the data holdings (T_DataHoldings), the data themes (T_DataThemes, T_DataHoldings_DataThemes) and the contacts (T_Contacts)

Step 5
The user is prompted to enter data for the fields described in DataHoldings_LaboratoryData table.

When entering the data, the user selects laboratory data parameters (T_Parameters) from a list. In addition to selecting the parameter from the list, it is very important that the user be able to view the parameter description and the parameter entry instructions in order to enter the value, units and text data properly. The latter applies to all data entry scenarios where parameters have to be selected (e.g. many of the 'data theme' tables).

See **Figure 4** for database relationships.

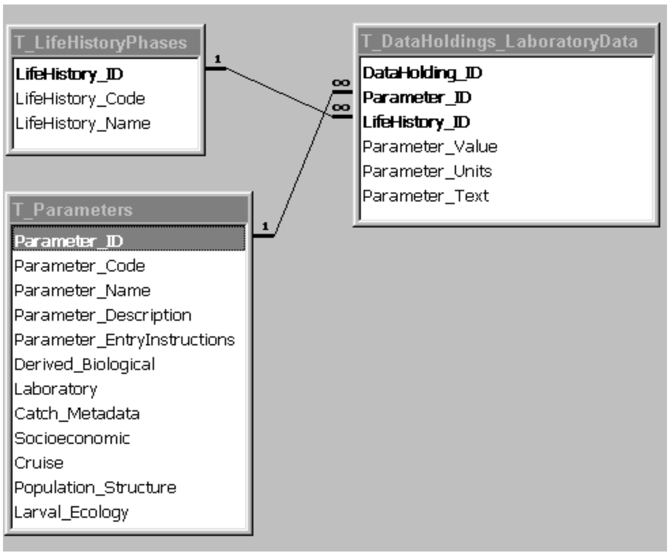


Figure 4 Relationships between laboratory data (T_DataHoldings_LaboratoryData) and parameters (T_Parameters) and life history phases (T_LifeHistoryPhases)

Specific Steps for Sea Location Data

Data entry for sea location data is more complex than laboratory data as there are 11 types of data (i.e. data themes) that may be associated with a sea location. In addition, some of these data themes have lower levels of data and information that a user may wish to enter (e.g. Catch Metadata and Landings and Effort data have lower levels of data related to the 'data theme' table).

Step 6

The user is asked to input information on the data holding based on the fields in the T_DataHoldings_SeaLocations table.

The user may need to add in new species (T_Species) when entering this information.

See **Figure 5** for database relationships.

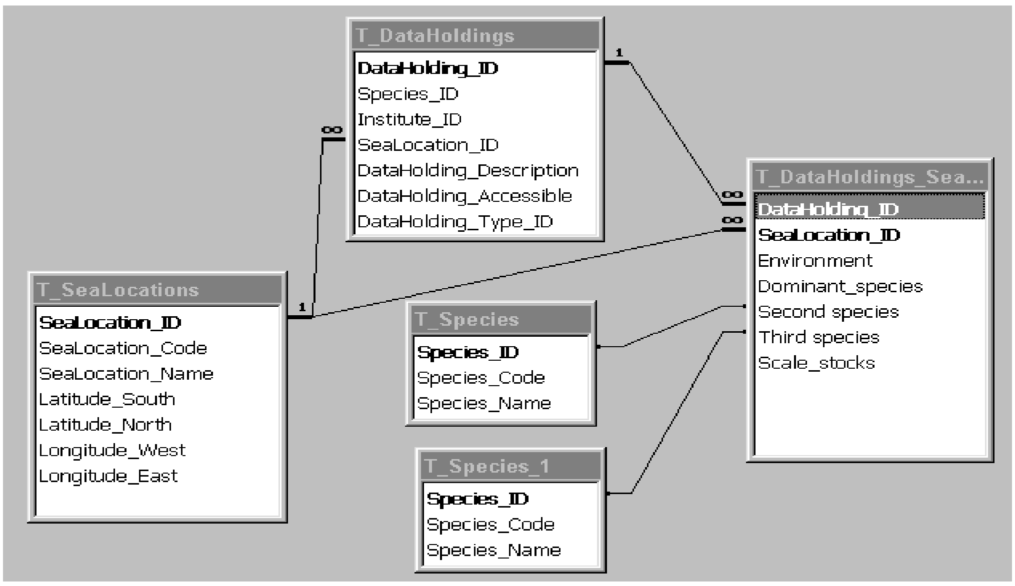


Figure 5 Relationships between data holdings (T_DataHoldings) and sea locations (T_SeaLocations)

Step 7
Then the user can optionally select to provide more detailed data on one or more of the data themes detailed below, each of which corresponds to a table in the database.

When the user chooses a data theme, the contact details for that type of data must be entered (as described for laboratory data above) and the T_DataHoldings_DataThemes table updated prior to entering the data (see Figure 3 above for relationships).

When the user is entering the data for a specific theme, links to the other data themes should be made available from the current page to make it easy for the user to move between data themes.

The user enters the appropriate information for the data theme selected. As mentioned previously, there may be other tables associated with the main data theme tables to which the user must have access. For example, if Catch Metadata is selected, the user has the option to provide additional information on Cruises for entry into the T_Cruises table. If a cruise is entered for the catch metadata, the user has the option of entering cruise parameters (T_CruiseParameters), sampling designs (T_SamplingDesigns) and gears (T_Gears). See **Figure** for Catch Metadata database relationships. Also, if the user selects Landings/Effort data additional gears may be associated with the data and so on. See **Figure 12** for Landings and Effort database relationships.

Data theme 1: Management Measures (T_DataHoldings_Measures)

When entering the management measures data, the user should have the option of entering a new measure into the T_Measures table. The user is prompted to enter name, description and entry instructions fields. The addition of the new measure will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the management measures data in the data table (T_DataHoldings_Measures), the names, descriptions and the entry instructions for the selection of measures stored in the table T_Measures must be available to the user.

There is a unique key set up in the data table on the fields DataHolding_ID, Measure_ID and Start_Date.

An extra check needs to be implemented by the application to avoid having more than 1 data record for the *same* measure 'open' i.e. no end date has been entered for that record. If the same measure (Measure_ID) is entered for a data holding as was previously entered, the application must ensure that the previous data record for that same measure is 'closed' by insisting an end-date is entered for that previous record. Entering an end date 'closes' that data record. Note: a data record refers to a record in the table T_DataHoldings_Measures.

Thus, for a data holding, while you can have more than 1 data record 'open' for *different* measures (e.g. BOAT_LIMIT, GEAR_LIMIT), you can only have 1 data record open for the *same* measure (e.g. BOAT_LIMIT). All the other data records for the same measure must be 'closed'. Note: once the data records are closed you can have multiple data records for the same measure (each with a different start date).

For example, if there is a measure "BOAT_LIMIT" in operation for a data holding, the user chooses to enter a new data record. The user selects the "BOAT_LIMIT" measure from a drop-down list of measures. The user then enters '20' in the value field (i.e. 20 boats can fish for this species in the sea location), enters ‘vessels’ in the units field and ‘01/01/1995’ in the start date field as this measure has been in operation since 1995. If the boat limit is increased to 30 in 2001, then the user needs to add the new measures data for the *same measure*. The user adds a new data record for the data holding, selects the “BOAT_LIMIT” measure, enters ‘30’ in the value field, ‘vessels’ in the units field and ‘01/08/2001’ in the start date field. *In this case, the user must also be prompted to enter an end date for the previous measure (BOAT_LIMIT) data.*

See **Figure 6** for database relationships.

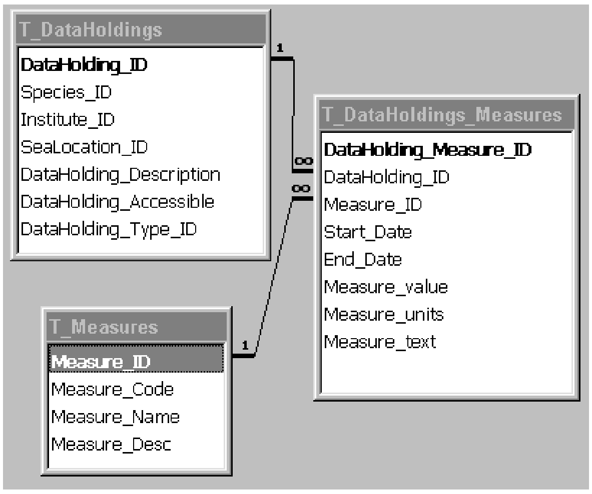


Figure 6 Relationships between data holdings (T_DataHoldings), Management Measures data (T_DataHoldings_Measures) and Management measures (T_ManagementMeasures)

Data theme 2: Management Objectives (T_DataHoldings_Objectives)

When entering the management objectives data, the user should have the option of entering a new objective into the T_Objectives table. The user is prompted to enter name and description fields. The addition of the new objective will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the management objectives data in the data table (T_DataHoldings_Objectives), the names and descriptions of the objectives (T_Objectives) must be visible to the user.

There is a unique key set up in the database on the fields DataHolding_ID, Objective_ID and Start_Date.

An extra check needs to be implemented by the application to avoid having more than 1 data record for the same objective ‘open’ i.e. no end date has been entered for that record. If the same objective (Objective_ID) is entered for a data holding as was previously entered, the application must ensure that the previous data record for that same objective is ‘closed’ by insisting an end-date is entered for that previous record. Entering an end date ‘closes’ that data record. Note: a data record refers to a record in the table T_DataHoldings_Objectives.

Thus, for a data holding, while you can have more than 1 data record ‘open’ for different objectives (e.g. Socio-economic objective, Biological objective), you can only have 1 data record open for the same objective (e.g. Socio-economic objective). All the other data records for the same objective must be 'closed'. Note: once the data records are closed you can have multiple data records for the same objective (each with a different start date).

See Figure 7 for database relationships.

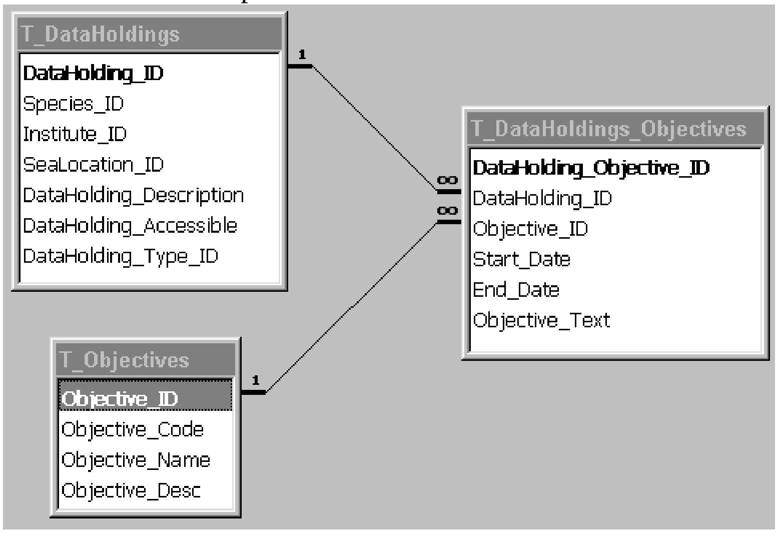


Figure 7 Relationships between data holdings (T_DataHoldings), Management objectives data (T_DataHoldings_Objectives) and Management objectives (T_Objectives)

Data theme 3: Management Structures (T_DataHoldings_ManagementStructures)

When entering the management structures data, the user should have the option of entering a new management structure type into the T_ManagementStructureTypes table. The user is prompted to enter name and description fields. The addition of the new structure type will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the management structures data in the data table (T_DataHoldings_ManagementStructures), the names and descriptions of the structures (T_ManagementStructureTypes) must be visible to the user.

There is a unique key set up in the database on the fields DataHolding_ID, ManagementStructureType_ID and Start_Date.

An extra check needs to be implemented by the application to avoid having more than 1 data record for *any* management structure 'open' i.e. no end date has been entered for that record. If any other (the same or different) management structure (ManagementStructureType_ID) is entered for a data holding, the application must ensure that the previous data record is 'closed' by insisting an end-date is entered for that previous record. Entering an end date 'closes' that data record. Note: a data record refers to a record in the table T_DataHoldings_ManagementStructures.

Thus, for a data holding, you cannot have more than 1 data record for management structures 'open'. Before you can enter a new data record, the previous data record must be 'closed'.

See **Figure 8** for database relationships.

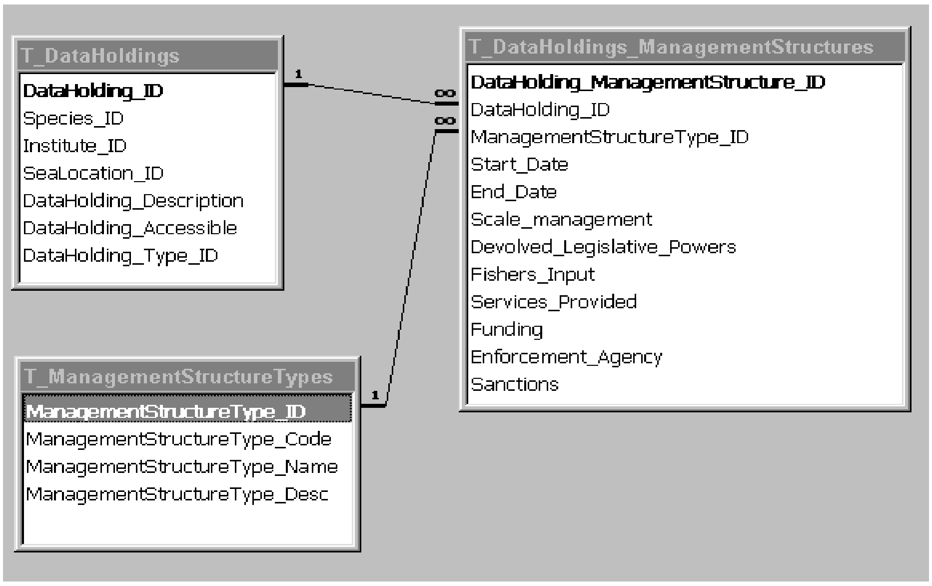


Figure 8 Relationships between data holdings (T_DataHoldings), Management structures data (T_DataHoldings_ManagementStructures) and Management structure types (T_ManagementStructureTypes)

Data theme 4: Derived Biological Parameters (T_DataHoldings_Derived Biological Parameters)

When entering the derived biological parameter data, the user should have the option of entering a new parameter into the T_Parameters table. The user is prompted to enter name, description and entry instructions fields (when saving the record to the T_Parameters table set Derived_Biological field = true). The addition of the new parameter will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the derived biological parameter data in the data table (T_DataHoldings_DerivedBiologicalParameters), the names, descriptions and the entry instructions for the derived biological parameters (T_Parameters) must be available to the user.

There is a unique key set up in the data table on the fields DataHolding_ID, Parameter_ID, Gender_ID, Start_Date and End_Date.

See **Figure 9** for database relationships.

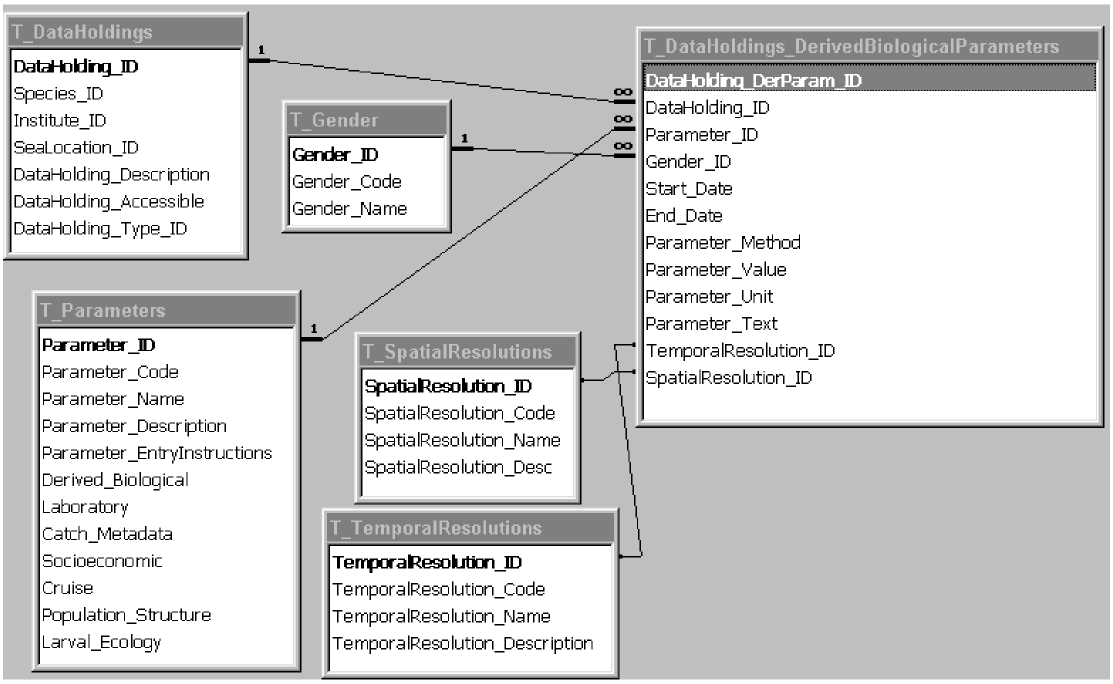


Figure 9 Relationships between data holdings (T_DataHoldings), Derived Biological Parameter data (T_DataHoldings_DerivedBiologicalParameters) and Derived biological parameters (T_Parameters)

Data theme 5: Larval Ecology (T_DataHoldings_LarvalEcology)

When entering the larval ecology data, the user should have the option of entering a new parameter into the T_Parameters table. The user is prompted to enter name, description and entry instructions fields (when saving the record to the T_Parameters table set Larval_Ecology field = true). The addition of the new parameter will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the larval ecology data in the data table (T_DataHoldings_LarvalEcology), the names, descriptions and the entry instructions for the larval ecology parameters (T_Parameters) must be available to the user.

There is a unique key set up in the data table on the fields DataHolding_ID, Parameter_ID.

See **Figure 10** for database relationships.

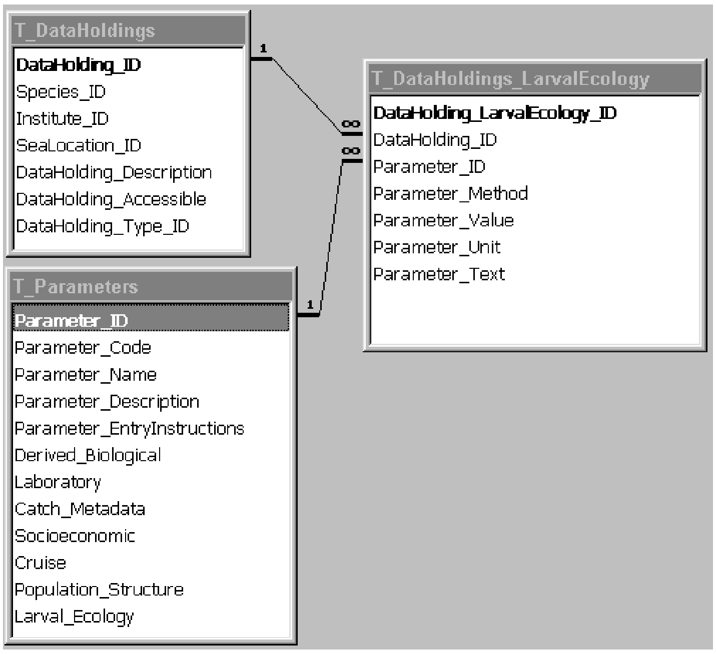


Figure 10 Relationships between data holdings (T_DataHoldings), Larval Ecology data (T_DataHoldings_LarvalEcology) and Larval Ecology parameters (T_Parameters)

Data theme 6: Population Structure (T_DataHoldings_PopulationStructure)

When entering the population structure data, the user should have the option of entering a new parameter into the T_Parameters table. The user is prompted to enter name, description and entry instructions fields (when saving the record to the T_Paremters table set Population_Structure field = true). The addition of the new parameter will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the population structure data in the data table (T_DataHoldings_PopulationStructure), the names, descriptions and the entry instructions for the larval ecology parameters (T_Parameters) must be available to the user.

There is a unique key set up in the data table on the fields DataHolding_ID, Parameter_ID.

See **Figure 11** for database relationships.

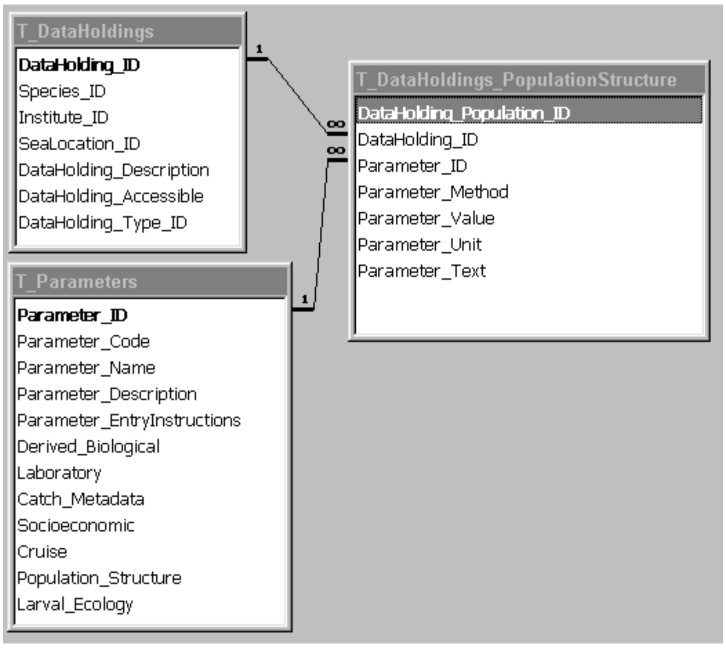


Figure 11 Relationships between data holdings (T_DataHoldings), Population Structure data (T_DataHoldings_PopulationStructure) and Population Structure parameters (T_Parameters)

Data theme 7: Landings/Effort (T_DataHoldings_LandingsEffort)

After entering the landings and effort data in the landings/effort data table, the user may wish to associate 1 or more gears with this data. A user must be able to enter new gears (but not gear types) also at this stage if the gear used is not available in the database. There is a unique key set up in the data table on the fields DataHolding_ID, Landings_Year, Country_ID. There must be appropriate validation on the Landings_Year field to only allow a valid year to be entered

See **Figure 12** for database relationships.

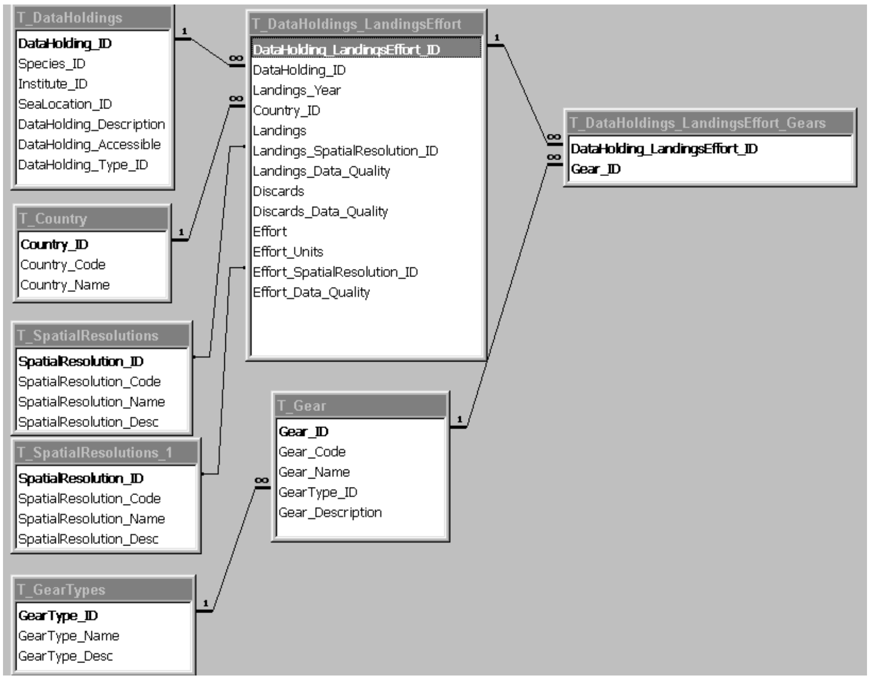


Figure 12 Relationships between data holdings (T_DataHoldings), Landings and Effort data (T_DataHoldings_LandingsEffort) and gears (T_DataHoldings_LandingsEffort_Gears, T_Gears)

Data theme 8: Stock Assessment Methods (T_DataHoldings_StockAssessmentMethods)

When entering the stock assessment data, the user should have the option of entering a method into the T_Methods table. The user is prompted to enter name and description fields. The addition of the new method will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the stock assessment data in the data table (T_DataHoldings_StockAssessmentMethods), the names and for the methods (T_Methods) must be available to the user.

There is a unique key set up in the data table on the fields DataHolding_ID, Method_ID, Start_Date and End Date.

See **Figure 13** for database relationships.

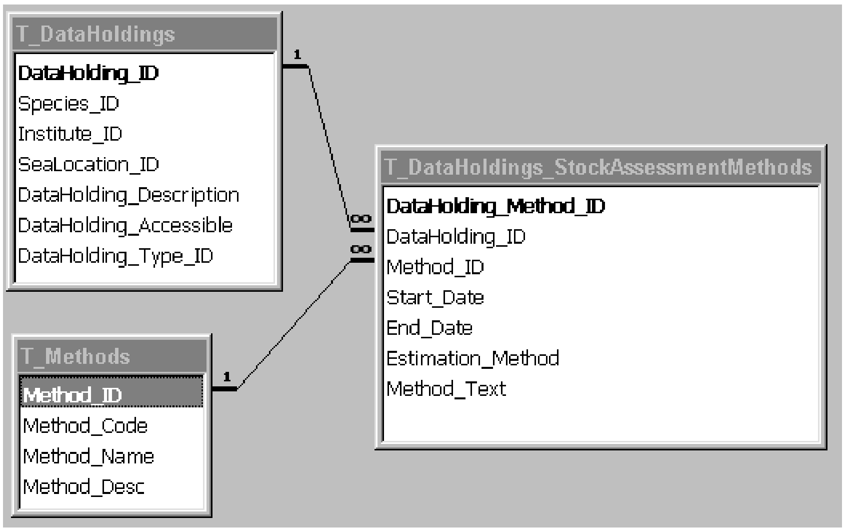


Figure 13 Relationships between data holdings (T_DataHoldings), Stock Assessment Data (T_DataHoldings_StockAssessmentNethods) and Stock Assessment Methods (T_Methods)

Data theme 9: Stocks (T_DataHoldings_Stocks)

When entering the stocks data, the user should have the option of entering a new stocks parameter into the T_Parameters table and a new method into the T_Methods table. For parameters, the user should be prompted to enter name, description and entry instructions fields (when saving the record to the T_Parameters table set Stocks field = true). For methods, the user is prompted to enter name and description fields. The addition of a new parameter and/or method will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the stocks data in the data table (T_DataHoldings_Stocks), the names, descriptions and the entry instructions for the parameters (T_Parameters) and methods (T_Methods) must be available to the user.

There is a unique key set up in the data table on the fields DataHolding_ID, Parameter_ID, Method_ID, Start_Date, End_Date.

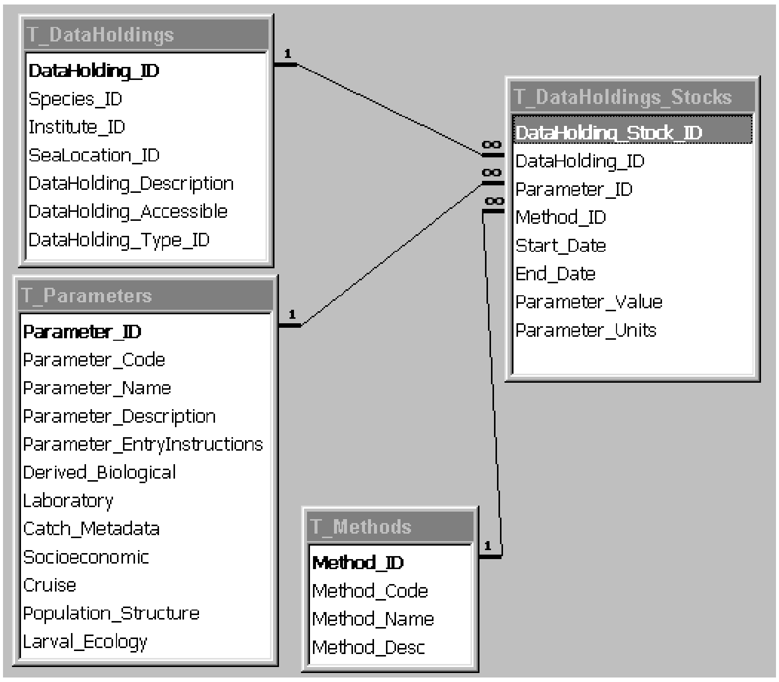


Figure 14 Relationships between data holdings (T_DataHoldings), Stocks data (T_DataHoldings_Stocks and Stocks parameters (T_Parameters)

See **Figure 14** for database relationships.

Data theme 10: Catch Metadata (T_DataHoldings_CatchMetadata)

The catch metadata is more complex than the other data themes as the user may enter information on cruises (T_Cruises) associated with the catch metadata and also cruise data (T_CruiseParameters) associated with the cruise.

When entering the catch metadata, the user should have the option of entering a new parameter into the T_Parameters table. The user is prompted to enter name, description and entry instructions fields (when saving the record to the T_Parameters table set Catch_Metadata field = true). The addition of the new parameter will cause a notification message to be sent behind the scenes to the administrator. The user should also be able to add a new gear to the T_Gears table.

When the user is entering the catch metadata, the names, descriptions and the entry instructions for each of the parameters (T_Parameters) must be available to the user.

There is a unique key set up in the data table on the fields DataHolding_ID, Parameter_ID, Start_Date, End_Date and CatchMetadata_Type_ID.

When the user has entered each catch metadata record, the option of associating cruises with the catch metadata record should be available. The user will need the facility to add a new cruise to the T_Cruises table.

If the user has entered a cruise, the option to enter cruise data should be available (T_CruiseParameters). When the user is entering the cruise data, it may be necessary to enter a new cruise parameter if an appropriate parameter does not already exist in the database. The user is prompted to enter name, description and entry instructions fields (when saving the record to the T_Parameters table set the Cruise field = true). The addition of the new cruise parameter will cause a notification message to be sent behind the scenes to the administrator. The user may also need to add a new gear to the T_Gears table.

See **Figure 15** for database relationships.

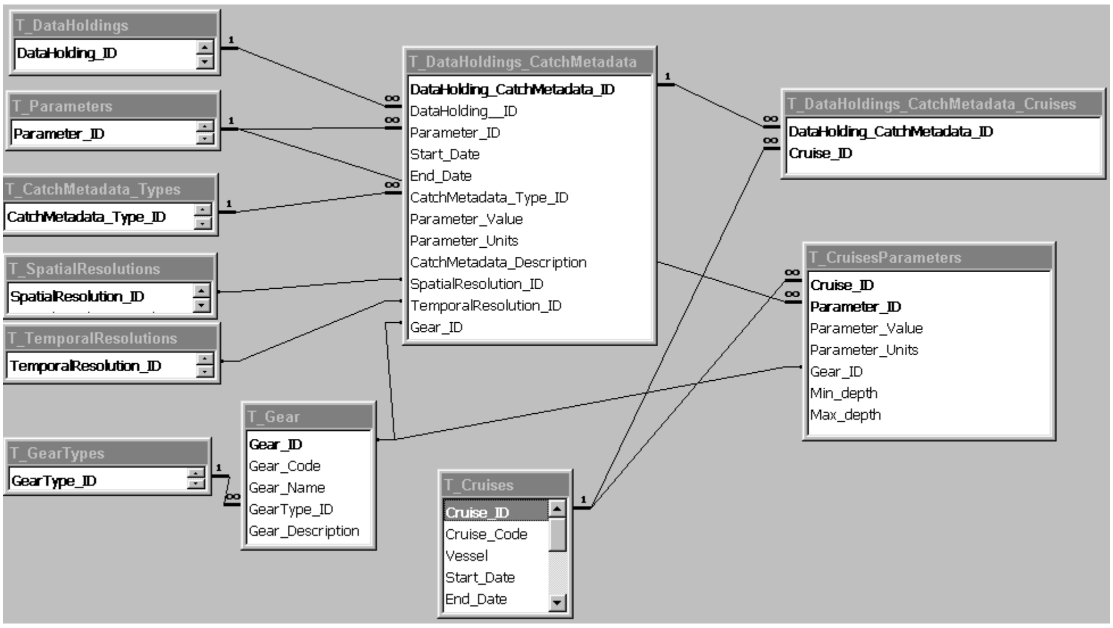


Figure 15 Relationships between data holdings (T_DataHoldings), Catch Metadata (T_DataHoldings_CatchMetadata) and parameters (T_Parameters), Catch metadata (T_DataHoldings_CatchMetadata), cruises (T_Cruises), cruise data (T_CruiseParameters) and parameters (T_Parameters)

Data theme 11: Socio-Economics (T_DataHoldings_SocioEconomic)

When entering the socio-economic data, the user should have the option of entering a new parameter into the T_Parameters table. The user is prompted to enter name, description and entry instructions fields (when saving the record to the T_Parameters table set the field Socioeconomic = true). The addition of the new parameter will cause a notification message to be sent behind the scenes to the administrator.

When the user is entering the socio-economic data in the data table (T_DataHoldings_SocioEconomic), the names, descriptions and entry instructions of each parameter (T_Parameters) must be visible to the user.

There is a unique key set up in the database on the fields DataHolding_ID, Parameter_ID and Start_Date.

An extra check needs to be implemented by the application to avoid having more than 1 data record for the *same* socio-economic parameter 'open' i.e. no end date has been entered for that record. If the same socio-economic parameter (Parameter_ID) is entered for a data holding as was previously entered, the application must ensure that the previous data record for that same socio-economic parameter is 'closed' by insisting an end-date is entered for that previous record. Entering an end date 'closes' that data record. Note: a data record refers to a record in the table T_DataHoldings_SocioEconomic.

Thus, for a data holding, while you can have more than 1 data record 'open' for *different* socio-economic parameter (e.g. No. crew per boat, Average earnings), you can only have 1 data record open for the *same* objective (e.g. Average earnings). All the other data records for the same socio-economic parameter must be 'closed'. Note: once the data records are closed you can have multiple data records for the same socio-economic parameter (each with a different start date).

See **Figure 16** database relationships.

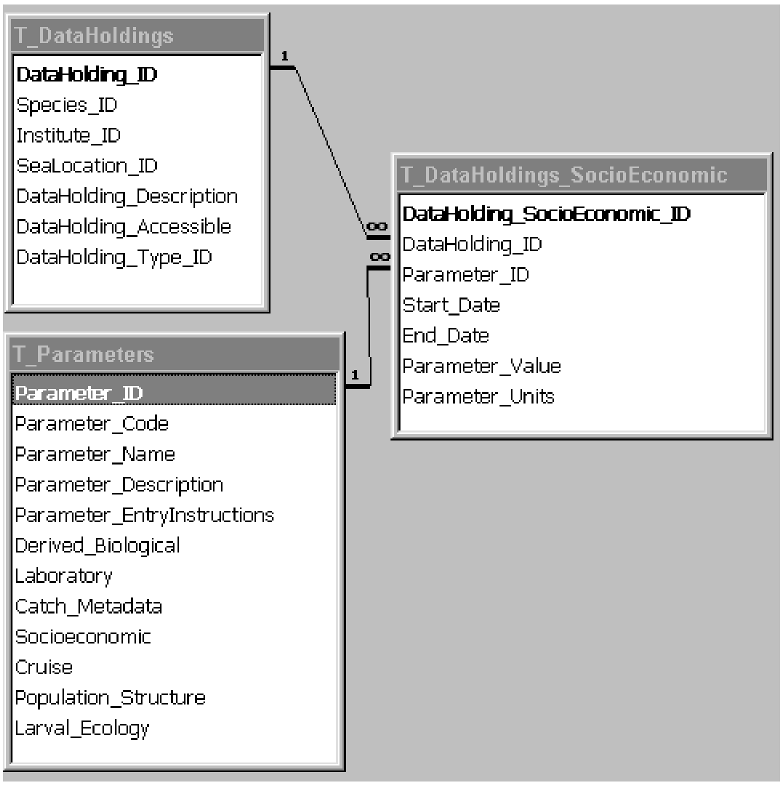


Figure 16 Relationships between data holdings (T_DataHoldings), socio-economic data (T_DataHoldings_Socioeconomic) and socio-economic parameter s(T_Parameters)

VI. Query the Database

This part of the site will be accessible by scientific users and the general public alike.

There will be two broad approaches to querying :

- A general search that allows the novice user to interactively drill down into the data.
- A detailed search to allow specialists to quickly identify the data they are interested in.

Query criteria will be selected from drop down lists for performing searches against the database. The query results will mainly be displayed in tabular form. A default number of records will be returned (e.g. Top 10 results) but the user should be allowed to amend this setting to return more or less data. The user will have the option to download the data displayed in a format e.g. .csv, which they can easily import into standard office packages such as Excel. Copy and paste and print functions should all be available.

Tables relevant to any database queries are listed in this section of the document. Relationships between the tables can be identified by indentation.

General Search

Select one species ***or*** one institute ***and*** select laboratory-based or location-based data.

If laboratory or location based data is not available for a species or institute selected from the list, the appropriate option should be disabled.

Query Tables:

T_DataHoldings
    T_DataHoldings_Types
    T_Species
    T_Institutes

Laboratory-based Data

If laboratory-based data is selected, the search returns general information on the data holdings in tabular format (see Table 1).

For example: Results of a species search

Institute Name	Data Holding Description	Access	Contact
TCD – Trinity College Dublin	Laboratory data	Restricted	Dr. Oliver Tully
UNIVGOA - University of Genova	Laboratory data	Restricted	Dr. Julio Chello

Table 1 Available laboratory based data holdings for Species X

Query Tables:

T_DataHoldings
    T_DataHoldingsDataThemes
        T_Contacts
        T_DataThemes (=”Laboratory data”)
    T_Institutes
    T_Species

If searching on a single species, Institute Name should sort the rows. If searching on a single institute, the rows should be ordered by Species.

Note: the *Institute Name* is a concatenation of Institute code and name in the database.

Functions:

Functions required at this stage include the following:-

- View Institute details for the data holding
    T_DataHoldings
        T_Institutes
- View Contact details for the data holding
    T_DataHoldings
        T_DataHoldingsDataThemes
            T_Contacts
- View publications associated with the data holding
    T_DataHoldings
        T_DataHoldings_Publications
            T_Publications
- Display the Laboratory data for the data holding
    T_DataHoldings
        T_DataHoldings_LaboratoryData
            T_Parameters

T_LifeHistoryPhases

- Link to the institute Web-site for the data holding
  T_DataHoldings
  T_Institutes
- Send e-mail to the contact for the data holding
- Parameter Search (see below)
- New search

VII. Parameter search

The user may select one or more (or all) of the data holdings returned and choose 1 or more parameters from a list of laboratory-based parameters. If reasonable, only the parameters that have associated laboratory data should be displayed in this list with a link to displaying all laboratory data parameters so that the user can see what parameters are included in the database. The parameter name and description should be available to the user.

Query Tables:
T_DataHoldings
T_DataHoldings_LaboratoryData
T_Parameters
T_LifeHistoryPhases
T_DataHoldings_DataThemes
T_Contacts
T_DataThemes (=”Laboratory Data”)
T_Species
T_Institutes

The results of this search are displayed in tabular format (order by Species and Parameter) and may include such fields as follows (see Table 2):-

Species/Institute, Parameter, Description, Value, Units, Text, Life History Phase, Contact Name.

If a single species is selected in the previous step, the species column could be omitted from the listing and contained in the title only and likewise for the institute.

Note: A contact may not always be associated with a data theme.

For example:

Parameter	Description	Life History Phase	Value	Units	Text	Institute	Contact
Parameter 1	Parameter 1 description	Larval stages	20	mm	More ..	TCD – Trinity College Dublin	Dr. Oliver Tully
Parameter 2	Parameter 2 description	Adult stages	40	mm		TCD – Trinity College Dublin	Dr. Oliver Tully

Table 2 Laboratory data for ‘Species X’

Functions:
The following functions may be required at this stage:-

- View the contact details for a single parameter record
  T_DataHoldings
  T_DataHoldingsDataThemes
  T_Contacts
- View the institute details for a single parameter record
  T_DataHoldings
  T_Institutes
- View associated publications for one or more records (allow selection of multiple records)
  T_DataHoldings
  T_DataHoldings_Publications
  T_Publications
- New parameter search
- New general search
  - Send e-mail to the contact

Location-based data
If the user selects location-based information then the user must choose 1 or more (or all) of the higher-level sea locations to search on.

The information is returned in tabular format and may include the following fields ordered by species and sea location:-

Sea Location, Species or Institute, Data holding description, Data Accessibility, Environment, Dominant Species, 2nd Species, 3rd Species, Length of coastline over which the species is distributed.

Query tables:

T_DataHoldings
T_DataHoldings_SeaLocations
T_SeaLocations (and/or new tables)
T_Species
T_Institutes

Note: the *Institute Name* is a concatenation of Institute code and name in the database.

Functions:

Functions required at this stage include the following:-

- View Institute details for the data holding
  T_DataHoldings
  T_Institutes
- View Contact details for the data holding. Display the contact details for each data theme that is available for the data holding
  T_DataHoldings
  T_DataHoldingsDataThemes
  T_Contacts
- View publications associated with the data holding
  T_DataHoldings
  T_DataHoldings_Publications
  T_Publications
- Link to the institute Web-site for the data holding
  T_DataHoldings
  T_Institutes
- View available data themes for one or more of the data holdings (see below)
  T_DataHoldings
  T_DataHoldingsDataThemes
- New search

VIII. View available data themes

The user may choose 1 or more data holdings to view the types of data (data themes) that are available. A list of data themes for the selected rows is returned.

For example, if there are more data available on socio-economics, derived biological parameters and management structures in place to manage the fishery, these 3 items are listed.

The user must have the facility to select one of these data themes. The data for the selected data theme are displayed in tabular format ordered by species and sea location.

For example: If the user chooses socio-economic data, the data from the T_DataHoldings_SocioEconomic table may be displayed in tabular format as follows (ordered by species and sea location):-
Species/Institute, Sea Location, Parameter, Description, Value, Start Date, End Date, Value, Units, Contact Name

Query tables:

T_DataHoldings
T_DataHoldings_SocioEconomic
T_Parameters
T_DataHoldings_DataThemes (=”Socio Economics”)
T_Contacts
T_Institutes

Functions:
The functions required at this stage may include the following:-
View Institute Details for a record
View Contact Details for a record
View associated publications for one or more records
Send e-mail to the contact for a data theme

For some of the data theme tables, there are further levels of data stored in the database (e.g. Catch metadata, Landings and Effort data). This data must also be accessible to the user. Perhaps, this might be implemented by allowing the user to view more data for these data themes on a record-by-record basis (e.g. the cruise data [T_Cruises, T_CruiseParameters, etc.] associated with a catch metadata record or the available gears [T_Gears, T_DataHoldings_LandingsEffort_Gears] for a landings data record).

IX. Advanced Search

Step 1
User selects a species and either a data theme *or* a sea location. As the user selects a species, the data themes and sea locations need not reflect this as having to update both items may degrade performance.

Step 2
The user may now select either a data theme *or* a sea location (depending on the previous choice).

If a data theme was chosen in Step 1, the user can now select a sea location. Only the sea locations associated with the selected species and selected data theme are displayed to the user. This choice of sea location for the user should include both the higher and lower level categories of seas as appropriate. If the user selects a high level sea, then the associated lower level seas are automatically included in the search. If the data theme selected in Step 1 was

'Laboratory Data' then this step is redundant and not available to the user. If there are no data themes for the user's selection then an error message is displayed to the user and step 1 re-displayed.

Query tables:
T_DataHoldings
    T_DataHoldings_SeaLocations
        T_SeaLocations
    T_DataHoldings_DataThemes
        T_DataThemes (="selected data theme")
    T_Species (="selected species)

If a sea location was chosen in Step 1 the user can now select a data theme. Only the data themes associated with the selected species and selected sea location(s) are displayed to the user. If there are no sea locations for the user's selection then an error message is displayed to the user and step 1 re-displayed.

Query tables:
T_DataHoldings
    T_DataHoldings_SeaLocations
    T_SeaLocations(="selected sea location")
    T_DataHoldings_DataThemes
        T_DataThemes
  T_Species (="selected species)

Step 3
The user selects one or more parameters. The list of parameters will depend on the data theme that was selected and the data available for the criteria entered by the user (assuming that this does not have serious performance issues). However, a link to view all the parameters for the data theme should also be available.

Query Tables:
(For the selected socio-economic data theme)
T_DataHoldings
   T_DataHoldings_SocioEconomics
        T_Parameters
   T_Species (="selected species")

Step 4

The data is now returned in tabular format according to the criteria entered by the user.

For example:
A search on socio-economic data might display the following information (see Table 3):-
Sea Location, Parameter, Description, Start Date, End Date, Value, Units, Institute, Contact Name.

Note: A contact may not always be associated with a data theme.

Sea Location	**Parameter**	**Description**	**Start Date**	**End Date**	**Value**	**Units**	**Institute**	**Contact**
Sea 1	Parameter 1	Parameter 1 description	01/01/2000		20	Vessels	Institute 1	Ms. P. Smith
Sea 1	Parameter 2	Parameter 2 description	01/01/2000	01/01/2001	5	Crew	Institute 1	Ms. P. Smith

Sea 2	Parameter 1	Parameter 1 description	01/01/2000		50	Vessels	Institute 1	Ms. P. Smith

Table 3 Socio-economic Data for Species X

Functions:
The following functions may be required at this stage:-

- View the contact details for a single parameter record
  - T_DataHoldings_SocioEconomics (=”selected DataHolding_ID)
  - T_DataHoldings_DataThemes (=”selected data theme”)
    - T_Contacts
    - T_DataThemes
- View the institute details for a single parameter record
  - T_DataHoldings
    - T_DataHoldings_SocioEconomics (=”selected DataHolding_ID)
    - T_Institutes
- View Data Holding information for 1 or more records
  - T_DataHoldings
    - T_DataHoldings_SocioEconomics (=”selected DataHolding_ID)

Display the data holding AND sea location information for all data themes with the exception of ‘laboratory data’. Display the information in the same way as described for ***Location-based data*** in the General Search section of this document. See this section also for functions that are required at this stage. Additional tables to display this information are listed in that section.

Otherwise for ‘laboratory data’, display the information in the same way as described for

Laboratory-based Data in the General Search section of this document. See this section also for functions that are required at this stage. Additional tables to display this information are listed in that section.

- View associated publications for one or more records
  - T_DataHoldings
    - T_DataHoldings_SocioEconomics
    - T_DataHoldings_Publications
      - T_Publications
- New advanced search
- Send e-mail to the contact

Database Look up tables

The actions a user can perform on the look up tables are listed below.
T_CatchMetadata_Types (None)
T_Contacts (A, U), (D for newly added records during the same session only)
T_Country (None)
T_Cruises (A – all users) (D, U for newly added records during the same session only)
T_DataHolding_Types (None)
T_DataThemes (None)
T_Gear (A – all users), (D, U for newly added records during the same session only)
T_GearTypes (None)
T_Gender (None)
T_Institutes (A, U), (D for newly added records during the same session only)
T_LifeHistoryPhases (A – all users), (D, U for newly added records during the same session only)

T_ManagementStructureTypes (A – all users), (D, U for newly added records during the same session only)
T_Measures (A – all users), (D, U for newly added records during the same session only)
T_Methods (A – all users), (D, U for newly added records during the same session only)
T_Objectives (A – all users), (D, U for newly added records during the same session only)
T_Parameters (A – all users), (D, U for newly added records during the same session only)
T_Publications (A – all users), (D, U for newly added records during the same session only)
T_SamplingDesigns (A – all users), (D, U for newly added records during the same session only)
T_SeaLocations (None)
T_SpatialResolutions (None)
T_Species (A – all users), (D, U for newly added records during the same session only)
T_TemporalResolutions (None)

None = no permissions to update, add or delete records
All = all permissions
A = add permission, D = delete permission, U = update permission

Note: as referential integrity is enforced when possible in the relationships between the look up and other tables, in these cases the database will not allow deletion of a look up record that is in use by other tables.

X. Administration of the Database

There is a requirement to provide the data administrator with the ability to remotely access the database in order to check the quality of data entered and perform edits if necessary.

MS Access forms will be developed to facilitate off-line data entry by the administrator. This will also require a facility on the Website to publish the next date for administration of the database in addition to disallowing access to the Data Entry section of the site until the administration tasks have been completed.

Help
Simple Help pages need to be available to assist users in entering data and in running queries.

Perhaps tool tips could also be used to give a brief description of the fields and functions available on the Web pages.

2. *Description of the website (ECFM)*

Based on the user requirements described above a web site was developed that allows registered users to enter data and general users to search the database. The design and functionality of the web site is described below. A separate brochure on the web site and a help manual will be produced during the 3rd year of the project.

Fig. 18. Home page for the European Crustacean Fisheries Metadatabase. The user can choose to enter new data or search for existing data. Background information on EDFAM and ECFM is available through the hyperlinks

In order to enter new data or to update existing data which the user has previously input a login password is required. Afer logging in the user is presented with the options in Fig. 19.

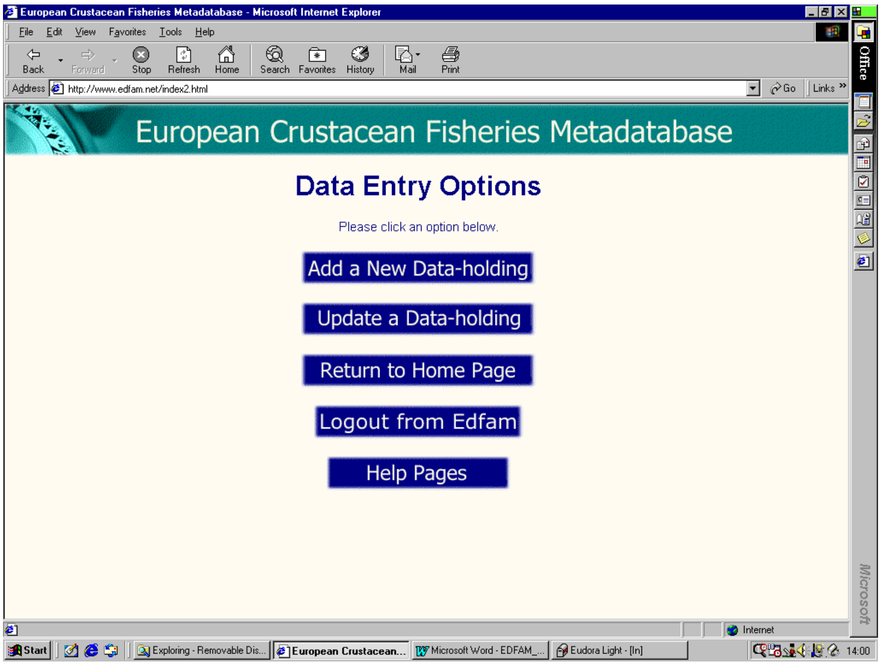


Fig. 19. Data entry options presented to the user after logging into the ECFM site

On choosing to enter a new data holding the user is requested to choose an institute, species and sea location and to provide other information on the data (Fig. 20)

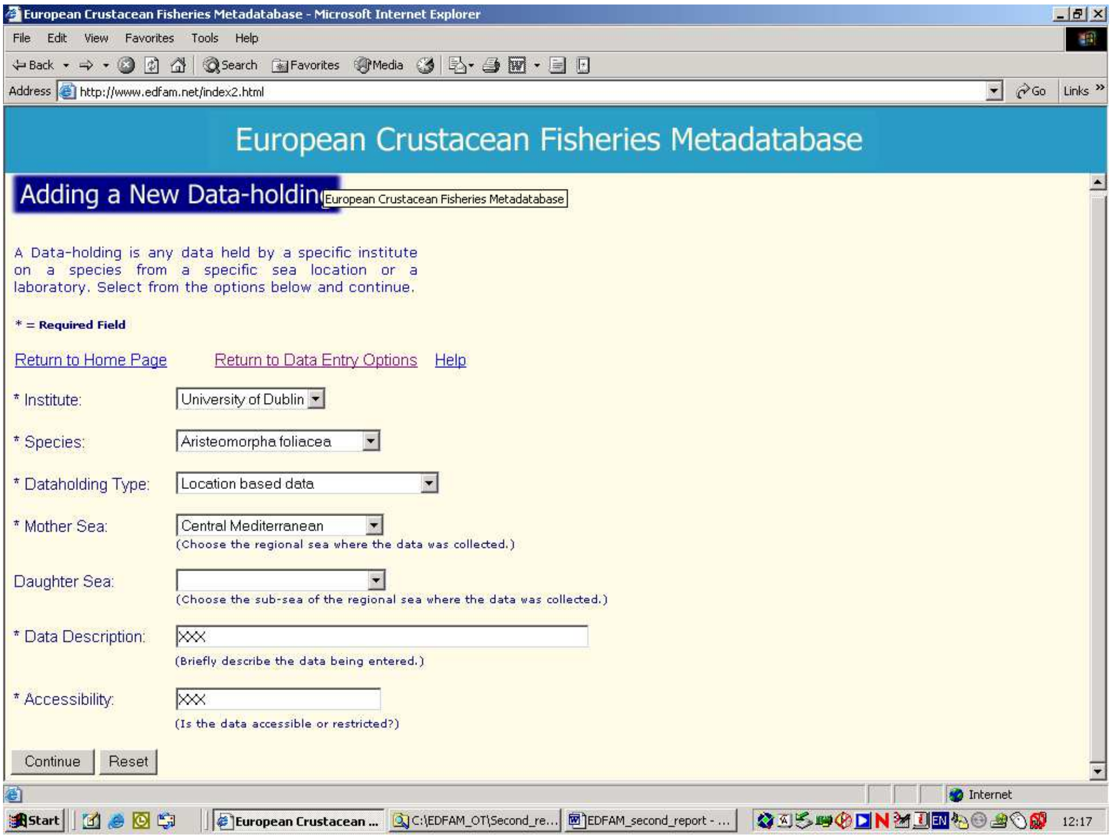


Fig. 20. High level data defining a dataholding.

Once the dataholding is defined the user is then asked for the types of data that are associated with this data holding. There are 11 such themes and the user can choose each successively and to add data on that theme that is associated with the dataholding (the institute, species, sea location combination).

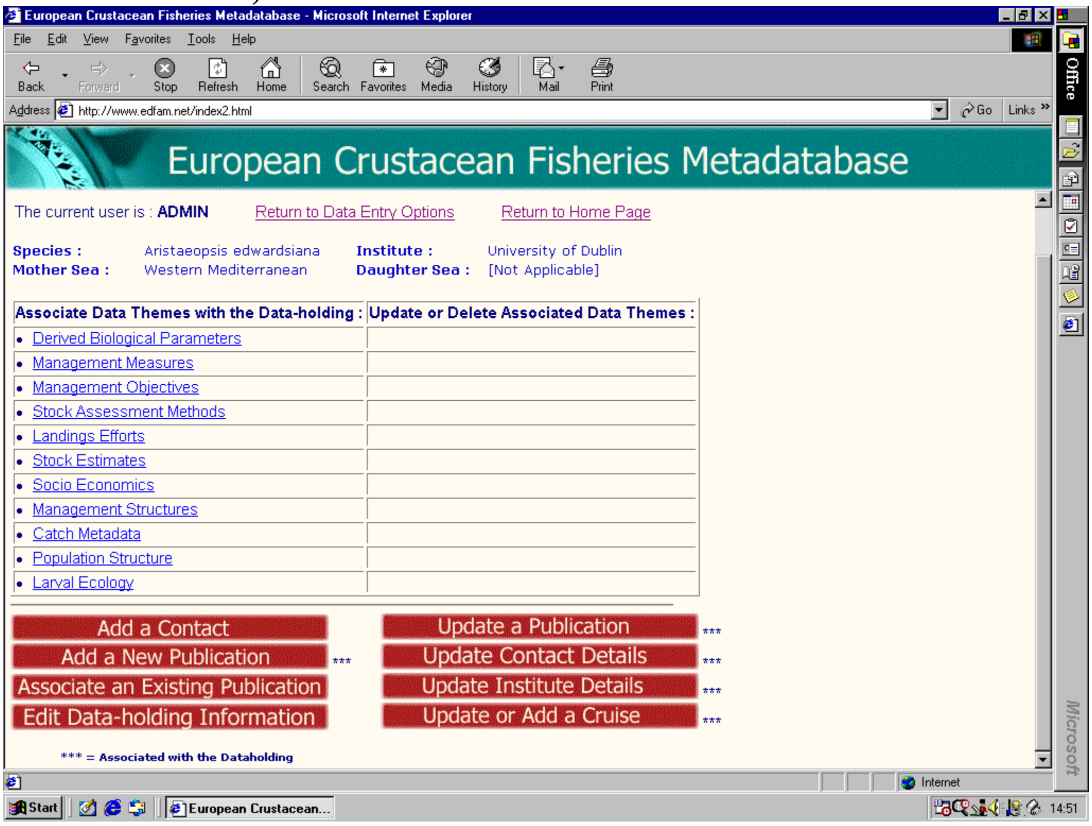
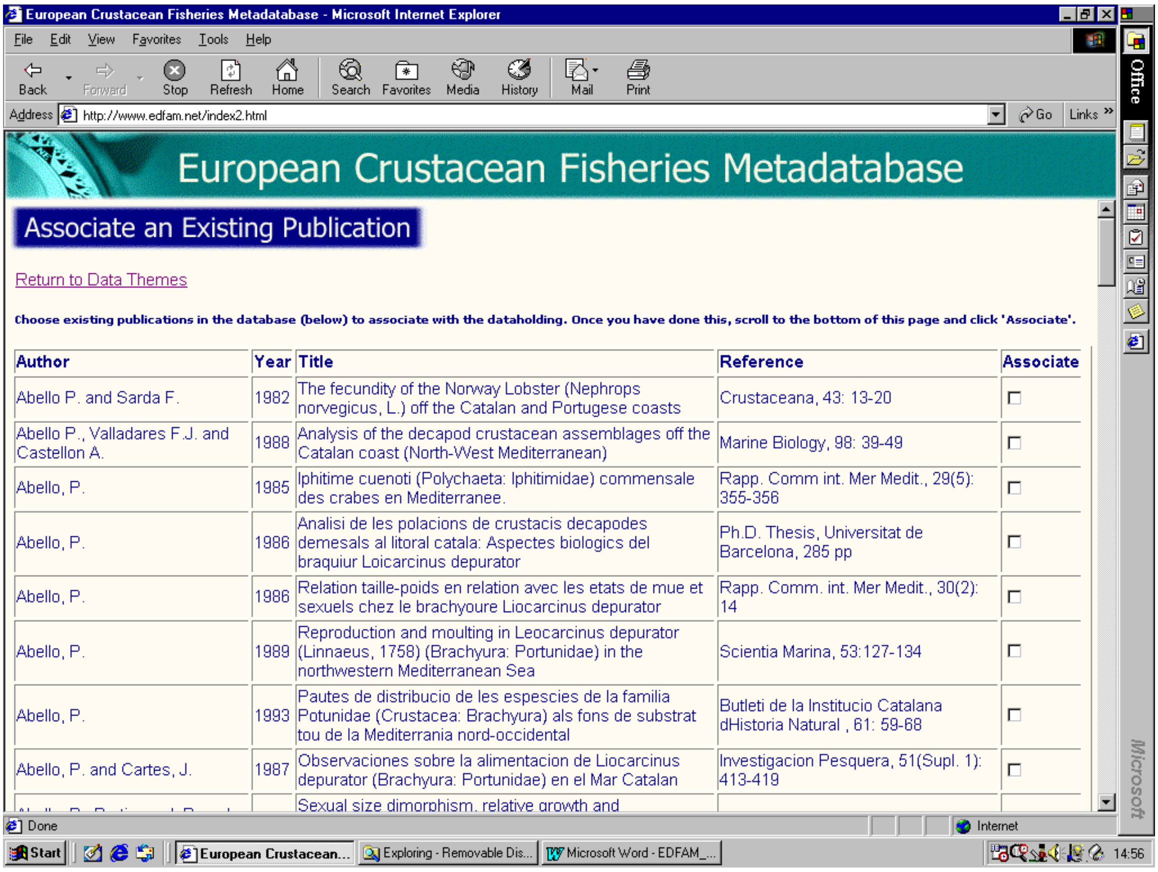


Fig. 21 Data themes (different types of metadata) that can be associated with a data holding. The data in each theme can be associated with a contact, a list of publications or specific cruise information.

Contacts for and publications associated with these data themes or the data holding. An example of how to choose to associate a publication with a data theme in a data holding from an existing list of publications is shown in Fig. 22.



European Crustacean Fisheries Metadatabase

Associate an Existing Publication

Return to Data Themes

Choose existing publications in the database (below) to associate with the dataholding. Once you have done this, scroll to the bottom of this page and click 'Associate'.

Author	Year	Title	Reference	Associate
Abello P. and Sarda F.	1982	The fecundity of the Norway Lobster (Nephrops norvegicus, L.) off the Catalan and Portugese coasts	Crustaceana, 43: 13-20	☐
Abello P., Valladares F.J. and Castellon A.	1988	Analysis of the decapod crustacean assemblages off the Catalan coast (North-West Mediterranean)	Marine Biology, 98: 39-49	☐
Abello, P.	1985	Iphitime cuenoti (Polychaeta: Iphitimidae) commensale des crabes en Mediterranee.	Rapp. Comm int. Mer Medit., 29(5): 355-356	☐
Abello, P.	1986	Analisi de les polacions de crustacis decapodes demesals al litoral catala: Aspectes biologics del braquiur Loicarcinus depurator	Ph.D. Thesis, Universitat de Barcelona, 285 pp	☐
Abello, P.	1986	Relation taille-poids en relation avec les etats de mue et sexuels chez le brachyoure Liocarcinus depurator	Rapp. Comm. int. Mer Medit., 30(2): 14	☐
Abello, P.	1989	Reproduction and moulting in Leocarcinus depurator (Linnaeus, 1758) (Brachyura: Portunidae) in the northwestern Mediterranean Sea	Scientia Marina, 53:127-134	☐
Abello, P.	1993	Pautes de distribucio de les especies de la familia Potunidae (Crustacea: Brachyura) als fons de substrat tou de la Mediterrania nord-occidental	Butleti de la Institucio Catalana dHistoria Natural , 61: 59-68	☐
Abello, P. and Cartes, J.	1987	Observaciones sobre la alimentacion de Liocarcinus depurator (Brachyura: Portunidae) en el Mar Catalan	Investigacion Pesquera, 51(Supl. 1): 413-419	☐
		Sexual size dimorphism, relative growth and		

Fig. 22. Associating a data theme of a particular data holding with an existing publication list. The tick boxes on the right hand column are checked to associate the publication

Metadata for each data theme can be included by choosing the data theme. For example if the derived biological parameters theme is chosen the screen presented in Fig. 23 is shown. Values for any one of a number of derived biological parameters (eg von Bertalanffy growth parameters) can be associated with the data holding .

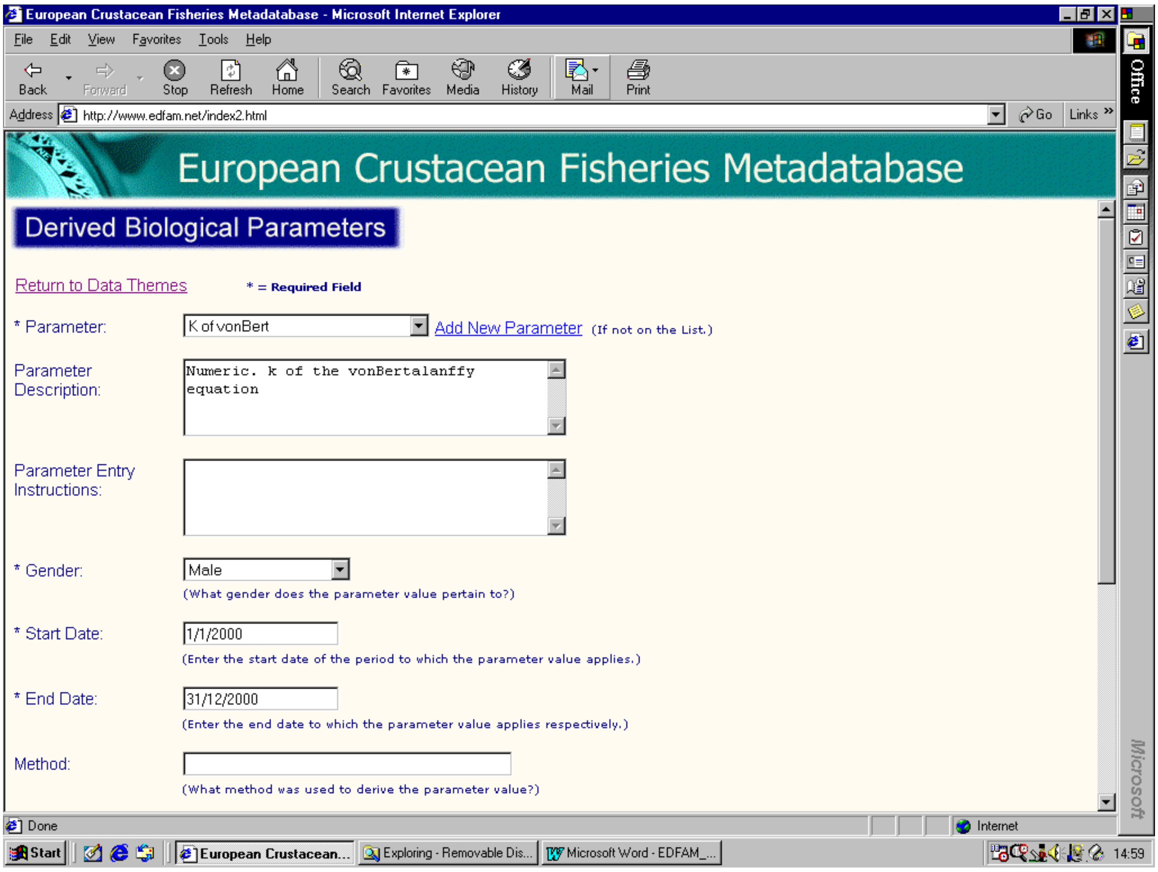


Fig. 23. Entering data in the derived biological parameters data theme

Searching the database :

There are 2 search options

- one that allows a general search or exploration of the database and
- a specific search for a particular parameter value or other piece of data. This is a directed search from the start.

Results of a general search for data on *P. longirostris* in the western Mediterranean is shown in Fig. 24. By selecting the first record returned (Data from IZUG in this example) the available data themes associated with this dataholding (species, location and institute combination) is presented (Fig. 25). In this example the derived biological parameters theme is selected and the values for life span of this species and location are presented. The life span for the species in the Ligurian Sea according to Relini at IZUG is 4 years as shown. These estimates were obtained between 1985 and 1999.

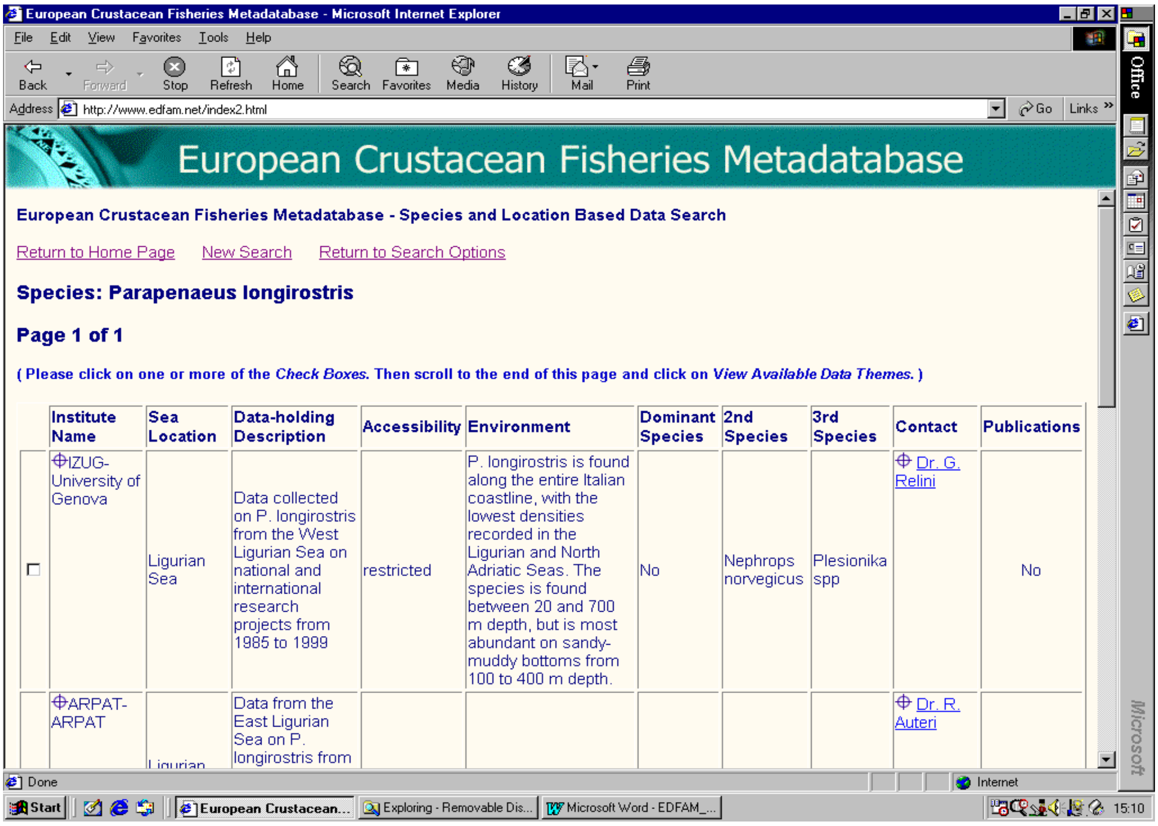


Fig. 24. Result of searching the database for location based information on Parapenaeus longirostris in the western Mediterranean. Hyperlinks to the contact for the information is available.

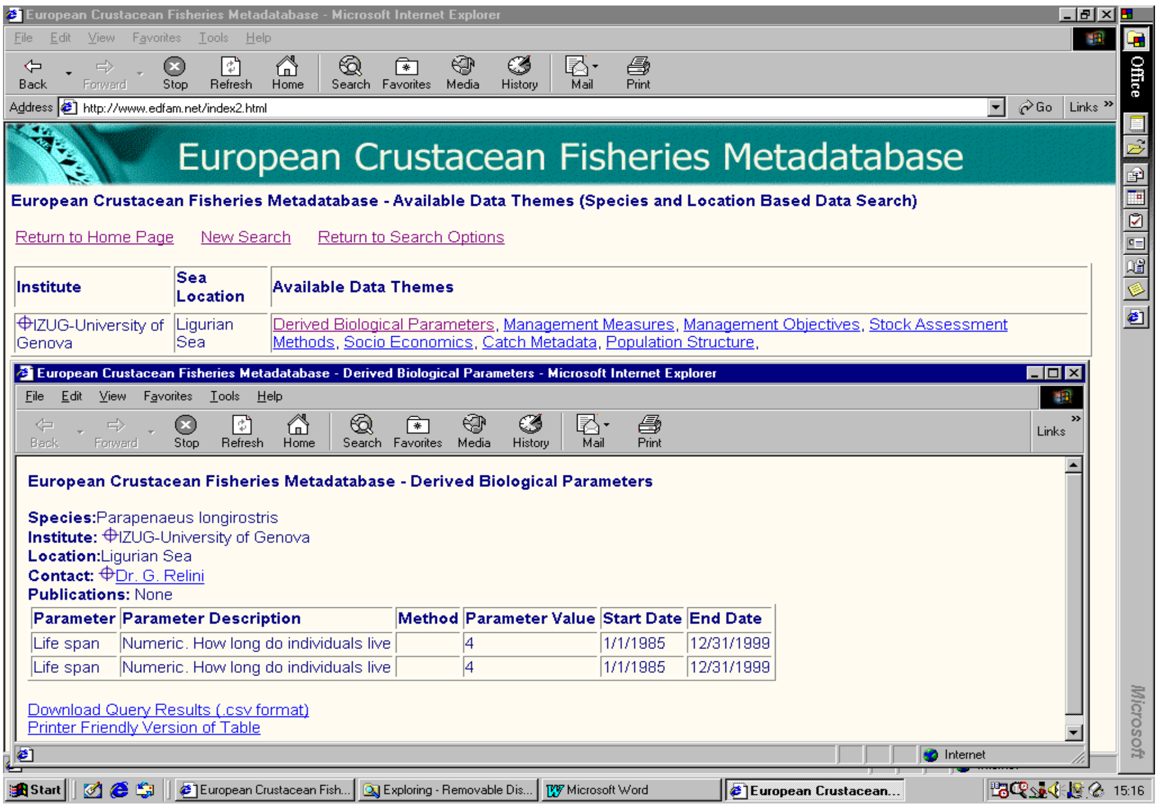


Fig. 25. Data themes available for Parapenaeus longirostris at IZUG – found by selecting the first record in Fig. 23. Output from the derived biological parameters theme is shown in the bottom screen.

The results of a similar type of search for management measures for P. longirostris in the Ligurian Sea indicates that there is a closed season, mesh regulations and limited entry in place (Fig. 25).

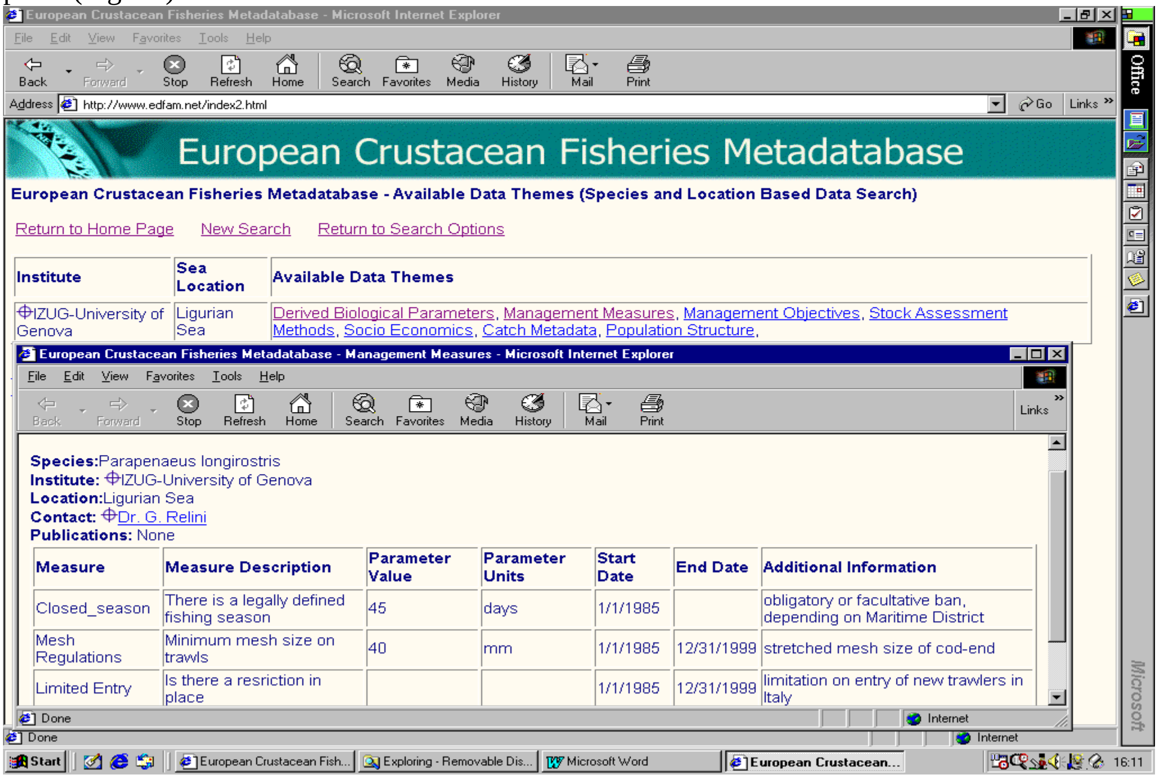


Fig. 25. Results of search for management measures for Parapenaeus longirostris in the Ligurian Sea

The start point for an advanced search of the database is shown in Fig. 26. A species and data theme or sea location are selected in the first step. A data theme and a parameter related to that theme is then selected in the second step.

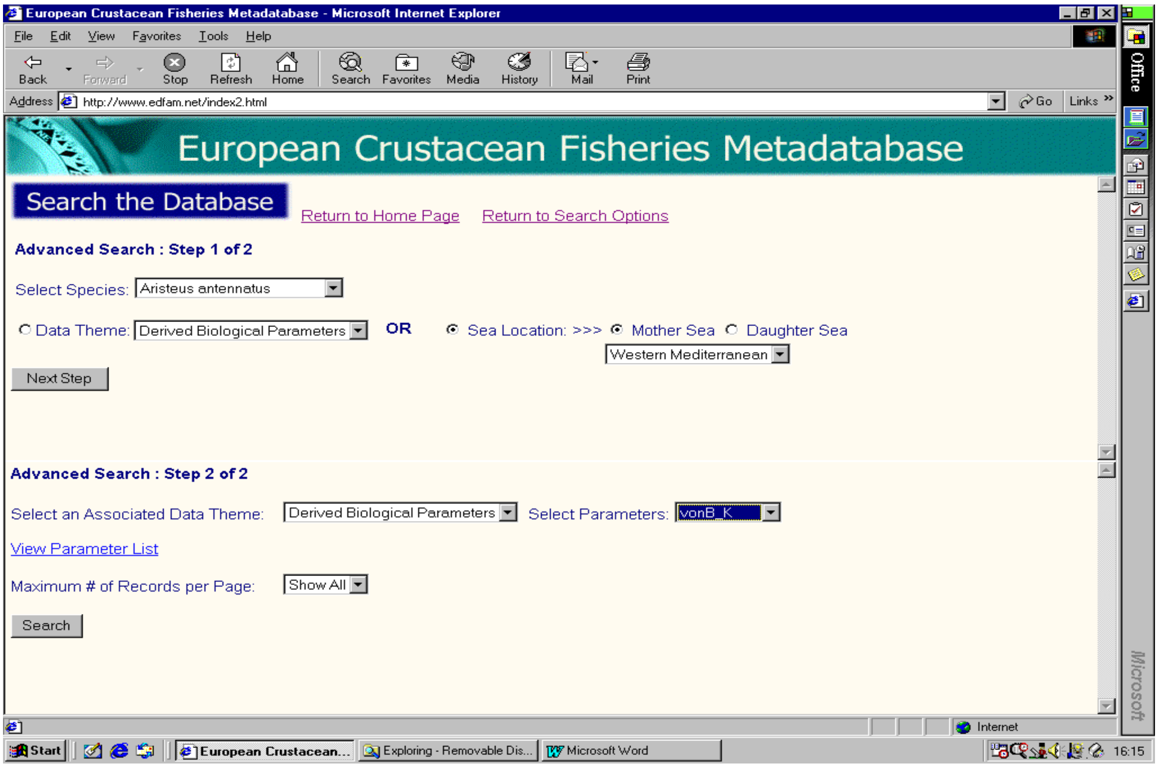
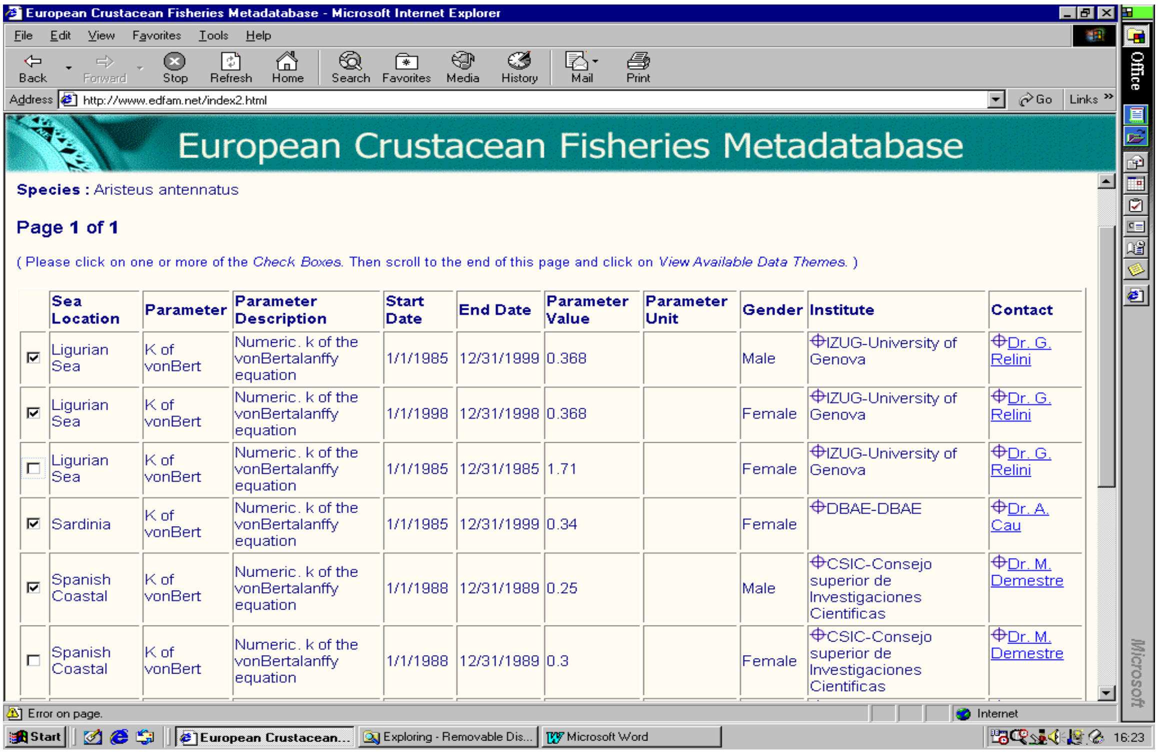


Fig. 26. Design of the advanced search facility in ECFM. Step 1 involves selecting a species and a datathem or a sea location. In this case Aristeus antenattus is the selected species and the sea location is the Western Mediterranean. A smaller sea area could be chosen by selecting the daughter sea option. In the second step the derived biological parameter them is selected from the list of data themes and values of k of the von Beralanffy equation are selected. The search results are in Fig. 27.

The results of the advanced search criteria in Fig. 26 are shown in Fig. 27. The output shows different values for the k parameter of the vonBertalanffy growth model for different locations in the western Mediterranean. Contact details for the person and institute responsible for the study are shown. Any associated publications can be viewed by selecting the records by ticking the boxes on the left hand side of the screen. The publications associated with the 4 records that are ticked are indicated in Fig. 28.



European Crustacean Fisheries Metadatabase - Microsoft Internet Explorer

Address http://www.edfam.net/index2.html

European Crustacean Fisheries Metadatabase

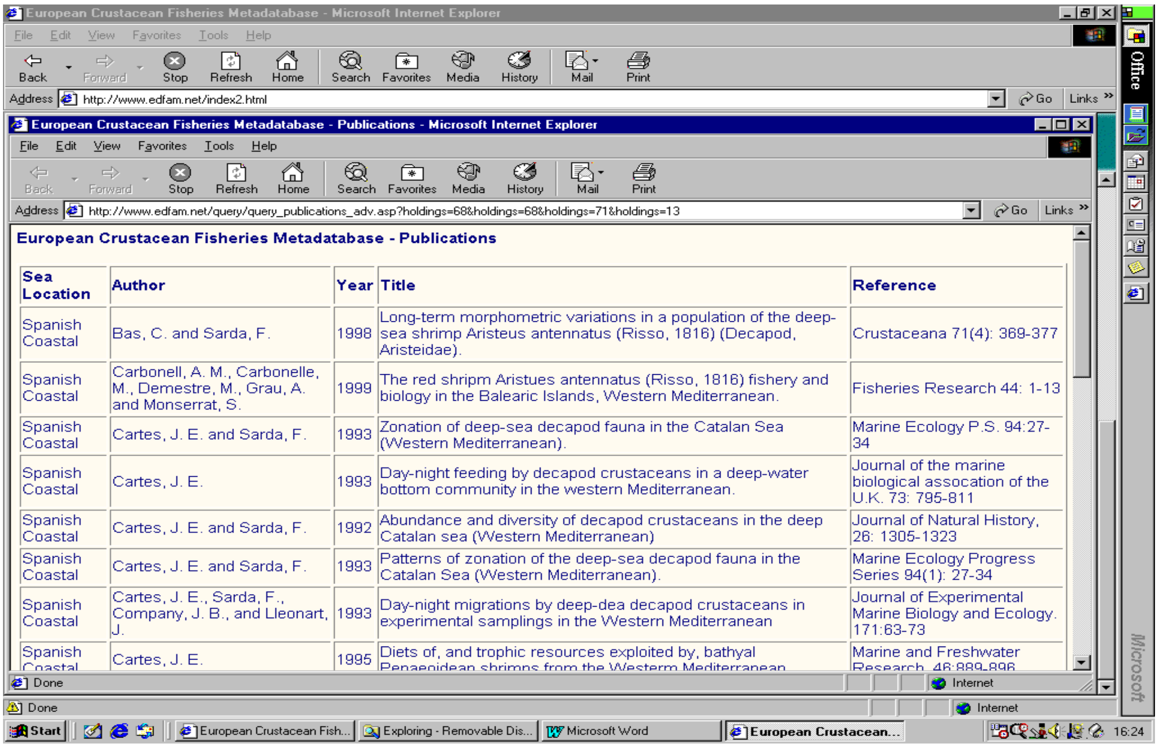
Species : Aristeus antennatus

Page 1 of 1

(Please click on one or more of the *Check Boxes*. Then scroll to the end of this page and click on *View Available Data Themes*.)

	Sea Location	Parameter	Parameter Description	Start Date	End Date	Parameter Value	Parameter Unit	Gender	Institute	Contact
☑	Ligurian Sea	K of vonBert	Numeric. k of the vonBertalanffy equation	1/1/1985	12/31/1999	0.368		Male	IZUG-University of Genova	Dr. G. Relini
☑	Ligurian Sea	K of vonBert	Numeric. k of the vonBertalanffy equation	1/1/1998	12/31/1998	0.368		Female	IZUG-University of Genova	Dr. G. Relini
☐	Ligurian Sea	K of vonBert	Numeric. k of the vonBertalanffy equation	1/1/1985	12/31/1985	1.71		Female	IZUG-University of Genova	Dr. G. Relini
☑	Sardinia	K of vonBert	Numeric. k of the vonBertalanffy equation	1/1/1985	12/31/1999	0.34		Female	DBAE-DBAE	Dr. A. Cau
☑	Spanish Coastal	K of vonBert	Numeric. k of the vonBertalanffy equation	1/1/1988	12/31/1989	0.25		Male	CSIC-Consejo superior de Investigaciones Cientificas	Dr. M. Demestre
☐	Spanish Coastal	K of vonBert	Numeric. k of the vonBertalanffy equation	1/1/1988	12/31/1989	0.3		Female	CSIC-Consejo superior de Investigaciones Cientificas	Dr. M. Demestre

Fig. 27. Results of search defined in Figure 26. Records 1,2,4 and 5 are selected in order to view the associated publications (Fig. 28).



European Crustacean Fisheries Metadatabase - Publications - Microsoft Internet Explorer

Address http://www.edfam.net/query/query_publications_adv.asp?holdings=68&holdings=68&holdings=71&holdings=13

European Crustacean Fisheries Metadatabase - Publications

Sea Location	Author	Year	Title	Reference
Spanish Coastal	Bas, C. and Sarda, F.	1998	Long-term morphometric variations in a population of the deep-sea shrimp Aristeus antennatus (Risso, 1816) (Decapod, Aristeidae).	Crustaceana 71(4): 369-377
Spanish Coastal	Carbonell, A. M., Carbonelle, M., Demestre, M., Grau, A. and Monserrat, S.	1999	The red shripm Aristues antennatus (Risso, 1816) fishery and biology in the Balearic Islands, Western Mediterranean.	Fisheries Research 44: 1-13
Spanish Coastal	Cartes, J. E. and Sarda, F.	1993	Zonation of deep-sea decapod fauna in the Catalan Sea (Western Mediterranean).	Marine Ecology P.S. 94:27-34
Spanish Coastal	Cartes, J. E.	1993	Day-night feeding by decapod crustaceans in a deep-water bottom community in the western Mediterranean.	Journal of the marine biological assocation of the U.K. 73: 795-811
Spanish Coastal	Cartes, J. E. and Sarda, F.	1992	Abundance and diversity of decapod crustaceans in the deep Catalan sea (Western Mediterranean)	Journal of Natural History, 26: 1305-1323
Spanish Coastal	Cartes, J. E. and Sarda, F.	1993	Patterns of zonation of the deep-sea decapod fauna in the Catalan Sea (Western Mediterranean).	Marine Ecology Progress Series 94(1): 27-34
Spanish Coastal	Cartes, J. E., Sarda, F., Company, J. B., and Lleonart, J.	1993	Day-night migrations by deep-dea decapod crustaceans in experimental samplings in the Western Mediterranean	Journal of Experimental Marine Biology and Ecology. 171:63-73
Spanish Coastal	Cartes, J. E.	1995	Diets of, and trophic resources exploited by, bathyal Penaeoidean shrimps from the Westerm Mediterranean	Marine and Freshwater Research 46:889-896

Fig. 28. Publications associated with 4 selected (Fig. 27) estimates of k (von Bertalanffy) for *Aristeus antennatus* in the western Mediterranean.

3. The ECFM Guidebook

European Crustacean Fisheries Metadatabase Guidebook

www.edfam.net

What is the European Crustacean Fisheries Metadatabase?

The European Crustacean Fisheries Metadatabase (ECFM) (Fig. 1) is a unique web-based resource that provides summary data on an extensive range of topics relating to the biology and fisheries of exploited marine crustaceans in Europe. The database is maintained under the EDFAM project.

The information summarised in the database is presently held in various European institutes in different formats (databases, spreadsheets, internal reports and published scientific papers). ECFM is an inventory for metadata relating to these many sources of information. The main purpose of the website is to promote greater awareness of crustacean fisheries management and assessment issues in Europe and to encourage co-ordination among various research groups and institutes. ECFM offers a restricted data entry facility for registered users at institutes that hold relevant data and wish to become involved, in addition to a search facility open to all users of the site.

Fig. 1. European Crustacean Fisheries Metadatabase Home Page (www.edfam.net)

What type of data is held in ECFM?

The ECFM database is designed to hold data on a wide variety of data themes relating to crustacean fisheries in Europe (Fig. 2). The data themes cover the biological, physical, management and assessment aspects of crustacean fisheries. Each data holding within the database is a summary of the information held by a specific institute on a species from a specific sea location or laboratory. For each data holding, summary data is available on a selection of the data themes. Each data theme has a pre-defined list of parameters, but users have the option to add new parameters to the specified themes.

Associate Data Themes with the Data-holding

The current user is : **TCD** Return to Data Entry Options Return to Home Page Help

Species:	Nephrops norvegicus	**Institute:**	University of Dublin
Mother Sea:	Irish Sea	**Daughter Sea:**	Irish Coastal

Associate Data Themes with the Data-holding:	**Update or Delete Associated Data Themes:**
• Derived Biological Parameters	• Derived Biological Parameters
• Management Measures	
• Management Objectives	
• Stock Assessment Methods	
• Landings Efforts	
• Stock Estimates	
• Socio Economics	
• Management Structures	
• Catch Metadata	
• Population Structure	
• Larval Ecology	

Add a Contact	Update a Publication
Add a New Publication	Update Contact Details
Associate an Existing Publication	Update Institute Details
Edit Data-holding Information	Update or Add a Cruise

Fig. 2. Central page of the ECFM data entry facility for location based data

In addition to the parameter data held within each of the data themes, the database holds information on how to source information relating to each data holding. This section of the database comprises contact details for individuals and institutes, as well as a complete bibliography of relevant publications (Fig. 3).

European Crustacean Fisheries Metadatabase - Publications

Author	Year	Title	Reference
Orsi Relini L. and Relini G.	1989	Reproduction of Nephrops norvegicus L. in isothermal Mediterranean waters	JS and PA Tyler (Eds.) Reproduction, genetics and distributions of marine organisms, 23rd EMBS; 153-160
Orso Relini L. and Relini G.	1985	Notes on the distribution, reproductive biology and fecundity of Nephrops norvegicus in the Ligurian Sea	FAO Fish. Rep., 336:107-111

Download Query Results (.csv format)
Printer Friendly Version of Table

Fig. 3. Tabular output from a basic search (Nephrops:Western Mediterranean) on publications from University of Genova

European Crustacean Fisheries Metadatabase - Contact Details

Name	
	Dr.Ch.Mytilineou
Address	
	NCMR Aghios Kosmas Hellinikon 16604 Athens Greece
Telephone	
	(+30) 1 9822557 116
E-mail	
	Dr. Ch. Mytilineou
Coordinator	
	No

Download Query Results (.csv format)
Printer Friendly Version of Table

Fig. 4. Tabular output from a basic search on contact details

Data-Entry facility

The data-entry facility is available to registered users of the site. Individuals or research groups can apply to the administrator for a user id and password to gain access to this facility. The administrator can be contacted via the e-mail link on the home page. Once a user has entered data into the metadatabase, this data becomes available to view through the search facility. Only the registered user who has entered the data can subsequently modify or delete this data.

Search facility

A basic and an advanced search facility are both open to all visitors of the site and can be accessed via the search function on the home page. The basic search function is recommended for users who are unfamiliar with the database or are looking for general information on management and fisheries in a specific region or for a particular species. The advanced search function is targeted towards users who are familiar with the ECFM database and are targeting very specific information e.g. Stock Assessment Methods used for the Nephrops norvegicus fishery in the Irish Sea. The output from both the basic and advanced search functions is in tabular format. Within each table, further selections allow the user to narrow or expand the search results. Search results can be downloaded in csv format, which opens in Microsoft Excel, or can be converted to a printer-friendly version for printing.

Data Confidentiality

Entering summary information on your research data into ECFM does not necessitate public access to the data. Storing metadata in the database does, however, allow members of the public to know the specific type of data being collected by your institute on particular species at specified locations and times. First-time users of ECFM may have concerns regarding the confidentiality of their data. This issue has been addressed in the design of the website. It is important to remember that no raw data is held in the ECFM database; the site is simply an inventory of summary information derived from raw data, contact details for raw data and information on management of fisheries and fisheries statistics.

Users who are entering metadata into the database are provided with a confidential password, which means that no other user of the site can alter the information they have entered in any way. Once logged in, a user's 'session' is set to 60 minutes in length. If a user does not actively use the site for 60 minutes, then the system will automatically log out that particular user. Once finished a session, users are required to log-out. This measure is in place to ensure that users do leave open access to their data and provides the system administrator with information on the number of active users at any one time. For all data-holdings entered into the metadatabase, users are asked to specify whether the source data has restricted or open access and have the option of entering contact details for the institute and individual who holds the data.

Site navigation

Both the search facility and data-entry facility of the ECFM site are designed to be easily comprehensible and navigable. A help section is available throughout the site, providing useful instructions on how to enter and retrieve data (Fig. 4). In the data-entry facility, captions under each data field describe the specific information required. Similarly, captions throughout the search facility provide instructions on how to make selections and progress through the site.

On each page throughout the site, there are numerous options, links to other pages and to the homepage. Live external links to associated partner institutes and e-mail links to individual researchers are also available through the search facility.

User requirements

Please note that the ECFM website is best viewed with a screen resolution of 1024*768. To change your screen resolution, go to the Start, Settings, and Control Panel and choose the Display option. Within the display option, choose ‘Settings’ and set your screen resolution to 1024*768.

Please also note that the website is supported by the web browsers Internet Explorer versions 5.5 and 6.0. On accessing the site with a different type of Internet browser or with an older browser version, the site automatically directs the user to a free download of IE versions 5.5 and 6.0. While this make take a few minutes to download, it ensures easy and bug-free site access.

European Decapod Fisheries: Assessment and Management (EDFAM)

European **D**ecapod **F**isheries: **A**ssessment and **M**anagement **(EDFAM)** is a concerted action project funded by the 5th Framework programme of the European Commission. The EDFAM project was initiated in response to the lack of co-ordinated monitoring and research programmes for decapods in Europe, the absence of formal stock assessments for many species and locations and the increasing economic importance of these species in Europe. Approximately 27 species of crustacean are fished in European waters. In some countries, crustaceans are now the most important commercially fished species. In a great number of cases, significant depletion has already occurred and some stocks have collapsed. Many species are fished by artisanal fleets and are very important socio-economically.

The EDFAM project has 4 principal objectives:

- To review sampling and assessment programmes
- To collate and make available, in a variety of formats, the results of monitoring and research programmes in Europe
- By taking into account world wide developments in decapod research, to recommend new approaches to the sampling and assessment of these resources
- To review and explore new structures and processes for the management of crustacean resources

The output from EDFAM will be in the form of:

- Research papers which present state of the art information on the life history of each species presented in the context of the issues that are important for management
- Reports on current sampling and assessment protocols
- A metadatabase, described here, which provides an inventory of research and monitoring activities in Europe and the relevant metadata arising from these programmes
- A book on the biology and fisheries for commercially important crustacean species in Europe
- The proceedings of a conference on ‘Life Histories, Assessment and Management of Crustacean Fisheries’ will be published in a special volume(s) of Fisheries Research.

European Decapod Fisheries: Assessment and Management (EDFAM)

Concerted Action Project number QLK5 1999 01272

Workpackage 1: Draft Final Report

III. Review of the Biology and Fisheries of Decapod Crustaceans in Europe

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Workpackage 1 of EDFAM

The draft final report of Workpackage 1 of EDFAM contains 3 deliverables

1. The current monitoring and research activities for Crustacean Fisheries in Europe (Document : WP1 Part I)
2. A newly developed metadatabase which holds metadata relevant to the biology and fisheries for crustaceans in Europe. This is hosted on the www and available to the public (Document : WP1 Part II)
3. A series of papers reviewing the biology and fisheries for each of the commercially important decapod crustaceans in Europe (this document)

The Biology and Fisheries for Decapod Crustaceans in Europe

Part III of WP1 of EDFAM presents a series of papers reviewing the 'Biology and Fisheries for Crustaceans in Europe'. These papers are presented below. A proposal to publish these as a book was presented to Blackwell Science who sent the proposal for external review. The outcome of the reviews was positive and Blackwell agreed to publish a book under the above title. The reviewers comments are presented below followed by drafts of the papers.

Review 1

1.-Is the book needed? Yes. The literature on European crustacean fisheries is dispersed in many sources, published in different languages, largely not available or easily accessible to non-European readers (and even to many European ones). Even the information contained in ICES documents (largely in English) is intricate for non-Europeans, and consequently rarely utilized or cited outside very limited circles. Yet, biological knowledge on European crustacean resources, the regulation of the fisheries that they support, and the corresponding management systems are of great general interest. Publication of the book would be timely, and welcome by scientists, practitioners and the industry.

2- Markets? Overseas.

a.- Primary markets include specialized libraries (marine sciences, fisheries) both in academia in management agencies, practitioners (mostly professionals in management agencies and consultants for the industry and other groups), and people in academia involved with invertebrate fisheries (faculty and graduate students)

b.- Secondary markets include members of the industry itself, and undergraduate students (mostly at the senior level).

c.- Student use? As one of several texts, at the senior undergraduate and graduate levels (e.g. in the School of Fisheries FISH 310/ Commercially valuable invertebrates; FISH 406/ Crustacean Fisheries, FISH 525/ Ecology of Fish and Shellfish, and graduate seminars on special topics.

d.- Reasonable price? This is difficult to judge. Price-wide, the readership of this book should be expected to be rather elastic. Libraries and interested readers may be expected to spend more than they do in more general books. One case I am familiar is the book on scallops that was edited by Sandy Shumway. It is rather comparable in many ways to the one you are considering. Half of the book is a country-by-country overview of scallop resources, their biology, and their fisheries. The book sold very well, and Sandy is now putting together a second (revised) edition.

3- Sales in 3yrs? Probably in the order of 2000, although I have not experience at the quantitative eyeballing of markets.

4- Author achieve purpose? The list of authors is a comprehensive directory of mostly everybody with something substantive to say about European crustacean fisheries. Considering that they have been working together in an EC "concerted action", the editor & authors are most likely to achieve their purpose.

5. Authors reputation? Same as above.

6. Coverage OK? Yes.

7. Modifications needed? I cannot think of any. The book is conceived as a collection of modules, all with the same basic structure. That structure, and the contents described, appear appropriate.

8. Importance? I think that it will be a welcome addition to the shellfish literature, making a vast volume onf information available to a wide readership.

9.Competing books? None that I know of. There are some Proceedings volumes that contain info on a few of the fisheries contemplated in the book, but these do not qualify as competitors

10. When out of date? Books of this type remain valuable for a long time. Sandy Shumway's book on scallops (Scallops: Biology, Ecology and Aquaculture; Elsevier, 1991), or a book edited by John Caddy (Marine Invertebrate Fisheries: their Assessment and Management, John Wiley & Sons, NY, 1989) are widely used and still in print 10 years after publication.

11. Scholarship? Adequate. This is not strictly a scholarly text, as much of its content deals with technical (management) subjects.

12. Accept for publication? Yes.

Review 2

Dr. Tully proposes to edit a reference work on crustacean biology and fisheries of Europe. This is a natural outgrowth of his work with EDFAM and the conference he is organizing next fall. My impression, gleaned from the material you sent, is that the book is intended to be a compendium of what is known about a wide variety of exploited crustacean species found in European seas. Some of the species are quite valuable commercially and heavily fished, others are not.

The proposed book serves the purpose of bringing a lot of knowledge together, and presumably identifying important gaps in the knowledge base. It would be a basic reference for fisheries laboratories and universities in Europe. However, its quite local focus will limit its impact. I suspect the majority of sales would come from nations that border the eastern North Atlantic and Mediterranean. Thus, I think the book will be valuable, but limited in its potential because of its limited scope.

1. Yes, the book will be useful to crustacean biologists in Europe.
2. I can't judge the market in the UK; in the USA I suspect the sales potential is limited to libraries of coastal universities and fisheries labs, and perhaps only a limited set of those. The book is not intended for the student market. I imagine a reasonable price for a book such as this would be US$125.
3. I have a hard time judging how many this book would sell in 3 years. Perhaps 1000?
4. The book is pretty straightforward not hard to put together once the manuscripts have been received from the chapter authors. That will be the tough part. The goal of the book is to be a reference work. I suspect it will be successful at that.
5. Dr. Tully is well known and competent.
6. I do not believe the coverage of the book is all it could be. As proposed, the book is to be a series of chapters devoted to species specific information, with a couple of chapters at the end which are supposed to be integrative but it is hard for the reviewer to see how. There does not appear to be any conceptual link among species, nor any dominant theme other than they are all caught in Europe. While useful, the book as proposed seems intellectually uninteresting.
7. To make it more interesting, perhaps gather similar species together (similar here might mean ecologically, taxonomically, or in terms of fishing methods) in single larger chapters and make deliberate comparisons. Or choose a few species as case studies to focus on and provide more depth. Certainly it would help to make comparisons to, and draw lessons from, crustacean fisheries in other parts of the world
8. Style and presentation are hard to judge since no chapter sample was presented with the proposal. The standard format to each chapter will make each chapter accessible but dry.
9. I rate this book as being important to European fisheries scientists who work on crustaceans.
10. I see no competitors for a book of this nature.
12. The book will be out of date in 5 years, but continue to make a useful contribution for many years.
13. It is hard to judge scholarship from this proposal. Scholarship will be in the hands of the various authors.
14. Accept for publication? I think this is a toss-up. Again, I see the book as having a limited market as a reference work.

Biology and fisheries of the deep shrimp *Aristeus antennatus* (Risso, 1816)

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Description and distribution

Physical appearance

Aristeus antennatus is a typical penaeid shrimp. The abdomen is longer than the carapace and the body is laterally compressed. The rostrum is armed with 3 dorsal teeth in the basal part. Its colour is pale pink to light red-bluish in shade. Adult females are much larger than males and have a much longer pointed rostrum (Zariquiey-Álvarez, 1968; Holthuis, 1980). Different external sexual characteristics are very evident in adults: females show the thelycum and males the petasma. The first description of sexual dimorphism was by Heldt (1932, 1938) for two Tunisian specimens. Adult males have a much shorter rostrum than females. This dimorphism is not evident in juveniles (Sardà and Demestre, 1989).

Taxonomic position and relationship to other species

The definitive and accepted systematic position of *A. antennatus* is the one presented by Bowman and Abele in 1982.

The systematic position of *A. antennatus* is: Order: Decapoda Latreille, 1806; Sub-Order: Dendrobranchiata Bate, 1888; Super-Family: Penaeoidae Rafinesque, 1815; Family: Aristeidae Wood-Mason, 1891; Genus: *Aristeus* Duvernoy, 1840; Species: *Aristeus antennatus* (Risso, 1816).

Only two synonymies has been reported: *Penaeus antennatus* Risso, 1816:96 and *Aristeus antennatus* Bouvier, 1908: 71-75.

The genus *Aristeus* includes 5 species *A. alcocki* Ramadan, 1938, *A. varidens* Holthuis, 1952; *A. antillensis* A. Milne Edwards & Bouvier, 1909, and *A. virilis* (Bate, 1881), but only *A. antennatus* occurs in the Mediterranean (Holthuis, 1980; De Freitas, 1985; Pérez Farfante, 1988). Nevertheless, de Freitas (1985) records this species along the east African coast and in the Maldive Islands. Other species distributed in the Mediterranean within the same Super-Family are *Aristeomorpha foliacea* and *Gennadas elegans*, both in the Familia Aristeidae; *Parapenaeus longirostris* and *Penaeus kerathurus* in the Family Penaeidae; *Solenocera membranacea* in the Family Solenoceridae and *Sicyona carinata* in the Family Sicyonidae.

Only *A. foliacea, P. longirostris, P. kerathurus* and *S. membranacea* are commonly exploited. Recently, *Penaeus japonicus* has been introduced for aquaculture to the Mediterranean.

Distribution

Geographic distribution.

The general distribution of *A. antennatus* includes the Mediterranean except the Adriatic Sea and some zones of the Sinai Peninsula. It is absent from the Black Sea. It is also found in the eastern Atlantic, from the North of Sines in the south Portuguese coast to Mauritania and the Islands of Cape Verde (Holthuis, 1980, 1987) (Fig. 2)

Bathymetic distribution and densities

The red shrimp is a demersal resource that is captured exclusively by the bottom-trawling fleet. It occurs from 200-3300 m depth. Sardà (2001) found this species at depths of 3.300 m in the abyssal plain of the Ionian Sea. The spatial distribution of *A. antennatus* is strongly related to the substratum geomorphology and the largest catches of the shrimp are obtained in submarine canyons of the continental shelf and upper slope at depths of 300-900 m (Arrobas & Ribeiro-Cascalho, 1987; Relini & Orsi Relini, 1987; 1992, Sardà & Demestre, 1987, 1989; Cartes & Sardà, 1989; Matarresse et al., 1992, Demestre, 1993, 1994a, Sardá and Cartes, 1993a,b, 1994ª, 1997; Arculeo et al., 1994, Campillo, 1994, dos Santos & Ribeiro-Cascalho, 1994; Ragonese & Bianchini, 1994, Righini & Abella, 1994, Vacci et al., 1994, Yahiaoui, 1984a, Martínez-Baños, 1997; Abelló et al., 1998; Carbonell et al., 1999a).

In Portugal this shrimp lives at depths of 350-800 m, along the Southern coasts, from South of Cabo da Roca to V. Real Stº António (Algarve). Some specimens were found also off South-West Berlengas. The high abundance indices of *A. antennatus*, at depths of 400-600 m, seem to coincide with intrusions of Mediterranean water into the Atlantic Ocean (Ribeiro Cascalho, 1993). According to fishermen, this species is mainly caught between depths of 350-500 m (Santana, 1990; Simões, 1997).

On the Spanish Mediterranean coast maximum densities of *A. antennatus* are found between 350-900 m depth in the vicinity of submarine canyons, so the distribution is not continuous along the coast (Cartes & Sardà, 1992; Demestre & Martín, 1993; Martinez-Baños, 1997; Carbonell et at, 1999a). A. Antennatus is not present in areas where the continental shelf is broad and where there are no submarine canyons.

Campillo et al., (1991) and Campillo (1994) reported the highest densities of *A. antennatus* between 450-750 m depth in the Gulf of Lyons, although it has occasionally been caught at around 80 m depth. In the South of Marseilles this species was occasionally fished at a depth of 1200 m. According to this author, *A. antennatus* was exploited regularly in this area until 1970. Since 1959 both species *A. antennatus* and *A. foliacea* were fished in the same proportion between 400-1000 m, and since 1984 the latter species has disappeared.

The abundance of *A. antennatus* in Italian waters is somewhat erratic. Its highest abundance is observed in the Ionian Sea, in the central and Southern Tyrrhenian Sea and along south-western coast of Sardinia (Ardizzone and Corsi, 1997)**.** It is totally absent from the northern and central Adriatic Sea and rare in the southern Adriatic Sea (Vaccarella *et al*., 1986). *A. antennatus* is generally found on mesobathyal bottoms, deeper than 400 m. However, migrations towards shallow waters (123 and 165 m depth) during the night have been observed in the northern Ionian Sea (Matarrese *et al.* 1995) on bottoms characterised by canyons. In the same area, but along the Sicilian coast, some specimens were caught at less than 200 m during diurnal experimental hauls (Pipitone and Andaloro, 1994) again on steep slopes with caynons. In the Easter Ionia Sea (Western Greece) it is very abundant and caught mainly at depths of more than

450 m, mainly 700-900 m. It is found sporadically in the Aegean Sea (Central, North and South Aegean Sea) (Koukouras *et al*., 1997, Kapiris *et al*., 2000; Papacontantinou & Kapiris, 2001).

Spatio-temporal distribution and seasonal changes.

In Portugal, both sexes occur between 450-730 m depth. The males and the larger females are found in deeper layers than the smaller females. Higher abundance of both sexes occurs in spring.

Spatial segregation seems to be related to age (juvenile/adult) and maturity (breeding/spawning). The occurrence of juveniles is related to the dispersal of post-larvae by submarine currents (dos Santos & Ribeiro Cascalho, 1994; Cartes *et al*., 1993, Sardà & Cartes, 1997.). The distribution of juveniles is related to bottom topography. Data from surveys show that smaller individuals occur generally in deep and narrow areas near the canyons (Cascalho, 1995).

Between 400-700m depth females outnumber males, while from 1000-2200 m the population seems almost exclusively male (Mura & Cau, 1989; Cartes & Sardà 1992; Martínez-Baños, 1997). Demestre & Martín, (1993) and Sardà et al 1997, suggest spatio-temporal movements are linked to geomorphological and hydrological structures between the slope and the margin of the submarine canyons. Mature females tend to school on the slope during spring and early summer. A higher proportion of males and juveniles are found in the margins of submarine canyons during autumn and winter.

There is a clear seasonal relationship between depth and size distribution of *Aristeus antennatus* in the Ionian Sea. In Greek waters, there are differences in the seasonal depth distribution of males and the females. From December to March shoals are caught in shallower water than from April to November. This suggests a seasonal migration between the two depth zones (500-700 m and 700-900 m), that does not appear to differ among sexes. Both sexes occur at depths of 450-730 m. Males and larger females occur in deeper layers than smaller females. Highest abundance of both sexes occurs in spring (Kapiris *et al*., 2000; Kapiris & Thessalou-Legaki, 2001, Papaconstantinou & Kapiris, 2001).

Habitat characteristics and dominating environmental factors

A. antennatus occurs mainly on muddy substrates (Ribeiro-Cascalho, 1988.).

Ghidalia and Bourgeois (1961) reported that the optimum temperature for this species is 12.8 ºC. The temperature of the Mediterranean water mass inhabitated by *A. antennatus* varies between 11-12ºC. Salinity ranges between 35.9-36.0 ‰ (Font et al., 1988, Lopez Jurado & Díaz del Rio, 1994). On the Algarve coast (South Portugal), water temperature between 200-300 meters is 12.4ºC in winter and 13.9ºC in summer (Carvalho, 1983; Ribeiro-Cascalho, 1988). In Algerian waters *A. Antennatus* occurs between temperatures of 12.8-14ºC (Yahiaoui 1994a). In the rest of the Mediterranean it is found at around 12.8 ºC.

Life history

Growth

Population structure

The carapace length frequency distributions of *Aristeus antennatus* are different for males and females. Females reached a larger size than males. In general the sizes obtained in the different areas and from different studies are within the same range.

In the Portuguese coast, Arrobas & Ribeiro-Cascalho (1987) and Ribeiro-Cascalho (1988) obtained a size composition of 19-39/40 mm for males, and 17-68 mm for females. In the Algarve (Portuguese south coast), the size composition was between 16-44 mm for males and 18-68 mm for females (Pinho, 1990). In the same area, Dias (1992) found a range of 20-40 mm for males and 18-70 mm for females.

The same size distribution occurs on the Spanish coast. In the Balearic Islands the exploited sizes range between 15-61mm for females and 15-38 mm for males (Carbonell 1994a; Carbonell & Alvarez, 1995, Carbonell *et al*., 1999b). On the Catalan coast and País Valencià females and males vary between 15-66 mm and 17-38 mm respectively, although males from País Valencià reach 42 mm (Sardá & Demestre, 1987, Demestre, 1990, 1994a, Demestre & Martín, 1993). On the Murcia coast size of females ranged from 13-65 mm. In the case of males the range was 14-38 mm. The sizes observed in Ibiza channel were 15-59 mm for females and 15-37 for males (Martínez-Baños, 1997, García-Rodriguez & Esteban, 1999). On the Almeria coast females range from 16-62 mm and males from 17-38 mm (Martínez-Baños et al., 1990, Martínez-Baños & Mas, 1994). Sardá & Cartes (1993a) captured 15 juveniles ranging in size from 6.4-14.1 mm between 1190 and 1286 m depth using an experimental suprabenthic sledge.

In French waters of the Gulf of Lyons, females ranged between 23-63 mm and males had a maximum carapace length of 36 mm (Campillo, 1994).

In Italina waters carapace length of males ranges from 40-57 mm and females from 66-71 mm. In the Ligurian Sea males range from 20-40 mm and females 23-71 mm (Relini Orsi & Relini, 1979; Orsi Relini, 1980, Orsi Relini and Relini, 1998). In the Tyrrhenian Sea from North to South, females are between 24-57 mm (Righini & Abella, 1994), 62 mm (Greco *et al*., 1994), and 12-62 mm (Spedicato et al., 1995). In Sicily, the sizes were 10-30 mm for males and 15-52 mm CL for females. Smallest males (16 mm) were found in unexploited grounds in east Sicily (Pipitone and Andaloro, 1994),16-66 mm for females in the North Western of Sicily (Arculeo *et al*., 1992), and 43 mm for males and 20-66 mm CL for females in Sicilian Channel (Ragonese *et al*., 1994; Ragonese and Bianchini, 1996). The Sardinian Channel showed a range between 11 -32 for males and 11-61 for females (Mura & Cau, 1989, Mura & Cau, 1994). In the Ionian Sea the ranges were 18-41 mm and 20-65 mm for males and females respectively (D'Onghia *et al*., 1994).

According to Kapiris & Thessalou-Legaki (2001) in the south Ionian Sea female size ranges from 14-59 mm. Male size ranges from 11-36 mm. More information from the Ionian Sea Papaconstantinou & Kapiris, (2001) found females of 12-62 mm and males of 9-45 mm in the Ionian Sea.

In Algeria females ranged from 13-63 mm CL and the males from 13-48 mm CL (Yahiaoui, 1994b). The same study showed an important decrease of mean size over a 10 year period. In 1979-80 mean size was 37.38 mm for females and 26.73 for males. In 1987-1988 mean sizes were 31.07 mm for females and 23.4 mm for males.

Relative growth

Both males and females showed a significant negative allometry between carapace length and weight ($b < 3$). Carvalho (1983) however found $b > 3$ for both sexes.

The values of both parameters *b* and *a* of the size-weight relationship showed similar ranges in a very long series of studies carried out in Mediterranean waters and Atlantic Portuguese coasts (Table 1): Arrobas & Ribeiro Cascalho, 1984; Demestre, 1990; Campillo, 1994; Carbonell, 1994a; Martínez-Baños et al., 1990; Righini and Abella, 1994; Petrakis and Papaconstantinou, 1998; Petrakis, 1998).

The relative growth of the rostrum has also been studied in relation to sexual maturity and size (Bas, 1966; Burukovsky, 1969; Burukovsky and Romesky, 1972; Arrobas & Ribeiro Cascalho, 1987;, , Mura & Cau, 1989, D'Onghia and Maiorano, 1996). Shortening of the rostrum has been found in males and is mainly related to season and maturation and occurs in its first year of life. Immature males have a relatively longer rostrum while mature adults have an extremely short rostrum. The shortening of the rostrum occurs quite abruptly between February and April of their first year of life. In contrast females retain a relatively longer rostrum over their entire life (Sardá & Demestre, 1989, Kapiris & Thessalou-Legaki, 2001).

In other studies the relative growth of different morphometric characters (standard length, length and height of cephalotorax and 6 somites) have been examined (Balesta et al., 1975). In others, growth as reflected by measurements of different body parts (abdomen, scaphocerite, uropods, and segments on the third and four pereiopods), was related to carapace length (Sardà *et al*, 1995). Morphometric variability has been observed over a long period of 30 years (Bas & Sardà, 1998). When comparing *Aristeus* populations from different Mediterranean regions and the Atlantic, no enzymatic differences have been observed between the same populations (Sardà *et al*., 1998).

Table 1. Parameters (a and b) of power functions describing the size weight relationship in A. antennatus by region.

	Region					
Sex	**Portugal**	**Spain**		**Italy**		**Greece**
Male	Algarve	Areas	a/b	Areas	a/b	SE Ionian
	0.0226/2.5	Catalan	0.004/2.32	West Ligurian	0.0035	0.0106/2.31
	0.0023/2.48	Valencia	0.005/2.25	East Ligurian	0.003	
		Balearics	0.003/2.37	S Tyrrhenian	0.0024	
		Ibiza	0.0032/2.40			
		G.Vera	0.0053/2.25			
		Murcia	0.00212.5			
Female	0.00232/2.49	Catalan	0.00264/2.47	West Ligurian	0.0035/2.38	0.011/2.45
	0.00228/2.49	Valencia	0.00354/2.39	East Ligurian	0.003/2.45	
		Balearics	0.0025/2.46	S Tyrrhenian	0.0024/2.48	
		Ibiza	0.0024/2.48			
		G.Vera	0.0028/2.45			
		Murcia	0.00172.59			

Annual cycle of growth.

A number of studies have estimated the Von Bertalanffy growth parameters in *A. antennatus* (Table 2).

In Portuguese waters, according to Ribeiro-Cascalho (1988), shrimp can can live for at least 4 years. Cadima *et al*. (1995) assume a longevity of five years. Studies carried out by Pinho (1990) and dos Santos & Cascalho (1994) showed the same result.

Similar values were obtained in different areas of Spain as the Balearic Islands, the Catalan coast, the Ibiza Channel, Valencia and Murcia coasts concerning studies of growth parameter and estimations of the longevity. In these areas both male and females longevity has been also estimated. An important amount of values has been estimated in different years in each area.

The length frequency distribution is multi-modal for both females and males but female distributions always have a higher number of modal classes than males. Consequently the life span of females (5-6 yrs) may be longer than males (3-4 yrs) (Sardà & Demestre, 1987; Demestre, 1993; Demestre & Martín, 1993; Carbonell, 1994a; Martinez-Baños & Mas, 1994). A comparative study using several pseudocohorts and a complete cohort was carried out in the Catalan coast from 1984 to 1991 to estimate the longevity of the population. The results demonstrated that pseudocohorts analysis has the same validity to cohort analysis (Demestre & Lleonart, 1993). A similar comparative analysis was run within the population of Murcia waters and the same conclusion was reached (Martinez-Baños, 1997) (Table 3).

Table 2. Parameters of the vonBertalanffy growth equation for A. antennatus by region. Each set of values is from a single dataset and estimation.

	Region						
Sex	**Algeria**	**Portugal**	**Spain**		**Italy**		**Greece**
	$L_{inf}/k/t_o$	Algarve	Areas	L/k/to	Areas	$L_{inf}/k/t_o$	
Male	35/0.4	43/0.34/-0.86	Catalan	54/0.25/-0.5	W Ligurian	39-46/0.21-0.52/-0.019-(-0.12)	SE Ionian
		45/0.26/-1.14	Valencia	54/0.25/-0.5	C Tyrrhenian	67	54/0.43/-0.46
			Balearics	44/0.4/0.77	S Tyrrhenian	67	58/0.43/-0.46
			Ibiza	55/0.38/-0.43	Sardinia		
			Ibiza	48/0.23/-1.04	N Sicilian		
			G.Vera	55/0.36/0.33	Sicilian Ch.		
			Murcia	52/0.27/-0.91	W Ionian	55/0.99/-0.14	
Female	65/0.33	74/0.35/-0.003	Catalan	76/0.3/-0.07			
		75/0.36/-0.3	Valencia	76/0.3/-0.07	W Ligurian	63-77/1.71/0.44	66/0.39/-0.38
		67/0.35/-0.38	Balaerics	74/0.38/0.157	C Tyrrhenian	67/0.49	66/0.39/0.38
		76/0.34/-0.8	Ibiza	73/0.36/-0.41	S Tyrrhenian	67/0.56/-0.24	
		73		74/0.26/-0.66	Sardinia	77/0.34/0.36	
			G. Vera	75/0.4/-0.23	N Sicilian	87/0.26	
			Murcia	75/0.38/0.05	N Sicilian	69/0.34	
					Sicilian Ch.	72/0.45	
					Sicilian Ch.	69/0.53	
					Sicilian Ch.	61-72/0.75	
					W Ionian	66/0.93/-0.06	
					W Ionian	77/0.35/-0.36	

In the Gulf of Lyons females have 5 modal components reaching a length of 30.74 mm in year 1 and 59.55 mm in year 5 (Campillo, 1994).

Some differences have been obtained in studies carried out along different areas of Italy. Nevertheless, in general, the results suggested the length frequency distributions of females generally have several modal components while those of males usually have only one (Orsi Relini and Pestarino, 1981; Orsi Relini & Relini, 1985a, b; Matarrese *et al*., 1992; Tursi *et al*., 1993; Vacchi *et al*., 1994; Spedicato *et al*., 1995; Orsi Relini and Relini, 1996, 1998; Ragonese and Bianchini, 1996; D'Onghia *et al*., 1997). In the Ligurian Sea results obtained by following a group of recruits over a period of three years indicated a life span of 6-10 yrs with a growth rate of about 5 mm per year (Orsi Relini and Relini, 1988, 1998). Ragonese and Bianchini (1992), also found slower growth of females in the Sicilian Channel. In the southern Tyrrhenian Sea Spedicato *et al*. (1995) estimated growth parameters similar to Cau *et al*. (1994) in Sardinian waters, and Arculeo *et al*. (1992, 1994) along the north-western coast of Sicily.

Table 3. Longevity of A. antennatus by region

	Region					
Sex	**Portugal**	**Spain**		**Italy**		**Greece**
	Algarve	Areas	Yrs	Areas	Yrs	
Male	2.0-5.0	Catalan	3	W Ligurian	2.25	SE Ionian
		Valencia	4	C Tyrrhenian		5
		Balearics	4	S Tyrrhenian		
		Ibiza	3	Sardinia		
		G.Vera	4	N Sicilian		
		Murcia	4	W Ionian		
Female	2.0-5.0	Catalan	4			
		Valencia	5	W Ligurian	4	5
		Balaerics	5	C Tyrrhenian		
		Ibiza	4	S Tyrrhenian		
		G. Vera	5	Sardinia		
		Murcia	5			

Natural mortality has been estimated by a number of authors and estimates range from 0.4-0.8 in males and 0.4-0.55 in females (Table 4).

Table 4. Estimates of natural mortality of A. antennatus by region

	Region					
Sex	**Portugal**	**Spain**		**Italy**		**Greece**
	Algarve	Areas	M (yrs^{-1})	W Ligurian	M (yrs^{-1})	SE Ionian
Male	0.76	Catalan	0.8	C Tyrrhenian		0.62
	0.64	Valencia	0.5	S Tyrrhenian		
	0.96	Balearics	0.8	Sardinia		
	0.63	Ibiza	0.41	N Sicilian		
	0.73	Ibiza	0.56	Sicilian Ch.		
	0.6	G.Vera	0.47	W Ionian		
		Murcia	0.44			
Female	0.7	Catalan	0.5	W Ligurian	0.3-0.5	0.55
	0.59	Valencia	0.5	C Tyrrhenian	0.45-0.72	
	1.3	Balaerics	0.5	S Tyrrhenian	0.58-0.69	
	0.58	Ibiza	0.4	Sardinia	0.56	
	1.25	Ibiza	0.54	Sicilian	0.5-0.8	
	0.6	G. Vera	0.47			

	0.68	Murcia	0.5			
	0.42					

Studies of growth have also been carried out in Algeria by Yahiaoui (1994b). These data indicate a life span for females of 4 –5 years and 2-4 for males.

In summary females grow fast during the first two years of life, reaching around 25-30 mm and 40-45 mm at the end of the first and second year respectively. Males reache18-23 mm and 24-30 mm respectively. Some differences occur in the Ionian Sea, where faster growth and shorter life span (2 years) was observed in females (Matarrese *et al*., 1992; D'Onghia *et al*., 1998). At the end of the first and second year of life, females reached 40-45 mm and 55-58 mm respectively, while the males reached 30-33 mm at the end of the first year.

Reproduction

Reproduction and moult cycles

Increment at moult and moulting frequency have not been used widely to assess growth in *A. antennatus*. Carvalho (1983) suggested that moult frequency decreased with age; being twice per month in juveniles and once or twice per year in adults. Some data on the moult cycle are available for both sexes in the Catalan coast (Bas, 1965, Sardá & Demestre, 1985, 1987) based on microscopic observations of setae of the pleopods. These show an intermoult period of about 46 days and that moult frequency decreases with size.

Reproduction, growth, and moulting as interrelated processes have been analysed on the Catalan coast (Demestre, 1995.). This shows that the moult cycle is related to reproductive strategy to ensure the mating and spawning occurs successfully. Moult activity of both sexes occurs throughout the year but increased in females (60%) during the reproductive period. In February and December, which are months without spawning activity, the percentage of moulting is also high 55-58 % and it is a period during which the females grow.

In the Ligurian Sea, between June and November (Orsi Relini & Relini, 1985[a]) only 2% of the population are newly moulted. Eighty two % had spent ovaries and 15 % were in a state of advanced maturity. Moulting, therefore, is associated with the spawning rate, the inter-moult period generally being as long as the cycle of ovary maturation. One year old females (32-47 mm) are thought to ovulate and moult up to a maximum of three times in their reproductive season. Two year old females moult only once or twice. Two of the most important environmental parameters influencing reproduction and growth are light and temperature (Pipitone & Andaloro 1994).

Reproductive cycles

The same pattern of reproductive activity is observed throughout the Mediterranean (Massutí, 1961, Bas, 1966; Relini Orsi & Relini, 1979, Orsi Relini,1980, 1982; Mura et al., 1987, 1992; Sardà & Demestre, 1987; Mura and Cau, 1989; Demestre, 1990; Martínez-Baños et al., 1990; Carbonell, 1994a; Orsi Relini & Relini, 1994, 98; Arculeo *et al*., 1995, Follesa *et al*., 1998;), and Atlantic Portuguese coast (Ribeiro Cascalho & Arrobas, 1982, Arrobas & Ribeiro Cascalho, 1982, 1984, 1987).

Oogenesis in the Ligurian Sea was studied by Relini Orsi & Pestarino (1981), Relini Orsi & Relini (1979) and Orsi Relini and Semeria (1983). They identified from macroscopic observation four stages of maturation and their relationship with external colour of the ovary (white, pink, lilac and purple). Differences with *Aristeomorpha foliacea* have been identified. Demestre (1990) and Demestre and Fortuño (1992) identified two more stages (proliferation phase and oosorption phase) of ovary maturation involving cytological changes. A key to the macroscopically identifiable sexual stages of gonad development was presented based on gametogenesis and development of sexual characteristics. Structure of the sperm and spermatophore formation have been studied (Demestre et al., 1993, 1997; Medina, 1995).

A distinct female reproductive cycle has been found wherever studies have been carried. Mature females appear in spring and summer with a marked peak between June/July and August. The functional activity of the ovary is evident for almost 6 months of the year from April to November. On the other hand, males have a more protracted seasonal reproductive cycle. Mature males are found throughout the year. Highest levels of reproductive activity is found from March – August when practically 100% of females hold spermatophores. As in other penaeids there is no egg-bearing period. The occurrence of copula is indicated by the presence of the spermatophore in the female thelycum.

The highest frequency of occurrence of spermatophores in the thelycum of females (80-100%) occurs between May and September. Terminal ampulla and joined petasma are more common in males between March – August. Large females mate earlier than small females. Nevertheless, in the majority of 0^+ females also reach sexual maturity (Orsi Relini & Tunesi, 1982, 1987; Ribeiro Cascalho; 1988, Arculeo *et al*., 1992,1994; Demestre & Fortuño, 1992; Greco *et al*., 1994; Demestre, 1995; Martínez- Baños, 1997 Carbonell et al., 1999a,b; Kapiris et al., 2000, Kapiris & Thessalou-Legaki, 2001, Papaconstantinou & Kapiris, 2001).

Although the reproductive period on the Portuguese coast occurs between April and August, females with spermatophores are found throughout the year. These are, in general, large individuals, with low moult frequency, consequently preserving the spermatophore in the thelycum for longer periods of time (Arrobas and Ribeiro-Cascalho, 1984, 1987). Also in the Ionian Sea (Matarrese *et al*., 1992; D'Onghia *et al*., 1997) females mate throughout thee year with maximum activity in summer and autumn.

In many areas along the Italian waters, in the Ionian Sea the pattern of recruitment is discrete occurring from May onwards. Individuals of 18 mm recruiting in May attain a size of about 24 mm by August-September. This recruitment pattern is in agreement with the higher abundance of juveniles in June in this area (Matarrese *et al*., 1992; Vacchi *et al*., 1994) and during August in the Ligurian Sea (Orsi Relini and Relini, 1988).

Cartes and Sardà (1993) and Sardà and Cartes (1997), found a high proportion of immature (< 15 mm) shrimp mainly in winter during experimental surveys between 1000-1300 m depth on the lower continental slope along the Catalan coast. Studies on juveniles have been also carried out in the Ionian Sea (D'Onghias et al., 1997). In the Spanish Mediterranean coast and southern Portuguese coast the recruitment occurs at 15-19 mm. These shrimp are captured by trawls mainly in winter and autumn.

Sex-ratio and distribution

In Portuguese waters the commercial the catch in the fishery is mainly female. In fact, the annual mean sex ratio obtained by Dias (1992) in the Algarve coast was of 8:1. However, males have been more common in surveys in the Faro area at depths of 720-750 m (Bartolomeu Dias plateau).

According to Dias (1992), the percentage of females is higher in September and lower in November. On the other hand, Pinho (1990) found a higher percentage of females during June-July and a lower percentage in November.

Females constitute the 70-80% of the catch on the Catalan coast (Bas, 1966; Sardá & Demestre, 1987; Demestre, 1993, Demestre & Martín, 1993). The distribution showed marked seasonality with movements along the submarine canyons. Highest abundance occurs in spring and summer at 800-900 m depth and at the end of autumn and winter at 400 m depth (Bas, 1966, Sardà & Demestre, 1987; Demestre & Martín, 1993). Experimental studies carried out along the Catalan coast at 900-2200 m depth showed a decrease in size with increasing depth. Also, significant differences were observed in the sex-ratio with increased depth. Variations in the depth-size relationship therefore are not attributable to changes in sex-ratio values with depth (Sardà & Cartes, 1993a). The results also showed that at depths less than 1000m a marked discontinuity in abundance and sex-ratio appears. Below this depth, the sex-ratio approached 1:1 and abundance was lower.

The sex-ratio in Murcia from 1987 to 1992 shifted in favour of females ranging from 66-85%. Similar percentages appear in Almeria (64%) and Ibiza Channel (63-72%: Martínez-Baños, 1997).

In the Balearic Islands the sex-ratio showed a clear predominance of females (7:1) for most months, except in March when the sex ratio was almost 1:1 (Carbonell et al., 1999b).

In the Ligurian Sea (Orsi Relini, 1982; Orsi Relini and Relini, 1985) males were found to constitute less than 10 % of the population at depths of 550-700 m. In the central (Colloca *et al*., 1998) and Southern (Greco *et al.,* 1994) Tyrrhenian Sea, in the Ionian Sea (Matarrese *et al*., 1992; 1994; D'Onghia *et al*., 1994) and along the southern coasts of Sardinia (Mura and Cau, 1989), females represented 80-95 % of the total catch. In the Sicilian Channel the sex ratio was 6.25:1 in favour of females (Ragonese *et al*., 1994).

In Greek waters as in other areas female shrimp are more abundant than males. Samples from January, February and March recorded the highest abundance of males (20-27 % of total catch). The minimum presence of males has been observed in June, July and September (1-9 %) (Papaconstantinou & Kapiris, 2001, Kapiris et al., 2000).

Size at first maturity

In all study areas shrimp generally mature in their first year of life. Nevertheless, along the Portuguese coast, according to Ribeiro-Cascalho (1988) the males mature at 1.5 years at a size of 24 mm. Females mature at 1 year and at 29 mm.

The size at first maturity on the Catalan coast is 26 mm in females and 21 mm in males. The proportion of immature individuals in catches is small throughout the year, in general not exceeding 20 % (Sardá & Demestre, 1987; Demestre, 1990; Demestre & Martín, 1993). Males mature at 20-22 mm and females at 24-27 mm in Murcia, 20 (Male) and 24 mm (female) in the Ibiza Channel and 20 (Male) and 26 mm (female) in the Balearic Islands (Martinez-Baños, 1997, Carbonell 1994a).

In the Ligurian Sea the smallest size of mature females was 27 mm (Orsi Relini and Relini, 1979). In the central Tyrrhenian Sea females reached maturity around 27 mm. In the southern Tyrrhenian Sea first maturity of females occurs at 35 mm, (Spedicato *et al*., 1995). In the Sardinian Seas the size of first maturity of females ranges from 23 to 25 mm (Follesa *et al*., 1998). Along the north-western coast of Sicily the minimum size of mature females does not exceed 27 mm (Arculeo et al., 1994). In the Ionian Sea D'Onghia *et al*. (1998) found a latitudinal gradient in first maturity of females: 46-48 mm, 42-44 mm and 38-40 mm in the northern, central and southern area respectively. The authors related these differences to different geomorphological, trophic and fishing effort conditions in the three sub-areas.

Fecundity

Fecundity was studied in the Ligurian Sea fecundity by Orsi Relini and Semeria (1983) and in the Catalan Sea by Demestre (1990, 1995). As no egg-bearing period occurs in this shrimp and fecundity has only been evaluated by oocyte counts in mature ovaries. In advanced maturity (ovary is violet) club-shaped bodies are situated in the peripheral cytoplasm and mature eggs (dark violet) show an ovoid profile and are found mainly between June-October. In the Ligurian Sea oocyte number ranged between 140,000 and 900,000 in each ovulation, and in the Catalan Sea between 50,000 and 650,000 per ovulation

Feeding

The analysis of stomach contents from the Portuguese coast, presented by Ribeiro-Cascalho (1988) show that this species is a nocturnal predator that moves to shallower areas during the night and also to the upper layers of the water column. Fish, crustaceans (amphipods, decapods, ostracods and decapod eggs), polychaetes, molluscs, foraminifera and sponges seemed to be the preferred preys.

The diet of this shrimp has been widely studied in the Catalan Sea between 500-2300 m depth (Cartes, 1994). Diet is composed of a wide variety of macrobenthic/macroplanktonic prey, and the trophic diversity of this species are among the highest of bottom-dwelling predators (5.2-5.3, Shannon index). *A. antennatus* consume mainly infauna (e.g. the macruran *Calocaris macandreae*, polychaetes, and bivalves), epifauna (ophiuroids), suprabenthos (amphipods, isopods, and cumaceans), and even some macroplankton (euphausiids, siphonophores). Depth, seasonality, and local topographic features (e.g. submarine canyons) influence the diet. Therefore, there is an increasing consumption of foraminiferans (meiofauna) and detritus below 1200 m, and an increasing importance of euphausiids in the autumn diet. There is less seasonal variation in diet below 1200 m. Size-related trends also occur in the diet consisting in a preferent consumtion of suprabenthic peracarids by small juveniles (CL < 18 mm). Differences were found in the diet composition of the various size classes, which exploit different resources levels, though overlap was high. Larger individuals search deeper in the substratum when feeding while the activity of smaller males and females is confined to the surface layer (Cartes, 1991; Cartes and Sardá, 1989, Maynou & Cartes, 1997). Dietary habits of *A. antennatus* are similar in other areas (off Morocco: Lagardère, 1977; SW Balearic Island: Cartes, unp. data). Low dietary overlap has been reported between the diets of *A. antennatus* and that of the giant red shrimp (*Aristaeomorpha foliacea*) (Cartes, 1995). The trophic level of *A. antennatus* (between 10.91-11.27%o determined by $\delta^{15}N$ stable isotopic composition) are in the range of other top-benthic predators such as Macrourid fish (Polunin et al., 2001). Cartes and Maynou (1998) pointed out that the shrimp has a key role in the bathyal food webs which it inhabits and has a relatively high food consumption (daily ration = 0.223 %DW/WW).

Very similar results have also been obtained from the Ligurian Sea. Twenty-two prey categories, a benthonic feeding habit and euryphagous behaviour were shown by Orsi Relini and Wurtz (1977). Sediment (mud) and Foraminifera (66 %) were frequently present in the stomach contents. The most important component of the diet was decapod, euphausids, peracaridean crustaceans, bivalves and gasteropods of small size and ophiuroids. The authors pointed out the high competition between *A. antennatus* and *Geryon longipes*. In the Sardinian Channel dietary studies have been also carried out (Mura *et al.*, 1993).

Larval Ecology

Ribeiro-Cascalho (1988) suggested that eggs and larvae develop in the plankton and are brought into surface waters by currents. The larvae take approximately two months to develop and recruit to the seabed where they join the demersal adult stock (Arrobas *et al.*, 1982).

From plankton samples collected in Portuguese waters from October 1986 to March 1994, only one specimen of *A. antennatus* was found. This larva was a Protozoea II, captured in August 1993 at a depth of 500 m deep off southern Portugal (dos Santos, 1998, Santos dos & Lindley, 2001).

The knowledge on larval stages of deep-water shrimps is scant. Heldt (1955) described Protozoeae I, II and III, and Mysis I of *A. antennatus*, from plankton and rearing material. The duration of each larval stage has not been established.

The fishery

History of fishing

Brian (1931) and Heldt (1932, 1938) first described the distribution and abundance of A. antennatus in the Ligurian Sea and in Tunisian waters. Nevertheless it was not until the middle 1950's when its importance as an exploited resource was realised (Arté, 1952, Bas et al., 1955, Bas, 1960, Massutí, 1961, Maurin, 1965, Relini-Orsi & Relini, 1972, Massutí & Daroca, 1978). It is one of the latest fisheries to be developed in the Mediterranean.

With the increasing economic importance of red shrimp fisheries, different studies related to its biology and fisheries began to be developed (Relini Orsi & Relini, 1979, Relini Orsi, 1980, Ribeiro Cascalho & Arrobas, 1982, Arrobas & Ribeiro Cascalho, 1987, Sardà & Demestre, 1987, Cartes and Sardà, 1989). From that point on, the research focused on studying the trends in exploitation rate in the Mediterranean and the Atlantic, in order to achieve sustainable management.

The crustacean fishery started in the Portuguese coast in the 50's with a combined fleet of both Spanish and Portuguese fishing vessels. The majority of the catches were taken by the Spanish component. In the 60's, this fleet started operating at greater distances from the coast and in deeper banks (Ribeiro-Cascalho, 1988; Santana, 1990). There are very few catch statistics from this first period. In 1977, the number of Portuguese vessels entering in the fishery started to increase and in 1983, after the end of the Portuguese-Spain fisheries agreement, only the Portuguese fleet was allowed to fish for crustaceans in Portuguese waters (Caramelo *et al.*, 1996).

Commercial capture of *A. antennatus* in the Mediterranean Spanish coasts have been carried out since the 1940´s. Arté (1952) first described some characteristics of this fishery at 300 m depth in the Catalan coast, and Massutí (1959) reported on the economic value of this species in the Balearic Islands.

In the Ligurian Sea, Brian (1931) reported *A. antennatus* as an important commercial species, similar in importance to *Aristaeomorpha foliacea*. In this study the author mentioned that the exploitation of *A. antennatus* had already started in Algeria earlier, according to Boutan et Argilas (1927).

No systematic fishery exists for this species in Greek waters. Some specimens were sporadically found in several Greek areas of the Aegean Sae being abundant in the Ionian Sea (as research projects showed). It is only exploited occasionally. Giving the high prices fetched by this species, it is expected that a targeted deep-water fishery will be developed soon.

Between the 1960's and 1980's there was an important number of studies describing all aspects of the fisheries biology of *A. antennatus* (Bas, 1960, 1965, 1967, Maurin, 1962, Massutí, 1973, 1975, Relini Orsi, 1973, Relini Orsi et al., 1979, Zunini Sertorio et al., 1974, Ribeiro Calcalho

& Arrobas, 1982, Carvalho, 1983; Orsi Relini & Relini, 1985a,b, Yahiaoui *et al*., 1986, 1994 b, Arrobas & Ribeiro Cascalho, 1984, 1987, Martinez Baños & Mas, 1987, Sardà, 1986, Sardà & Demestre, 1987, Tobar & Sardà, 1987). An important number of them were discussed during the III Colloquium Crustacea Decapoda Mediterranea held in 1985 in Barcelona (Sardà, 1987).

In the last decade a great number of studies focusing on estimating the exploitation rate of *A. antennatus* have been produced. Different management options, considering biological and fishing aspects, has been developed (Orsi Relini & Relini, 1998, Cascalho 1988, Demestre, 1990, Vieira, 1991; Demestre, 1993; Demestre & Martín, 1993; Matarrese et al., 1992, Bianchini and Ragonese, 1994, Vacci *et al*., 1994, Carbonell & Alvarez, 1995, Spedicato *et al*., 1995, Ragonese & Bianchini, 1996; Simões, 1997, D'Onghia at al., 1997, 1998, Carbonell et al., 1999a,b)

Characteristics of the fishery

A. antennatus is one of the most important exploited resources by otter trawl gear and is caught exclusively with this gear on the muddy bottom (this is called "shrimp-trawl" in Portugal, "huelvano" in Spain, "tartana" in Italy). It is still difficult to describe the exact gear dimensions, because it is partly a professional secret, although some general characteristics are known. Gear length varies between 65 and 110 m, vertical opening is 1.5-2 m and horizontal opening about 20-30 m. Door weights vary between 400 and 1000 kg. There is a strong link between the gear characteristics and the horsepower of the boats, although construction materials have to be taken into account. Gear design and construction influence the effective fishing effort.

In Portugal the cod end mesh size is 55 mm and in the Mediterranean 40 mm.

A. antennatus is the main deep demersal target species off the Mediterranean and Atlantic coasts. It is fished mainly between 400-900 m depth, and the fishing grounds are located in or close to submarine canyons. The fleet also operates along the southwest and southern coasts of Portugal (Alentejo and Algarve) fishing at depths of 100-700 m (Fig. 1).

The fishery for *A. antennatus* in the Mediterranean is different in character to other bottom trawling fisheries to such an extent that it can be considered as monospecific fishery. The shrimp is the target species of this deep fishery, and constitutes the major part of the catch, where the abundance of the co-occurring commercial (by-catch) species is very low, mainly represented by large individuals of hake, conger, anglerfish and European flying squid.

Off southern Portugal *A. antennatus* is caught in a multispecies crustacean trawl fishery that is responsible for 95% of the crustacean catches in Portugal. The other main crustacean species caught in this fishery are *Parapenaeus longirostris*, *Nephrops norvegicus*, and *Plesionika heterocarpus.* Other species such as *Micromesistius poutassou*, *Scyliorhinus canicula*, *Eledone cirrosa*, *Illex coindeti*, and *Octopus* spp are also captured.

Fishing is mainly done in daily hours because catches are smaller at night and in fact current legislation prohibits fishing at night (Relini & Orsi Relini; 1987, Tobar & Sardà, 1992; Lleonart, 1990; Bianchini, 1999). Other studies have shown that the shrimp undertake horizontal and vertical migrations at night (Cartes & Sarda, 1993; Sardà et al., 1997).

Profile of the fleet

The fleet devoted to the exploitation of *A. antennatus* comprises the largest demersal trawlers, except in Portugal where they are smaller than the demersal trawlers targeting finfish. Some of them were former sardine purse seiners converted into trawlers. The vessels have egine power of 400-500 hp, and are etween 50-80 grt. Furthermore, the vessels are equipped with navigational equipment such as GPS, radar, colour sonar and plotters. Newer vessels are steel hulled or even PVC. Very few of these are freezer trawlers. This change from wood to steel is less evident in the Greek fleet where very few vessels are devoted to this fishery (Table 2).

The vessel construction and technology has had to improve in order to access the deep waters inhabited by *A. antennatus*. In general, each haul lasts 4-6 hours and in areas where a daily limit on fishing time exists (12 hours approx.) vessels are only able to carry out one haul per day. The trawling speed varies between 2.5 and 3 knots. In Greece trawlers fish for 15-20 hours/day. In some parts of Italy the vessels perform trips of 1-3 days (North Tyrrhenian Sea) or even up to 2-3 weeks off the Sicilian coast.

Table 5. Profile of the fleet targeting A. antennatus by region.

	ITALY	**GREECE**	**PORTUGAL**	**SPAIN**
Number of vessels	Western Italy 294[1] Ionian Sea 75[2]	Only 4 trawlers working occasionally in the Ionian Sea[5]	35[6]	Baleares 40[7] Cataluña 112[9] Canal Ibiza 36[8] Murcia+Almería 19,17[8]
Average GRT	8-44 small Up to 90: bigger[2]	63,24[5]	97[6]	50-90[7, 8, 9]
Average length of vessel		23,8[5]	24[6]	16-30[7, 8, 9]
Average number of crew		4 /trawler[5]	10 /vessel[6]	5-8 /vessel[7, 8, 9]
Gear used	Otter trawl[3] Italian low-opening trawl (tartana)[4]	Otter bottom trawl[5]	Otter bottom trawl[6]	Otter Bottom trawl[7, 8, 9]
Targeted or by-catch	Targeted[3]	Targeted[5]	Targeted[6]	Targeted[7, 8, 9]
Dependency on this species			10-20%[6]	10%[9] 11-20%[8] 30-60%[10]

[1] Di Natale et al. , 1994 (Western Italian Basins),[2] Matarresse et al., 1994 (Ionian Sea),[3] EDFAM,[4] Righini & Abella, 1994,[5] EDFAM from Greece,[6] EDFAM from Portugal,[7] Carbonell & Alvarez, 1995,[8] Martínez-Baños, 1997,[9] Demestre, 1994, [10] Carbonell et. al., 1999

Impact of fishing gear. Discards

There is no discarding of *A. antennatus*. Discarding of non-commercial species (i.e. Mictophyidae, Macrouridae, *Etmopterus spinax*, *E. pusillus*, *Galeus melastomus*, *Micromesistius poutassou*, *Chimaera monstrosa*, *Scyliorhinus canicula*, Crangonidae, Sergestidae) averages 27% of the total catch by weight but this value varies seasonally and by area (Vieira 1991, Araújo 1997, Carbonell *et al*, 1998). *A. antennatus* inhabits the mesobathyal area, characteristized by the *Isidella elongata* community. The abundance of *I. elongata* is reduced by trawling and local extinctions have occurred.

Economic importance

In all areas, landings of *A. antennatus* represents in biomass around 2-5% of the overall catches. But their economic value is relatively higher at 10-30%. *A. antennatus* may constitute up to 50% of the value of the demersal catch. (Demestre, 1993, Ribeiro Cascalho & dos Santos, 1994, Carbonell *et al*., 1999a). Portugal one kg of *A. antennatus* is on average 7 times more valuable than the average value of all other species combined (Ribeiro Cascalho & dos Santos, 1994). In

Algeria this species accounts for 3-4 % of biomass and 10% of the value of the catch by trawlers.

Selectivity

A study on the selectivity of the otter trawl was carried out by Colloca et al. (1998) in the central Tyrrhenian Sea. Length of first capture ranged between 24-31.6 mm length in 16-18 mm mesh and 31.5-38.6 mm for mesh of 20-22mm. In the southern Tyrrhenian Sea the size and age at first capture for a 32 mm stretched mesh was 32.76 and 0.9778 respectively (Spedicato et al., 1995). Ragonese et al. (1994) in the Sicily channel realised some studies of selectivity and suggested a mesh size up to 28 mm side to reduce the juveniles in the caches.

Monitoring of the fishery

Landings and effort

Table 6 shows the landings of *A. antennatus* in Portugal, Spain and Italy during a period of more than 20 yrs.

Data from Italy suggests that high effort levels are required to maintain catches.

In Portugal the catches are mostly landed in the Algarve region. Until the beginning of the 80's all landings in the Algarve were into the port of Olhão. This extended to the ports of Portimão and Vila Real de Santo António after that time. At present, these three fishing ports (Vila Real de Santo António, Olhão e Portimão) account for almost all crustacean landings on the Algarve coast (Pinho, 1990). The important auctions for crustaceans are concentrated in Vila Real de Santo António.

The study of Pinho (1990) verifies that the annual catches of the red shrimp increased between 1975-1985, with a high increase in 1981. From 1983 to 1985 catches were over 100 tonnes. In 1986 an important decrease occurred but catches did not fall below 80-90 tonnes. According to Ribeiro-Cascalho *et al.* (1986), the increasing interest of the Portuguese fleet in this fishing resource was due to the decrease in catch of other species. In the south of Portugal, Ribeiro Cascalho & dos Santos (1994) indicated that catches of *A. antennatus* decreased by 33% between 1988 and 1993.

Table 6. Landings of A. antennatus by year and country.

Year	SPAIN	PORTUGAL	ITALY
1971	534,6		
1972	599,67		
1973	551,95		
1974	526,64	11,67	
1975	509,7	7,75	
1976	735,7	10,13	
1977	712,51	12,7	
1978	992,59	18,98	
1979	841,24	19,31	
1980	591,35	18,92	
1981	617,91	34,16	
1982	731,48	60,55	
1983	909,72	121,02	
1984	1125,88	112,41	
1985	1123,42	125,19	376,6
1986	832,01	81,81	406,1

1987	702,08	90,93	506,5
1988	702,28	89,45	317,8
1989	684,94	79,79	309,2
1990	867,63	95***	343,4
1991	1090,59	60***	409,6
1992	993,61	25***	446,8
1993	780.06	25***	386,5
1994	658.13	30***	385,6
1995	625,89	60***	245,3
1996	554,26	70***	217,1
1997	495,36	105***	
1998	474,86	210***	
1999	520,06	180***	
2000	146	230***	
2001	494,21		

Exploitation rate has increased in the Balaeric Is (Carbonell *et al.* 1999a). In the other Spanish Mediterranean fisheries the largest catches were taken during the 1960´s (approx. 700t/year) but minimum catches occurred during the 1980s. This decrease in catches coincided with that observed in other shrimp fishing grounds in the western Mediterranean (Ligurian Sea, Gulf of Lions). From 1983 a recovery began, and in recent years the annual catch has stabilised at a levels similar to that attained during the seventies (Martinez-Baños et al., 1990, Demestre & Martín, 1993; Sardà & Cartes, 1994b).

Although there are fluctuations in the annual landings it is difficult to detect a clear periodicity in the Mediterranean and Atlantic areas. In analyses of local fisheries, some inter-annual fluctuations with a periodicity of around 8 years have been detected (Tobar and Sardà, 1987, Carbonell *et al*., 1999a). Seasonally in the Balearic Islands highest yields were taken in winter and spring (Carbonell et al., 1999a). In Catalonia highest catches occur from April to September (Demestre & Martín, 1993). Trends in catch also occur on a daily basis (Aldebert *et al*., 1998, Sardà & Maynou, 1998). Other studies (Sardà & Cartes, 1994b) show a close relationship between light and catchability . Daily catch rates were highest (>15kg/h) during the 2 hours immediately after sunrise.

Landings of *A. antennatus* in Italy have fluctuated widely. In the Ligurian Sea the species was important until 1979. In the period 1976-1980 the population decreased progressively until commercial fishing in the area was suspended. From 1987 catches increased and at present catches are commercially viable although highly variable from year to year (Relini & Orsi Relini, 1987; Orsi Relini & Relini, 1994). Relini & Relini (1985) hypothesised that this variability was due to environmental decay, overfishing, diseases, hydrological changes, and failure of recruitment due to predation upon juveniles. In the Ionian Sea, one of the most important areas for this resource, the absence of *A. antennatus* was frequently observed in concomitance with high catches of *Micromesistius poutassou* and *Phycis blennoides* (Matarrese *et al*., 1992), suggesting a competition or predation.

There are no estimates of landings of *A. antennatus* in Greece, since no systematic fishing activity exists for this species. As Papaconstantinou & Kapiris (2001) pointed out, the Greek fishers have not exploited this resource because fishing technology to fish at depths is not available and it is not known to Greek consumers.

In Algeria daily landings from depths of 400-600 m are 1400 ind/h, and during night time optimum abundance (7000 ind/h) appears between 80-550 m. Around 30% of the total fleet is devoted to the exploitation of shrimp (Yahiaoui, 1994a).

In North Tunisian waters, between Tabarka and Cap Bon, experimental fisheries have been carried out at 700 m depth but catch rate has been low at 0.5 kg/h. Commercial fisheries devoted to this species do not exist in Tunisia (Ben Mariem, 1994)

Statistics

In Portugal landings data are recorded at auctions by vessel, species and commercial size category. These records also include data on the product value. Catch and effort statistics are available from logbooks, but the reliability of this information is questionable.

Landings data for the Spanish Mediterranean fisheries are collated by Fishermen's Associations by daily sales bills. The weight and economic value are recorded. The recorded landings do not however represent the total landings because part of the landings is sold in other fish markets or directly to restaurants. Catch rate data are available from research projects. From the end of the 40s until 1986 the captures by species, landed in each region of the Spanish Mediterranean coast were obtained and published by the General Secretariat of Fishing, depending on the Agricultural and Fishing Department (FROM). Since 1987 the information of the official landings is obtained independently by the Autonomous Communities.

In the Italian fishery landings data (ISTAT) for *A. antennatus* are included in the category "red shrimp" which includes *A. foliacea.* A study carried out on the red shrimp fishing in the western Italian basins (Ligurian and Tyrrhenian Seas) by Di Natale *et al*. (1994) pointed out to the lack of information in the official statistics on the component of the fleet targeting these resources.

The only existing data on *A. antennatus* fishery in Greece arise from the scientific projects carried out in the Greek sector in the Ionian Sea. These data represent a baseline for the species in it's unexploited state.

Abundance in trawl surveys

Experimental otter trawl surveys (MEDITS, Mediterranean International trawl Surveys) were performed in all Mediterranean seas starting in 1994 until 2003. Surveys covered the depth range of 0-700m. Cau et al. (2002) reported marked interannual changes in density (kg/km^2) of *A. antennatus* from these experimental trawl surveys between 1994 and 1999. However, the interannual changes were not the same for all geographical sectors or depth strata and no clear trends could be detected.

Impact of fishing on the population

Cirujeda-Delgado & García-Mamolar (1977) and more recently Carbonell & Azevedo (2003) have used production models to assess the impact of fishing on stocks of *A. antennatus*. Other assessments have been based mainly length based analytical models (Ragonese & Bianchini, 1996, García-Rodríguez & Esteban, 1999). The first age based Virtual Population Analysis (VPA) was carried out by Demestre & Lleonart (1993) and later by Martinez-Baños (1997).

The assessments show that stocks are generally not overexploited. The fact that *A. antennatus* appears to be underexploited or near the optimum level of exploitation, in contrast to the majority of demersal resources, is due to at least two biological characteristics of this species. Firstly, the entire stock is not available to commercial fishing (Demestre & Martín, 1993) due to the extremely wide distribution of the species in bathyal waters (Sardà et al., 1997). Secondly, the rate of turnover of the population is high in contrast to most other demersal resources (Demestre & Lleonart, 1993). Bianchini and Ragonese (1994) came to the same conclusion regarding Sicilian stocks who regarded current levels of high fishing pressure as sustainable. According to Fiorentino *et al*. (1996) analytical modelling of stocks frequently showed a state of slight overexploitation. The finding of a discrete recruitment in the Ionian Sea, D'Onghia *et al*., (1997) suggests that a closed fishing season may reduce fishing pressure on new recruits.

In the Greek Ionian waters where the shrimp stock is not commercially exploited the results showed only small differences from the situation in the Western Mediterranean. The biological characteristics of these different populations such as growth, mortality and life cycle are quite similar (Papaconstantinou & Kapiris, 2001).

Stock identification

Samples from different areas of the Mediterranean (Western, Central and Eastern) and Atlantic (Lisbon and Morocco) were analysed for genetic and morphological studies by Sardà et al., (1998). Morphological differences occurred along an east to west axis. A low level of genetic variability was recorded and was not corelated with the morphometric variation. Marchi *et al*. (1995) also studied genetic variation at 16 enzymatic loci.

Management

A specific management framework for *A. antennatus* does not exist in the Mediterranean or the Atlantic. No specific regulations apply to this fishery although fishing effort is expanding.

Research and management priorities

Substantial knowledge of the biology of *A. antennatus* exists along the Mediterranean and Atlantic area of its distribution. Greater research effort should be deployed in the Aegean Sea.

The specific mechanism of male female interactions and the final process of mating is unknown. The specific mechanisms of the interaction and final process in mating should be described such as the mechanism of opening the spermatophore and contact between sperm and oocyte.

More information on the distribution of larvae is necessary in order to understand the recruitment process and the location of nursery areas.

Monitoring programs for catch and effort and length frequency sampling should be established as the basis for future stock assessment in Mediterranean and Atlantic waters.

Enforcement of a larger mesh size, currently at 40 mm, and a more conservative assessment strategy would result in an increase in yield per recruit and help conserve spawning stock biomass.

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Biology and Fisheries of Deep Water Rose Shrimp (*Parapenaeus longirostris*) in European Atlantic and Mediterranean waters.

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Description and distribution

Introduction.

The deep-water rose shrimp, *Parapenaeus longirostris*, (Lucas, 1846) is a decapod crustacean belonging to the family Penaeidae. It is one of the three species included in this genus inhabiting the Atlantic Ocean (Perez-farfante and Keusley, 1997). The species shows a wide geographic distribution, from the eastern Atlantic in the north of Spain (Olaso, 1990) to the southern waters of Angola (Crosnier *et al*., 1968), as well as in the Mediterranean and its adjacent seas (Thyrrenian, Adriatic, Aegean and the Sea of Marmara) (Karlovac, 1949; Maurin, 1960; Massuti, 1963, Audouin, 1965, Holthuis, 1980).

In the Mediterranean Sea, the bathymetric distribution of the deep-water rose shrimp ranges between 20-750 m (Tom *et al*. 1988), but the species is common and abundant on sandy-muddy bottoms between 100-400m depth (Bombace, 1972; Holtuis, 1987) In the Atlantic waters off Portugal and in the Gulf of Cadiz its bathymetric distribution is similar to that in the Mediterranean. It is found in depths from 80-700 m depth in the Atlantic (Ribeiro-Cascalho, 1988) and from 28-650 m in the Mediterranean (Sobrino, 1988). However, in the African Atlantic waters it’s bathymetric range is more restricted. According to Sobrino and Fernandez (1991) it is found between 20-400 m in the Gulf of Guinea, and from 50-500 m in the Congo (Crosnier *et al*., 1970), and other areas of tropical Africa (Crosnier and Forest, 1973). In Senegalese waters, it has not been recorded in depths over 500 m (Lopez Abellan, pers. com.), while in Mauritania it ranges from 50-400 m (Diop, pers. com.). Finally, Sobrino and Cardenas (1996) did not find this species at depths greater than 400 m in the waters off Angola.

In all areas investigated the greatest biomass occurs between 100-300 m depth. In the Mediterranean Sea, Froglia (1982) found its greatest abundance between 200-350 m, whilst Ardizzone, (1990) found the highest densities in the range of 150-350 m. Crosnier *et al*. (1970) recorded the greatest densities in the waters off Congo between 200-300 m, while Sobrino and Cardenas (1996) found concentrations in 100-200 m.

This species is the main target species of a large fishing fleet working in the Eastern Atlantic. The principal fishing grounds are located in the south of Spain and Portugal (Pestana, 1991, Sobrino *et al*., 1994), as well as in areas off Morocco, Mauritania, Senegal, Guinea Bissau, Gabon and Angola (Cervantes and Goñi, 1986; Cervantes *et al.*, 1991, Sobrino and García, 1991; 1992a; 1992b). In the Mediterranean Sea, *P. longirostris* is caught almost exclusively by trawl. Longhurst (1970) indicated that the species is the most important crustacean resource along the coasts of Spain, France and Italy. Also in Algeria, Tunisia, Greece and Turkey the species shows a commercial value, although on a lesser scale. FAO catches and landings statistics from 1972 to 1991 indicated that deep-water rose shrimp is the fifth species in order of importance among crustaceans for biomass landed in the whole Mediterranean area (Stamatopoulos, 1993).

In spite of its abundance and high economic value, research on the biological aspects on this species in the Atlantic is scarce. In the Mediterranean Sea, many studies carried out in the last twenty years allowed collecting detailed information on distribution, abundance and biology, but there is a lack of knowledge on the exploitation state of this important resource. The main objective of the present paper is to describe the actual information available for the Atlantic waters off Portugal and for the Mediterranean waters off Spain, Italy and Greece.

Taxonomic position.

The taxonomy of *P. longirostris* proposed by Pérez-Farfante and Kensley 1997 is:

Superclass CRUSTACEA Pennant, 1777
Class MALACOSTRACA Latreille, 1806
Subclass EUMALACOSTRACA Grobben, 1829
Superorder EUCARIDA Calman, 1904
Order DECAPODA Latreille, 1803
Suborder DENDROBRANCHIATA Bate, 1888
Superfamily PENAEOIDEA Rafinesque-Schmalt, 1815
Family PENAEIDAE Rafinesque-Schmalt, 1815
Genus *Parapenaeus* Smith, 18856
Parapenaeus longirostris (Lucas, 1846)

Old synonyms have been: *Peneus cocco* PRESTANDREA, 1833; *Peneus longirostris* LUCAS, 1846; *Penaeus mebranaceus* HELLER, 1863; *Penaeus bocagei* JOHNSON, 1863; *Penaeus politus* SMITH, 1881; *Parapenaeus politus* SMITH, 1886; *Parapenaeus mebranaceus*, SENNA, 1903; *Neopenaeopsis paradoxus* BOUVIER, 1905; *Parapenaeus paradoxus* BOUVIER, 1908; *Penaeopsis paradoxus* SCHMITT, 1926.

Physical description

The rostrum has 7 dorsal teeth, one epigastric tooth is situated conspicuously posterior to the first rostral tooth. The rostrum is very variable in length and longer in female than in males. The carapace has an orbital spine, hepatic spine and branchiostegal spine, with a well-marked carina. The last three abdominal somites have an antenna spine and the telson is armed with pair of lateral spines.

Geographical Distribution

The species *P. longirostris* has a wide geographic distribution, from the eastern Atlantic in the north of Spain to the southern waters of Angola as well as in the Mediterranean Sea. In Atlantic and Mediterranean European waters, it constitutes a valuable target species for very viable fisheries.

In Portuguese waters, the species is caught in the south-west (south of Cabo Espichel, 38º 25’ N) and in the south (Algarve) coasts in depths of 80-700 m. Size varies with depth, larger sizes being found in deeper waters (Ribeiro-Cascalho, 1988). The highest yields are observed during daytime, when the species forms demersal concentrations between depths of 100-300 m. The preferred substrata are sandy and muddy sediments (Viriato and Figueiredo, 1991). It is found in areas where bottom water temperature range from 12-14° C and where the salinity is 35.6-36.1‰ (Ribeiro-Cascalho, 1988).

In Spanish waters, this species is mainly caught in the Gulf of Cadiz where it occurs between 40-650 m. The fishery occurs at depths of 100-300 m (Sobrino, 1988), where the maximum abundance occurs.

In the Spanish Mediterranean waters, the species is also important in the south (Alboran Sea) and the landings are lower in more northern areas of these water. The species occurs in all Italian waters. Highest abundance occurs in the Sicilian Channel and in the Ionian Sea and the lowest density in the Ligurian Sea and in the central and northern Adriatic Sea. In this latter area *P. longirostris* was recently found to be abundant along the Albanian coast (D'Onghia *et al.*, in press). The bathymetric distribution of the species ranges between depths of 20-700 m although the highest densities are observed between 100-400 m depth. In the northern and central Tyrrhenian Sea (Mori *et al.*, 1986; Ardizzone *et al.*, 1990), the vertical distribution of *P. longirostris* is very wide, but the species is mostly caught over muddy or muddy-sandy bottoms between 70-350 m depth. In the southern Tyrrhenian Sea (Spedicato *et al.*, 1996) it is distributed in depths of 61-587 m, with the highest abundance at 200-450 m. Off western Sicily, Bombace (1972) found *P. longirostris* between 150-350 m deep and related it to the presence of water masses of Atlantic origin (temperature of 14° C).

After the dispersion phase in shallow water shrimps move toward deeper water as they get older and larger. Juveniles settle at a depth of 100 m, although they can also be detected at 300 m, whereas the larger individuals are always found in water deeper than 350 m (Froglia, 1982; Mori *et al*., 1986; Ardizzone *et al.*, 1990; D'Onghia *et al*., 1998). In the Central Tyrrhenian Sea (Ardizzone *et al.*, 1990) most of the smaller males and females (<20 mm) occur in depths of less than 250 m. Individuals 21-30 mm carapace length were collected mostly between the 250-350 m, while the largest specimens mainly occurred at greater depths.

In Greek waters this species is found on mud or mud-sand substrates, mainly in depths ranging between 150-400 m. It is widespread both in the Aegean and Ionian Seas (Koukouras and Kattoulas, 1974; Koukouras *et al*., 1997; Politou *et al*., 1998; Tserpes *et al*., 1999) In the Southern Ionian Sea this species was also found, in lower abundance, in deep waters (500-700 m) (Anon., 1999). In the same area, larger individuals (26-35 mm) were found mainly in the deeper areas (500-700 m) whereas smaller shrimp (8-22 mm) occurred in shallower waters (300-500 m) (Anon., 1999).

Life history

Growth

The life span is between 2-3 years and males grow more slowly than females.

Morphometric characteristics are show in Table 2.1. Length-weight and total length (TL)–caparace length (CL) relationships are presented by sex.

Von Bertalanffy growth parameters have been estimated for several areas of the Mediterranean Sea and East Atlantic (Table 2.2.). In Portuguese waters some estimates of the growth parameters have been made using Ford-Walford and Gulland plots, SLCA and ELEFAN. The estimates presented by Ribeiro-Cascalho (1988) are the most reliable for that area according to Cadima *et al*. (1995). Sobrino (1998) obtained similar results in the Gulf of Cadiz using Ford-Walford and Beverton and Holt (1957) methods. In Italian waters, growth parameters were estimated in the Central Tyrrhenian Sea and in the Ionian Sea.

Growth rates of female shrimp appear to be similar in most areas studied (Tables 1-2) although it is slower in Greek waters. Male shrimp appear to be larger in Portugese waters compared to those in the Mediterranean.

Table 1. Von Bertalanffy growth parameters estimated for East Atlantic and Mediterranean Sea.

Area	**Sex**	**LC_∞ (mm)**	**K**	**t_0**	**Author**
Southern Portugal	Female	44	0.7	-0.3	Ribeiro-Cascalho (1988)
Southern Portugal	Males	36.0	0.9	-0.3	Ribeiro-Cascalho (1988)
Southern Spain (G. Cadiz)	Females	44	0.74	-0.15	Sobrino (1998)
Southern Spain (G. Cadiz)	Males	33	0.95	-0.2	Sobrino (1998)
Central Tyrrhenian Sea	Females	44.4	0.74	-0.13	Ardizzone *et al*., 1990
Central Tyrrhenian Sea	Males	33.1	0.93	-0.05	Ardizzone *et al*., 1990
Ionian Sea	Females	47.7	0.74	-0.19	D'Onghia *et al*., 1998.
Ionian Sea	Males	35.5	0.54	-0.29	D'Onghia *et al*., 1998
Greece	Females	37.2	0.52	-0.30	Anon. 1999
Greece	Males	33.7	0.62	-0.16	Anon. 1999

Table 2. *Mean carapace length (mm) at age for P. longirostris in southern Portugal and in some Mediterranean areas.*

Female					
Age (months)	S. Portugal	S. Spain	Tyrrhenian Sea	Ionian Sea	Greece
6	18.9	16.8	16.5	18.8	12.7
12	26.3	25.2	25.2	27.6	18.3
18	31.5	31.0	31.1	33.6	22.6
24	35.2	35.0	35.2	37.8	26.0
30	37.8	37.8	38.1	40.7	28.5
36	39.6	39.7	40.0	42.7	30.5
Male					
Age (months)	S. Portugal	S. Spain	Tyrrhenian Sea	Ionian Sea	Greece
6	18.5	16.0	13.3	12.3	11.3
12	24.8	22.4	20.6	17.8	17.3
18	28.9	26.4	25.3	22.0	21.7
24	31.5	28.9	28.2	25.2	24.9
30	33.1	30.5	30.0	27.6	27.2
36	34.2	31.4	31.2	29.5	28.9

Reproductive biology

Reproductive season

In Atlantic waters (south of Iberian Peninsula) mature females occur in deeper water except in February-April. Two spawning peaks occur, the first in summer and the second in autumn-winter (Banha, 1982; Ribeiro Cascalho and Arrobas, 1987; Ribeiro-Cascalho, 1988; Sobrino 1998). Caramelo *et al.* (1996) consider that the summer spawning is the most important. Sobrino (1998) found that larger mature females spawn in spring and smaller females spawn in Autumn. The analysis of the maturity stage composition in relation to depth showed few mature specimens in waters less than 100 m deep. Mature females become more common with increasing depth. Immature males only occur in waters less than 100 m deep. No trends in maturity with depth were observed in surveys carried out during a non-reproductive period in March in comparison with those carried out during the spawning period in October. The few larvae found in the area also suggest two spawning periods (dos Santos, 1998).

In Italian waters, information on the reproductive season is available for the Tyrrhenian Sea and Sicilian Channel. In the northern Tyrrhenian Sea, reproductively active females occurred in depths ranging from 150-350 m (Mori *et al*., 1986; 2000b). Ripe females were found throughout the year at these depths with two maxima of activity, one in spring and another at the beginning of autumn. This confirms the reproductive period previously identified by De Ranieri *et al.* (1986) in the same area. The presence of recruits (carapace length ≤ 15 mm) throughout the year confirmed that the reproductive activity is almost continuous in this area, although most recruitment seems to occur from July to October (De Ranieri *et al.,* 1998). On the contrary, in the central Tyrrhenian Sea, on the basis of data on recruitment of young shrimp to the benthos, Ardizzone *et al*. (1990) hypothesised a single winter spawning. The recruitment period is not easily identifiable but appears to be protracted over several peaks as indicated by the numerous micro-cohorts among new recruits. This conclusion agrees with the data given by Froglia (1982) showing one generation per year in the southern Tyrrhenian Sea. In the same area studies carried out by Spedicato *et al.* (1996) identified the highest frequency of mature females in spring-summer, although mature specimens were found all year around. Along the north-western Sicilian coast, Arculeo *et al.* (1993) found that mature females were more common in winter and spring. In the Sicilian Channel (Levi *et al*., 1995) mature females occur in all months of the year, although a peak occurs between November and February and another in April. The lowest percentage of mature females appears in June-July, but spawning seems to occur throughout the year. Recruits of 11.5-12.5 mm are present in the catches all year round except in August. This is 2 months after the lowest percentage of mature females are found.

In the Greek Ionian Sea the sex ratio is close to 1:1 throughout the year. The younger individuals (15-20 mm) were caught in December, January, March and July at 300-500 m depth reinforcing the view of the continuous reproductive activity (Anon., 1999).

Size of maturity

Along the coasts of southern Portugal and in the entire Mediterranean Sea male and female *P. longirostris* reaches sexual maturity in the first year of life.

Ribeiro-Cascalho (1988) estimated the size at first maturity as 20 mm for males and 24 mm for females in the South of Portugal, corresponding to an age of 8-10 months. However, Sobrino (1998) estimated that 50% of females are mature at a size of 21.5-22 mm. In males the joining of the two pieces of the petasma takes place at 12-15 mm. The size at which the 50% of males have a joint petasma was estimated at 12.9 mm CL. The spermatophoric mass on the coxae of the fifth pereiopods was present in male shrimp larger than 13 mm. Size at first maturity of males was estimated to be 14.8 mm.

In the northern Tyrrhenian Sea (De Ranieri *et al*., 1998; Mori *et al*., 2000b), the smallest females with ripe ovaries were 16 mm carapace length. The size at onset of sexual maturity estimated for different years ranged from 24.4 mm in 1993 to 19.5 mm CL in 1994. The percentage of post-moult females increased from January to August, decreased from September to October and rose from November to December. Most post-moult females were found with immature or post-spawned ovaries. In the southern Tyrrhenian Sea (Spedicato *et al*., 1996) the smallest females with ripe ovaries were 18.5 mm. The size at onset of sexual maturity was 28.4 mm ($LC_{50\%}$) and 31.2 mm ($LC_{75\%}$). In the Ionian Sea the size at first maturity in females was around 20-22 mm and the smallest mature individuals were 14-16 mm (Table 3)

Table 3. Size at first maturity of P. longirostris in different areas of Atlantic Ocean and Mediterranean Sea.

Area	Sex	$LC_{50\%}$ (mm)	Author

Southern Portugal	Female	24	Ribeiro-Cascalho (1988)
Southern Portugal	Males	20	Ribeiro-Cascalho (1988)
Southern Spain	Females	22	Sobrino (1998)
Southern Spain	Males	14.8	Sobrino (1998)
Northern Tyrrhenian Sea	Females	24.4	Mori *et al*. (2000b)
Southern Tyrrhenian Sea	Females	28.4	Spedicato et al (1996)
Ionian Sea	Females	20-22	Relini *et al*. (1999)
Morocco	Females	24.8	Sobrino and García (1993)
Gulf of Guinea	Females	25.5	Sobrino y Fernandez (1990)
Congo	Females	22	Crosnier et al. (1979)
Angola	Females	21.6	Sobrino y Cardena (1996)

Fecundity

Fecundity in *P. longirostris* has been studied in the Gulf of Cadiz and in the Northern Tyrrhenian Sea. Significant differences were observed between the two areas in the relationship between CL and egg number and the absolute fecundity.

In the Gulf of Cadiz absolute fecundity varied from 21,410 eggs for a female of 25.4 mm and 186,856 for a female of 34.2 mm carapace length. The average relative fecundity was 7,486 eggs/g, with values ranging from 2,048-13,371 eggs/g. Fecundity increased proportionally with size, increasing by approximately 10,000 eggs per mm carapace length and increasing by approximately 9,500 eggs/g body weight (Figure 2.2.).

In the northern Tyrrhenian Sea the fecundity was investigated by Mori *et al.* (2000). The number of oocytes in the ovary was related to the size of females and ranged from 23,000 oocytes at 26 mm to 204,000 at 43 mm. An exponential relationship was observed between fecundity and carapace length ($F= 0.0569\ CL^{4.0177}$ ($r = 0.829$)).

Diet:

A wide variety of prey is eaten by *P. longirostris*. During the hunting phase it feeds on small fish, cephalopods and crustaceans, while during digging behaviour polychaetes, bivalves, echinoderms and mostly foraminifers are taken (Relini, 1973).

Ribeiro Cascalho and Arrobas (1983) examined the stomach contents of 40 specimens of *P. longirostris*, in southern Portugal. Fish, crustaceans (Decapoda, Cirripedia and Ostracoda), polychaetes and foraminifers were the preferred prey types.

Studies made by Burukovsky (1969) in the Gulf of Cadiz and off the north-western African coast indicate that diet is age related. Thus, foraminifers and planktonic crustaceans dominate the diet of young specimens. These are replaced by amphipods and isopods and in older shrimp by shrimps, crabs, euphausiids and mysids, some cephalopods and fish.

In Italian Mori *et al.* (2000a) found a great variety of organisms in the diet of *P. longirostris*. The prey items consisted mostly of external skeletons of bottom organisms always crushed and often in advanced state of deterioration. In addition some inorganic material was found. Crustaceans dominated the diet both qualitatively and quantitatively; this food group was characterised by the high abundance of acarids, mainly represented by mysids (mainly *Lophogaster typicus*) and amphipods (Lysianassidae). Juvenile bivalves and gastropods, the sepiolid cephalopod *Sepietta oweniana*, small ophiuroids, sea urchins, holothurians, annelids of the families Aphroditidae and Nephytidae, globigerinid foramininferans and organic detritus were all present, were mainly recorded in foreguts containing small amounts of food. Organic detritus, mostly as unidentified debris, increases in occurrence with depth down to 300 m. Also, inorganic and plastic particles were found mostly in the specimens caught in the deepest area.

Larval ecology

The life cycle is completed in marine waters. Held (1938) has described the larval development of *P. longirostris*. The development of the egg at temperatures of 16ºC takes 51-55 hrs, while at temperature of 25-26ºC the hatching takes place after 18 hours. The nauplius phase is 0.33 mm in the first stage and up to 0.44-0.51 mm in the VIII stage. The next larval stage, the protozoea phase has a length of approximately 1 mm. There are three different protozoea (I, II, and III). The mysis phase follows the protozoeae. The first mysis measures 3.9 mm and the larval development ends at the mysis XIV with a total length of 12 mm and a CL of 3.6 mm.

Larvae have only been found in Portuguese waters. The occurrence of larvae on the south and southwest coasts coincides with the area of distribution of adults. Most larvae occur around the 100 m isobath that corresponds to the upper limit of the distribution of adults. This probably indicates a displacement of the adults during the spawning period to shallower depths (dos Santos, 1998).

Fishery in different countries

Introduction

P. *longirostris* is a target species of important fisheries. The fisheries, which are all bottom trawl fisheries, occur from the Mediterranean to the Eastern Central Atlantic.

The development of this fishery in the Atlantic (off the Gulf of Cadiz) began during the mid eighteenth century. Martínez de Mora (1977) cites the presence of 4 trawlers in 1743, the so called "BOUS", while Sañez Reguart (1791) cites the presence of fishing in the Gulf of Cadiz in 1755 and locating its origin in the Mediterranean Spanish-French coasts.

In the beginning, this fishing activity was mainly centred in the coastal zone. The first references of shrimp catch by this fleet in the Gulf of Cadiz (Machado, 1847) are in the mid-nineteenth century. The expansion of the fleet during the end of the nineteenth century and beginning of the twentieth century led to the development of the fishery off the northern coasts of Morocco, as indicated by Sancha (1975). All the technological advances, from methods of propulsion (sails, steam and explosion engines) to development of fishing gear and preservation methods (freezing), have had an effect in expanding the fishery.

The crustacean fishery started in the Portuguese coast in the fifties with a combined fleet of both Spanish and Portuguese fishing vessels. The majority of the catches were taken by the Spanish component, as the Portuguese fleet component was very small. In the sixties, this fleet started operating at greater distances from the coast and in deeper banks (Ribeiro-Cascalho, 1988; Santana, 1990; Caramelo *et al.*, 1996). There are very few catch statistics from this first period.

In 1977, the number of Portuguese vessels entering in the fishery started to increase and, since 1983, after the end of the Portugal-Spain bilateral fisheries agreement, only the Portuguese fleet was allowed to fish for crustaceans in Portuguese waters (Caramelo *et al.*, 1996). According to Ribeiro-Cascalho *et al.* (1986), the increasing interest of the Portuguese fleet in this fishing resource was due to the decrease in the fish species catch, the increase in the crustaceans abundance after the end of the agreement and the improvement of the fishing technology that allowed the landings to increase.

At present, there are important fisheries off the African Atlantic coasts. In Morocco, this species is fished from Larache to Agadir, between the parallels 35º 30' and 30º N (Poinsard and Villegas, 1975). The Spanish fleet initially exploited this fishing ground at the end of the nineteenth century. The Moroccan fleet started to exploit the fishery in 1978 (Cervantes *et al.*, 1985, 1991; Anon., 1990). Since then, the Moroccan fleet has gradually displaced the Spanish fleet and at present, the resource is wholly exploited by the Moroccan fleet. The mean annual registered catch for the last 30 years was 8,000 metric tons (mt).

From the Saharian fishing grounds to the borders of Mauritania off Cape Blanco (from 29º to 21ºN), *P. longirostris* is uncommon. From Cape Blanco a commercial fishery exists. This fishery started in the sixties with the development of freezing capacity on vessels (Sancha 1975) and now exists off Mauritania, Senegal, Guinea-Bissau, Gabon and Angola. A detailed description of these fisheries can be found in Sobrino and García (1991, 1992a, 1992b) and Lopéz Abellan *et al*. (1994).

The mean annual catch from the Mauritanian fishing grounds during the last fifteen years was 1,500 mt.

Fleet and Gears

At present, the Portuguese fleet is comprised of trawlers targeting demersal fish and trawlers targeting crustaceans.

The demersal fleet operates year-round along the entire coast of Portugal. Data on the average fish catch composition of this fleet show that in recent years horse mackerel and hake were the most valuable species (ICES, 1999).

There are 35 trawlers licensed to access the crustacean fishery in Portugal (Table 3.1). They are smaller than the demersal fish trawlers; some of them are former sardine purse seines converted into trawlers. On average, they are 25 m in overall length, 111 t of GRT and 484 HP. Some of them use their freezing capacity and make trips of 3 days or longer (Cadima *et al*., 1995; Caramelo *et al.*, 1996).

The gear used is a shrimp trawl with a codend mesh size of 55 mm. The catches are mostly landed in Algarve fishing ports in southern Portugal, particularly in Vila Real de Santo António, where the crustaceans are auctioned.

Until recently, the most important species in this fishery was *Nephrops norvegicus*, but in the last five years, *P. longirostris* has ranked first in terms of landed weight. The third most important species in this fishery is the red shrimp, *Aristeus antennatus*.

In the Gulf of Cadiz, as remarked previously, the fishery began in the mid-nineteenth century (Machado, 1847). The evolution of this fishery has been described by different researchers (De Miranda, 1921; De Buen, 1922; Rodriguez-Roda, 1955; Massutí, 1959). The modern fishery was described by Sobrino *et al*. (1994).

In the Gulf of Cadiz, a total of 270 trawlers operate (Table 3.1). These have a mean tonnage of 25 grt, a mean hp of 215, and a mean length of 13.9 m. This fleet exploits a diversity of species, constituting a typical multi-specific fishery in which the shrimp represents a mean value of 8%.

The main landing ports are Isla Cristina, Huelva, Sanlúcar de Barrameda and Puerto de Santa María.

In the Spanish Mediterranean, this species is important only in the southern area although it is not the primary species. The total annual catch does not exceed 700 mt.

The exploitation of P. *longirostris* in Italian Seas is exclusively by boats using bottom trawls, which is the fishing system which characteristics fishing activity in Italy. Before the second world war *P. longirostris* was rarely exploited, because the fishing boats used sails as the main propulsion system and deep water fishing was not possible. The introduction of otter trawls, powerful engines and navigation technology increased the catching capacity and the exploitable sea area. In particular this allowed the exploitation of crustaceans such as *P. longirostris*, *N. norvegicus* and red shrimps in deeper water.

According to recent statistics, during 1999 there were 4094 vessels in the Italian bottom trawl fleet (Unimar, 2001), representing 25.8% of the total Italian fishing fleet (Table 3.1). These boats are larger by on average 32 grt compared to the national fleet. It is difficult to determine the number of boats targeting *P. longirostris,* because they usually direct the fishing effort towards different target species during the year. For example, in Mazara del Vallo the most important Italian port for shrimp, about 70 of the total 350 trawlers target *P. longirostris* during the entire year on the fishing grounds located in the Sicilian Channel (Levi *et al*., 1995). In general, the trawlers less than 10 grt, representing about the 44% of the Italian trawl fleet and 12% of the total tonnage, do not exploit shrimp. Their activity is restricted to the continental shelf less than 200 m in depth. Boats fishing for crustaceans target *P. longirostris*, *N. norvegicus* and red shrimps (*Aristeus antennatus* and *Aristaemorpha foliacea*). These boats usually utilise some variants of the "Italian" bottom trawl net, characterised by a low vertical opening of the mouth (about 1 m), very long wings and 38-40 mm cod end mesh size. The most important ports are located along the southern coast of Sicily and in the Ionian Sea. Although to a lesser extent, *P. longirostris* is also economically important in the landings of some ports of the central (e.g. Terracina, Napoli, Salerno) and northern (Porto Santo Stefano) Tyrrhenian Sea.

There is no specialised crustacean fishery in Greece although a number of species are exploited as part of a multi-species fishery. Target crustacean species include *Nephrops norvegicus*, *Penaeus kerathurus*, *Palinurus elephas*, *Homarus gammarus* and *Parapenaeus longirostris.* There are 344 trawlers in the fleet (Table 3.1). The characteristics of these vessels are: average length 23.2 m, 63.24 grt and 390.3 hp. The mean age of these boats is 22.8 years. Average age of fishers is 45-50 yrs. On average there are 4 crew. There are 42 ports. The common trawl used has a mesh size cod end of 32 mm (ranging from 28-36 mm), with a horizontal opening of 15 m and a vertical opening of 1.5 m. The main fish markets are in Piraeus, Chalkis, Thessaloniki, Kavala, Chios, Patra, Preveza and Alexandroupolis. In the Ionian Sea, all the existing 43 trawlers may catch this species. Their fishing activity lasts 15-20 h/day. In the Aegean Sea, there are 277 trawlers, working 15-20 h/day, depending on the area. *P. longirostris* is caught at depths of 150-400 m on muddy-sandy bottoms, from October-May each year.

Fishing operation regime and fishing area

According to Cascalho (1988), the average duration of fishing trips for many years was 1 day. with 3 hauls per day (3 to 4 hours each), and around 17 fishing days per month. This fishing pattern has remained constant with only small variations. The freezer trawlers make longer trips (more than 5 days each) and the total number of fishing days per month is 22.

The mean number of fishing hours per boat also varies by boat and time of year and ranges between 10-14 hrs/day (Dias, 1992). More recent data indicate an increase in the average number of fishing hours per day. The trawling speed varies between 2.5 and 3 knots.

The crustacean fleet operating along the southwest and southern coasts of Portugal (Alentejo and Algarve), fish between depths of 100-700 m. Concentrations of deepwater rose shrimp are found mainly in areas shallower than 400 m. The southwestern coast is exploited by vessels that undertake longer fishing trips (Ribeiro-Cascalho *et al.*, 1986).

Fishing occurs on mud and sand substrates.

In the Gulf of Cadiz, the fleet carry out mostly one day fishing trips, although some fishing trips may last for 2-3 days. The species is mainly fished in the area from Ayamonte (Portuguese border) to the Bay of Cadiz, decreasing its abundance towards the Strait of Gibraltar. The fishing depth ranges from 90-380 m, although the species has been found at depths of 700 m (Sobrino, 1998).

In Italian waters trawlers undertake 1 day trips, performing 3 hauls with and average tow duration of 3 hours. The larger boats, with freezing and refrigeration equipment on board, can perform trips of 3-5 consecutive days. The fishing activity per month ranges between 18-22 days, depending on the fishing port.

The most important fishing grounds are located in the southern Tyrrhenian Sea, in the Ionian Sea and in the Sicilian Channel, where this species is abundant (AA. VV., 1988, 1993; Tursi *et al*., 1994). The seabed is muddy and the depth range is 200-400 m.

P. longirostris is fished throughout the Greek Seas and is the most important crustacean species in terms of catch weight, landings and value. The important ports are Pireas and Thessaloniki, followed by Kavala, Patra and Alexandroupoli.

The annual catches of *P. longirostris* in Greece showed a high degree of variability, in the period 1990-1997. Landings increased during the period. In fact, the landings of the species represented 23% of the catches in 1990 and 80% in 1998. The increase in the landings of *P. longirostris* was accompanied by a similar increase in their total annual value. However, the value/kg is negatively correlated with the volume of the landings (Mytilineou *et al*., submitted).

<u>Selectivity</u>

Several selectivity experiments have been carried out in Portugal, on board of commercial vessels and research vessels, using the covered codend method (Ribeiro-Cascalho, 1988; Ferreira *et al.*, 1993; Caramelo *et al.*, 1999; Fonseca *et al.*, 1999, 2000). The nominal coded mesh sizes tested were 45, 55, 60, 65, 70 and 80 mm. The codend cover mesh size was 20 mm. Table 3.2 summarizes the results of the more recent experiments conducted in a commercial crustacean trawler. The average duration of tows was 3 hours, at trawling speed of 3.1-3.2 knots (Fonseca *et al*., 1999, 2000)

In the Gulf of Cadiz the selectivity experiments has been done using the covered cod-end method. Two different selectivity survey designs were applied: firstly, using different mesh sizes and a fixed trawl duration (one hour) on board of an oceanographic vessel (6 surveys) (table 3.2), and secondly, carrying out the selectivity survey on board commercial fishing vessels (4 experiences) , using the standard fishing gear of the fleet at variable trawl duration times. In all the cases, the cod-end cover was 20 mm. All the results have been publishing in Sobrino *et al*., (2000).

At this moment, there is a lack of information regarding the selectivity of commercial trawl net on *P. longirostris* in the Italian waters. The only available value of L_{50}, estimated through an indirect method, was reported by Levi *et al.* (1995) for a commercial trawl net of 32 mm cod-end stretched mesh size in the Sicilian Channel. Projection backward of the descending arm of the catch curve (after logistic transformation), gave for this net L_{25}=14.9 CL, L_{50}=16.1 mm CL and L_{75}=17.2 mm CL, with R=0.9956 for the regression between logit probabilities and lengths. Hence it seems that about two months are needed to reach the CL for recruitment to the fishery in this area.

Monitoring of the fishery

Landings

Figure 3.1 presents landings data for *P. longirostris* in Portugal, Spain, Italy and Greece, for the period 1990-2000.

In Portugal the landings statistics are recorded at auctions by vessel, species and commercial size category. These records also include data on the product value. Catch and effort statistics are available from logbooks, but the reliability of this information is questionable.

The Portuguese landings of *P. longirostris* in the last two decades show alternate periods of high and low abundance, with maxima in 1984, 1989 and 1999. In 1995, due to the decline of the yields of Norway lobster, the crustacean fleet redirected the effort to the deepwater rose shrimp. In the period 1998-2000, the high effort on this species combined with an increase in abundance produced record landings.

The length composition of the landings is estimated by a sampling program at the main auction place for the crustacean fishery, in Vila Real de Santo António.

A specific program to compile information on the fishery from the main landing sites of the Gulf of Cadiz has existed since 1982. Trends in catches shows the typical variation of short-living species in which abundance is directly related to recruitment strength.

A certain similarity can be observed in the catch trends of the Portuguese and Cadiz fisheries (Figure 3.1) indicating a possible link between these stocks.

P. longirostris is one of the most important fishery resources of epibathyal grounds along the Italian coasts. The exploitation of this species takes place all year round, but peak landings are from March to July (Levi *et al.*, 1995). The whole catch is marketable, with the biggest specimens being of greater commercial value. Starting from 1985, ISTAT, Istituto Italiano Nazionale di Statistica, recorded landing data on Italian seas. From 1997, FAO statistics are available for Italian waters. The statistics show an evident reduction of biomass landed from 1990 (18368 t) to 1998 (4410) with a notable recovery in the last year (7500 t in 2000) (Figure 3.1). This trend could be directly influenced by the biomass of this resource at sea, being *P. longirostris* a short life cycle species with great abundance fluctuations year to year.

In Greek waters the fishing of this species with trawlers takes place between 150-400 m, in muddy-sandy bottoms, from October to May each year. The landings data mentioned below, arise from ETANAL - Company for the development of fishery, which are collected from the 10 Greek auction places, independently of the fishing area. The mean annual crustacean catches in the Greek waters increased from 175 t the period 1928-1934 to 1260 t the period 1964-1981 (Stergiou, 1986, NSSG data). In 1999, the crustacean catches were about 2780 t, representing 3.7% of the total catches (FAO data). During the same year, the crustacean landings from the Greek waters were about 2,300 t, representing 3.8% of the total landings; their value represented about 8% of the value of the total landings (ETANAL data).

Assessment of the impact of fishing on the population.

Assessment and management

Several surveys in Portuguese waters have reported abundance indices for crustaceans, in the period 1981-2000. Presently, a survey is carried out once a year, in summer, covering the main area of distribution of these species (Alentejo and Algarve). A new series of surveys directed at rose shrimp recruits started in 2002.

Natural mortality has been estimated by several authors using Pauly's formula, the method of Rikhter and Efanov and Tanaka's longevity curve (Banha, 1982; Ribeiro-Cascalho, 1988; Cadima *et al.*, 1995). The values ranged from 1.20 to 1.87 $year^{-1}$ for males and from 1.07 and 1.60 $year^{-1}$ for females.

Based on the geographic distribution of the species *P. longirostris* in the Portuguese fishing grounds, Pestana (1991) assumed there was one stock throughout waters off Southern Portugal (Alentejo and Algarve). He presented the results of assessment for the period 1984-1989, using age-converted length composition data in a Virtual Population Analysis. According to this analysis, the stock was overexploited and a reduction in fishing mortality was recommended. Attention was also called to the high fluctuations in recruitment.

Pestana and Ribeiro-Cascalho (1991) studied the effects of changing trawl mesh size and fishing effort on the stock and provided some guidelines for management purposes, suggesting either a decrease of 10% in the level of fishing effort without any mesh change or an increase in mesh size from 55 to 60 mm if effort was not reduced.

Cadima *et al.* (1995) presented an analysis of the trends in total catches and CPUE of this species for the period 1983-1994. A preliminary stock assessment was carried out fitting Schaefer and Fox surplus production models to this data set. The analysis suggested that the deepwater rose shrimp stock was overexploited.

A Thompson-Bell Yield per Recruit Model and Jones length cohort analysis were also applied to the rose shrimp data by Cadima *et al.* (1995). The Y/R model indicated that the stock was over-exploited. The length cohort analysis (applied separately for males and females) did not indicate overexploitation but showed that fishing effort should not be increased.

The shrimp fishery off Cadiz has being monitored since 1993. During this period, a series of demersal surveys began with shrimp as one of the main target species. Abundance and recruitment indices have been estimated which, with a sufficient time series of data, may be related to landings (Sobrino, 1998).

Size distribution sampling has also allowed Length Cohort Analysis to be developed. This shows fishing mortality estimates ranging from 0.3-0.7 depending on size class.

In order to assess the effects of changes in the pattern of exploitation, a Thompson and Bell (1934) model, adapted to size data as described by Sparre and Venema (1992), was applied. Although an increase in mesh size could cause immediate losses, these results should be considered cautiously with the penaeid fishery because it is fast-growing and short lived. The immediate losses would be regained during the first year, since the species takes only five months to grow from 17 mm (L_{50} with the 40 mm mesh) to 23.7 mm (L_{50} with the 55 mm mesh). As size at first maturity of females in this area occurs at 22.2 mm (Sobrino and Gárcia, 1998) there would be an important increase in spawning stock biomass. Depending on the mesh used (50 or 55 mm), this increase could be between 200-250% (Sobrino *et al.*, 2000). However, at the present exploitation level, there does not seem to be a relationship between spawning stock biomass and recruitment. Recruitment may be influenced more by variable oceanographic conditions than by spawning stock size (Sobrino, 1998).

National otter trawl surveys were performed in all the Italian seas from 1984-85 until the present. All seas were covered from 0 to 700 m depth, applying a stratified random sampling design. The ten most important demersal species, including *P. longirostris*, were chosen and the following data and results were obtained: length frequency distributions for each survey by stratum, sex ratio, growth parameters, length/weight relationship, sexual maturity, mortality and exploitation state.

From 1994 an international programme (MEDITS - Mediterranean International Trawl Surveys) was financed by the European Commission with the objective of acquiring demographic structure and biological data on the demersal resources along the coasts of the four Mediterranean countries of the European Union (Spain, France, Italy and Greece). Each year a campaign was carried out in late spring and beginning of summer, covering all trawlable areas on the shelves and the upper slopes (at depth from 10 to 800 m).

Results of analytical modeling in some areas along the Italian coasts in the period 1990-1998 showed that stocks were generally overexploited. To correct this fishing effort should be reduced by 10-20% of size at first capture should be increased. In the Sicilian Channel an attempt to assess *P. longirostris* using one year of landing data indicated a total mortality rate (Z), computed by the catch curve method, ranging between 0.705-0.941 depending on fishing grounds. A fit of the Beverton and Holt yield per recruit against exploitation rate suggested that fishing effort should be reduced by about 14 % to obtain higher benefits at short term. On the same data set, Thompson and Bell model suggested that a 70% reduction in effort would be necessary to reach maximum Y/R and maximise value of the catch on a long-term basis. The reduction in effort required to obtain maximum yield in weight in the long run was about 50%. In summary modest measures taken immediately would avoid the need for more serious actions in the future.

Management of the fishery

Table 3.3 summarises information on management measures and management structures for this fishery in different areas

Table 3.3. - Management measures and structures for P. longirostris by region

MANAGEMENT MEASURES	***Greece***	***Italy***	***Spain***	***Portugal***
Technical measures:				
Minimum landing size	No	No	22 mm CL (EU regulation)	24 mm CL or 94 mm TL
Sex restrictions	No	No	No	No
Mesh regulations in trawls	28 mm	40 mm	40 mm	55 mm
Trawl devices to exclude by-catch or undersized fish	None	None	None	None
Other technical restrictions	maximum engine power: 500 HP	None	None	Minimum of 30% of shrimp species
Effort control:				
Quota				
Seasonal or other closures	Closed season of 4 months (June-September)	30-45 consecutive days of closure per year. Fishery ban on Saturday and Sunday	Fishery ban on Saturday and Sunday	Closed area for trawling, from December to February.

No take zones	Areas prohibited to trawler or any fishing gear	Coastal 3 miles stripe and upper 50 m depth forbidden	Trawl ban < 6 miles from shore	Trawl ban < 6 miles from shore
Gear limitations	Maintenance of the total GRT, HP of the trawl fishery	Stop new licences	Stop new licences	Maximum number of licensed vessels: 35
Management Structures	Centralised	Centralised	Centralised	Centralised, co-management

Discussion

The deep water rose shrimp *P. longirostris* is one of the most important commercial decapod species in bottom trawl fisheries in Atlantic and Mediterranean waters.

P. longirostris is a short lived species, with a life span of approximately three years but the catch is composed almost entirely of 1-2 year old shrimp. Males grow more slowly and reach a smaller maximum size than females in all stocks.

In the Gulf of Cadiz, *P. longirostris* spawns in late spring (larger shrimp) and in autumn (all size classes). A similar situation has been observed by Ribeiro-Cascalho and Arrobas (1983, 1987) in south Portugal and by Sobrino and García (1994) in the Atlantic waters off Morocco, with two spawning peaks (June and October). In the water off Congo Crosnier *et al.* (1970) also identified one main spawning peak in April and May and a secondary one in September and October.

In the Mediterranean spawning patterns differ by location. Held (1938) described one single spawning peak between April and November in Tunisian waters, while Drobisheva (1970) found mature females only in spring in the Egyptian coast. In the coasts of Italy, Levi et al. (1995), and D' Onghia et al (1998), using a macroscopic maturity scale for the female gonads, describes a continuous spawning during the year. Tom *et al.* (1988), in the waters off Israel, relates the oogenesis with the temperature and distinguishes different reproductive periods according to depth. In shallow waters (between 47 and 73 m), the reproductive activity is continuous, while in deeper waters, spawning ceases from June to August.

The size at first maturity is variable. Ribeiro-Cascalho (1988) estimated the size of first maturity as 24 mm CL for females in south Portugal, while for Sobrino (1998) this value was around 22 mm CL in the Gulf of Cadiz. In Moroccan waters, Sobrino and García (1994) obtained values from 24.5 to 27.7 mm CL. Based on the results of a survey in the Gulf of Guinea, Sobrino and Fernández (1991) estimated the size of first maturity as 25.5 mm CL, although these authors pointed out that the non-exploited state of this resource could have an influence on its reproductive behaviour. The value determined by Crosnier *et al.* (1970) for the waters off Congo (22 mm), is very similar to the estimate of Sobrino and Cardenas (1996) off Angola (21.6 mm) and to the one given by De Ranieri *et al.* (1996) for the Mediterranean waters (21.5 mm).

There is a clear segregation by depth of the different maturity stages. Females in advanced stages of maturity or close to spawning occur at depths greater than 100 m. In shallower waters, gravid females are practically absent. This behaviour has been described also in other areas. In the Mediterranean (Thyrrenian Sea), Mori et al. (1986) located the spawning grounds in depths between 150-300 m, while in the Gulf of Guinea, they are deeper than 200 m (Sobrino and Fernández, 1991). In Angolan waters, they are concentrated between 100-400 m depth (Sobrino and Cardenas, 1996). However, these results differ from those in Tom *et al*. (1988) who reported a continuous spawning activity in the waters of Israel in depths from 47-73 m. They suggested that 16ºC was the limit below which spawning activity began to decline. In the Gulf of Cadiz, within the bathymetric range in which mature females are found (100-400 m), the water temperature ranges between 16.5ºC in depths from 100-200 m, to 14º C at 300 m and to 13º C at greater depths. These results are in agreement with Ghidalia and Bourgois (1961) who found a correlation between the abundance of shrimp and the water temperature, suggesting a lower temperature limit of 13.5º C and optimal temperature between 14 and 15º C.

The fishery for *P. longirostris* in the eastern Atlantic (Portugal) and southern Mediterranean (Spain, Italy, Greece) is well developed and carried out by the common bottom trawlers involved in a multi-species fishery. During the last decade an increase in landings was observed in Portugal, Spain and Greece. Because in almost all the above countries this species is considered to be slightly overexploited additional regulatory measures must be taken in order to maintain this resource.

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The biology and Fisheries of *Nephrops norvegicus* in the Mediterranean

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Introduction

Several authors have extensively reviewed the biology and fishery of this species in the past. Classical reviews include those of Figueiredo and Thomas (1967), Farmer (1975) and Chapman (1980). Sardà (1995) made a recent review, focusing aspects of it's life history. Studies covering specific aspects of the biology or fishery of the species in the Mediterranean include the work of Karlovać (1953) on general biology in the Adriatic Sea, Orsi Relini and Relini (1985, 1989) on reproduction in the Ligurian Sea, Froglia and Gramitto (1981, 1988) on biological parameters and mortality in the Adriatic Sea, Gramitto and Froglia (1980) on reproduction, Abelló and Sardà (1982) on fecundity in the Catalan Sea and Portuguese waters, Sardà (1985, 1991) on growth, moult and regeneration, Sardà and Cros (1984) on metabolism. Sardà (1998), in a special volume reporting the results of the NEMED project, described the biology in 7 different areas in the Mediterranean (and adjacent south of Portugal).

Hence, considering the large amount of information available, the present contribution will aim at synthetically reviewing the main lines of research on *Nephrops* in the Mediterranean, while emphasising recent trends and new developments since 1990.

Description and distribution

The Norway lobster (*Nephrops norvegicus,* L.) is a decapod crustacean belonging to the Infraorder Astacidea (Latreille, 1803), Superfamily Nephropoidea (Dana, 1852), Family Nephropidae (Dana, 1852), following the systematic classification of Bowman and Abele (1982).

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Common names (Farmer,1975; Holthuis, 1991) in different countries are: **Algeria:** Lângûstina; **Belgium:** Langoestin, Langoustine, Noorse Kreeft; **Cyprus:** Astakos; **Denmark:** Bogstavhummer, Jomfruhummer, Dybvandshummer, Gul Hummer; **Faeroe Islands:** Hummary; **France:** Langoustine, Cacahouète, Arganelle; **Germany:** Norwegischer Hummer, Buchstabenkrebs, Kaisergranat, Kaiserhummer; **Greece**: Karavída; **Iceland:** Humar, Letur Humar; **Ireland:** Dublin Bay Prawn; **Italy:** Scampo, Scampolo, Astracio; **Malta:** Ksampu; **Monaco:** Lengustina; **Morocco:** Azeffane, Langoustine; **Netherlands:** Noorsche Kreeft, Letterkreeft; **Norway:** Bokstavhummer, Keiserhummer, Sjøkreps, Sandhummer, Trollhummer, Jomfruhummer; **Portugal:** Lagostim; **Spain:** Cigala, Escamarlanch, Escamarlà, Maganto, Langostino; **Sweden:** Kejsarhummer, Havskräfta; **Tunisia:** Jarradh el bahr; **UK:** Norway lobster, Dublin Bay prawn, Prawn, Scampi; **Yugoslavia:** Skămp.

The distribution of *Nephrops* stocks is well known and encompasses suitable burrowing substrates on the shelf and slope of NE Atlantic and Mediterranean waters (Farmer 1975). In its northern distribution (Gulf of Biscay to Norway and Iceland), *Nephrops* is found mostly on the continental shelf and slope, while in its southern distribution (Portugal and Mediterranean) it is found also on deep-water fishing grounds, down to 800 m depth (Farmer 1975, Holthuis 1991; reported at 871 m by Sardà and Abelló 1984). In the Adriatic Sea, the North Euboikos Gulf and the Ebro delta shelf it is abundant at depths shallower than 100 m (Froglia 1972, Maynou and Sardà 1997, Mytilineou et al. 1998c). In the Mediterranean, *Nephrops* is abundant in the Western basin and the Adriatic Sea and becomes scarcer eastwards (Holthuis 1987). It is also abundant in Greek waters, especially in the North Aegean Sea (Anon. 2000, Mytilineou et al. 2002). In the south Mediterranean, it is present from the Straits of Gibraltar to the Nile delta, but it is absent from the Levantine coasts (Holthuis 1987).

In the Mediterranean, *Nephrops* is often associated with other decapods, such as *Pandalina profunda, Plesionika sp.*, *Calocaris macandreae*, *Alpheus glaber*, *Pontocaris lacazei, Munida tenuimana*, *Liocarcinus depurator*, and with demersal fishes such as *Galeus melastomus, Merluccius merluccius*, *Phycis* sp., *Micromesistius poutassou*, *Lophius* sp., *Lepidorhombus boscii*, and *Conger conger* (Abelló et al. 1988, Cartes and Sardà 1992, Politou et al. 1997, Mytilineou et al. 1998c).

The main determinant of the species distribution is the availability of suitable burrowing substrate of sandy mud or clayey mud, while temperature, salinity or depth are considered less relevant. The relationship between substrate characteristics and *Nephrops* distribution was studied by Maynou and Sardà (1997). These authors reported that *Nephrops* density was higher in fine-grained sediments on slope areas and lower in coarse sediments on the continental shelf off the Ebro delta. On the other hand, the distribution of *Nephrops* is not uniform over the depth ranges occupied by the species, but there exist high-density patches alternating with areas of lower abundance (Maynou et al. 1998). There is no spatial segregation of juveniles and adults (Maynou and Sardà 1997) and *Nephrops* does not undertake migrations.

As reported for Atlantic stocks (e.g. Tully and Hillis 1995), density-dependence of mean individual size and possibly growth rate has also been found in the Mediterranean (Maynou and Sardà 1997, Mytilineou et al. 1998c): mean individual size is larger in shallow-water, low-density populations off the Ebro delta than in deep-water, high density nearby populations at *ca.* 400 m depth.

Nephrops is caught almost exclusively by trawl in the Mediterranean, but occasional catches also occur on set fishing gears (e.g. trammel nets, traps) in Italian and Greek waters.

Stocks are ill-defined in the Mediterranean but results from morphometric (Castro et al. 1998) and genetic (Maltagliati et al. 1998) studies do not show any geographic patterns which could help in stock definition. In the present contribution, the fishing areas defined by FAO will be used as proxy for stocks.

In the Mediterranean most of the catch is sold and consumed fresh as a high-quality, local product. It is a highly prized species, with prices ranging from 5-40 Euro/kg at first sale, depending on size, quality and country. The unit price can reach up to 80 Euro/kg prior to Christmas.

Life history and behaviour

A thorough review of life history, complementing the reviews by Figueiredo and Thomas (1967) and Farmer (1975), was made by Sardà (1995). He reviewed developments and conflicting issues on morphometry, reproduction, moulting, relative growth, behaviour, feeding and physiology, based on literature from 1967 to 1990. As pointed out by other authors, key aspects of the life history, such as the reproductive cycle, vary with latitude in this species (Fig. 1 in Sardà 1995). In the Mediterranean, spawning is annual, the spawning season is protracted and eggs hatch earlier, at the end of winter, than in the Atlantic.

Life history traits for several study areas are given in Table 1-1.4.

Growth

Relative growth

Geographic and interannual variability in the *a* and *b* parameters of the allometric function relating total weight to carapace length ($W=a*L^b$) exists, but the differences by sex are not so pronounced and in many cases not significant (Table 1). The values reported for Mediterranean stocks are within the range of those of Atlantic stocks.

Table 1. Size weight relationship for male and female Nephrops by region

	Males		Females		Source
Parameter	a (mg)	b	a (mg)	b	
CATALAN SEA	0.500	3.080	0.700	3.000	Sardà and Fernández (1981)
CATALAN SEA	0.275	3.120	0.240	3.260	Sardà and Lleonart (1993)
LIGURIAN SEA	0.320	3.219	0.330	3.215	Abella and Righini (1995)
TYRRHENIAN SEA	0.300	3.300	0.300	3.200	Biagi et al. (1999)
S ADRIATIC SEA	0.500	3.099	0.500	3.099	Marano et al. (1998)
N EUBOIKOS GULF	0.520	3.089	0.830	2.962	Mytilineou et al. (1990)
NW AEGEAN SEA	0.209	3.315	0.219	3.294	Papaconstantinou et al. (1993)
NW AEGEAN SEA	0.269	3.238	0.501	3.072	Papaconstantinou et al. (1993)
CHALKIDIKI 'S CULFS	0.353	3.138	0.523	3.054	Mytilineou et al. (1995)

Absolute growth

Absolute growth in different Mediterranean stocks has been extensively studied the using von Bertalanffy Growth Function (vBGF). Table 2 reports the results of Froglia and Gramitto (1988), Abella and Righini (1995), Mytilineou and Sardà (1995), Mytilineou et al. (1990, 1993a, 1995, 1998a) and Tursi et al. (1998). The parameters L_{inf}, K and t_0 of the vBGF vary strongly across stocks (Table 2), with no clear geographic pattern. They are also very different by sex, with males growing to larger sizes than females.

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Table 2. Parameters of the vBGF for male and female Nephrops by region.

	Males			Females			Source
Parameter	Linf	K	t_0	Linf	K	t_0	
ALGARVE	71.3	0.10	-2.45	62.4	0.14	-1.19	Mytilineou et al. (1998a)
ALBORAN SEA	78.4	0.17	-0.38	59.4	0.20	-0.92	Mytilineou et al. (1998a)
CATALAN SEA	72.9	0.14	-1.43	54.9	0.18	-1.36	Mytilineou et al. (1998a)
GULF OF LIONS	84.5	0.01	2.52	68.4	0.01	1.58	Campillo (1992)
LIGURIAN SEA	65.2	0.16	-0.96	54.5	0.22	0.03	Mytilineou et al. (1998a)
LIGURIAN SEA	72.1	0.17	0	57.7	0.21	0	Abella and Righini (1995)
TYRRHENIAN SEA	80.8	0.13	0.07	69.4	0.12	-0.64	Mytilineou et al. (1998a)
N ADRIATIC SEA	70.2	0.04	1.70	57.1	0.04	1.47	Froglia and Gramitto (1988)
C ADRIATIC SEA	53.3	0.03	-1.91	38.5	0.04	-0.27	Froglia and Gramitto (1988)
C ADRIATIC SEA	71.4	0.11	-1.18	68.0	0.14	-0.21	Mytilineou et al. (1998a)
IONIAN SEA	79.8	0.20	-0.64	58.8	0.25	-0.56	Tursi et al. (1998)
EUBOIKOS GULF	82.4	0.12	-0.01	75.8	0.12	-0.11	Mytilineou et al. (1998a)
W-N. AEGEAN SEA	86	0.06		69	0.09		Mytilineou et al. (1993a)
W-N. AEGEAN SEA	87	0.06		66.8	0.1		Mytilineou et al. (1993a)
CHALKIDIKI 'S GULF	82.6	0.11		65.5	0.13		Mytilineou et al. (1995)

Age

Sardà (1995) presented a table of length-age data for *Nephrops* based on composite modal analysis for various stocks. However, there is some discrepancy in assigning years to this species. Based on Length Frequency Analysis, some authors (Castro 1990, 1992, Mytilineou et al. 1995, Mytilineou and Sardà 1995, Mytilineou et al. 1998c) assigned a female age of 4-5 years to the mean size at sexual maturity of 32 mm CL while Orsi Relini et al. (1998) assigned this size to the 3-4 year old cohorts. The former authors consider each Gaussian component of the LF distribution as a year of life, while Orsi Relini et al. (1998) believe that juveniles have a composite size structure due to the long recruitment period in *Nephrops*. Bianchini et al. (1998) estimated an age of 4-5 years for females of 31 mm CL (corresponding to the L_{50} of sexual maturity) for a *Nephrops* stock off Sicily. From these findings, it seems that mean age at maturity is 4 years in most Mediterranean stocks.

Moulting

Moult increment and moult frequency were studied by Sardà (1985) in the Catalan Sea from wild and laboratory-reared specimens. He found that growth increment by moult decelerated from 9% in juveniles to 4% in adults, while the length of the intermoult period increased with size.

Sardà (1985, 1991) reported the moult and growth pattern of *Nephrops* in the Catalan Sea. He identified 3 main moult periods: a *fixed* period (December to April), and two *optional* periods (June-July and Sep-Oct). In the fixed period, adult and juveniles of both sexes moult. This period is coincident with the moulting period of North European stocks (Charuau 1974, Conan 1975). A second period in June-July comprises mainly the moult of juveniles, while the third period in autumn affects all males and juvenile females. The period with the lowest frequency of moulting females coincides with the periods of gonad maturity and brooding of eggs, while the frequency of moulting in females increases in winter and coincides with the egg-hatching period (Sardà 1991). This post-hatching moult also coincides with the mating period of February to April. Sardà (1995) noted that the pattern of moulting and reproduction is slightly advanced in the southern latitudes with respect to the North Atlantic (see also Sardà 1991, Orsi Relini et al. 1998). In the Mediterranean, the incubation period is shorter (*ca.* 4-6 months), and spawning and hatching start earlier than in the North Atlantic (Sardà 1995).

Gramitto (1998) identified the moult pattern of *Nephrops* in the Mediterranean through gastrolith examination. She concluded that juveniles undergo multiple moults year round, while mature males and females moult at least once a year. Adult females moult in winter in the Mediterranean (December-March) after egg hatching, while males moult in summer-autumn (August-December). In males, a second moulting period is sometimes apparent (Tyrrhenian and Alboran seas), coinciding with the winter moulting of females. This moult synchrony among adults is common to all Mediterranean populations. Very old individuals may skip the annual moult (Sardà 1985, 1991). The studies of Gramitto (1998) and Sardà (1991) were based on different methodologies and in different study areas, but the results coincide, yielding a pattern that can be assumed constant for the entire Mediterranean.

The frequency of moulting by size class is summarised in Table 3

Table 3. Number of annual moults in relation to premoult size in Nephrops ((from Sardà 1991, 1995)

Class size (mm CL)	Number of annual moults
10-19.9	3-4
20-23.9	3
24-26.9	2-3
27-29.9	2
30-39.9	1-2
>40	0-1

Natural mortality

Values of M for various stocks are reported in Table 4. Generally, the values reported for males are lower than the values reported for females, but there is a strong variation related to the method used for computing M.

Table 4. Natural mortality of male and female Nephrops by region

	Males	Females	Source
Parameter	M	M	
CATALAN SEA	0.200	0.200	Sardà and Lleonart (1993)
CATALAN SEA	0.398	0.416	Sardà and Lleonart (1993)
LIGURIAN SEA	0.650	0.820	Abella and Righini (1995)
LIGURIAN SEA	0.500	0.700	Abella and Righini (1998)
TYRRHENIAN SEA	0.250	0.250	Biagi et al. (1999)
NW AEGEAN SEA	0.281	0.390	Mytilineou et al. (1993a)
NE AEGEAN SEA	0.282	0.422	Mytilineou et al. (1993a)

Reproduction

Reproductive cycle

Mating takes place in spring. The mean length at first mating of females is 32 mm CL in the Ligurian Sea, corresponding to 3-4 year old females according to Orsi Relini et al. 1998. Spawning starts at the beginning of summer, with ovarian maturation from May to September (maxima: June-July, Table 5, Orsi Relini et al. 1998). The egg incubation period varies from 6 months in the Ligurian Sea (Orsi Relini et al. 1998) to 10 months in the North Euboikos Gulf (Mytilineou et al. 1990) and takes place between June and February (with maxima in September-November for most areas, Table 5). Egg hatching takes place in winter, not in spring as in North Europe. The period from egg-laying to egg-hatching takes 6-10 months (Orsi Relini et al. 1998).

Table 5. Fecundity, maturity and egg incubation period in Nephrops

	Size-fecundity linear model		Size-maturity model		L_{50} (mm CL) Maturity size	Egg incubation period	Source
Parameter	a	b	s1	s2			
ALGARVE	-3795.5	160.83	10.893	0.3626	30	July-Feb	1
ALBORAN SEA	-5851.4	204.2	32.8042	0.9109	36	Aug-Feb	1
CATALAN SEA	-2852.6	113.46	20.2081	0.6767	30	Aug-Jan	1
LIGURIAN SEA	-7519.9	258.07	23.3594	0.7269	32	Aug-Feb	1
TYRRHENIAN SEA	-3311.4	132.27	20.12	0.6362	32	Aug-Feb	1
C ADRIATIC SEA	-2862.5	120.79	24.889	0.8442	30	June-Jan	1
S ADRIATIC SEA					25		2
NW AEGEAN SEA					29		3
NE AEGEAN SEA					27		3
GULF OF CHALKIDIKI					34		4
NEUBOIKOS GULF	-1752.4	90.117	15.8838	0.4788	33	June-Feb	1

Maturity

The relative growth in males was analysed from the chelae length-weight relationship by Sardà and Fernández (1981) and Sardà (1995). Males attain sexual maturity at 20-25 mm CL depending on the geographic location.

Sizes at maturity in females are reported in Table 5, together with the parameters of the size at maturity logistic function, based on stages III-IV of gonadal maturity. The mean size at maturity (L_{50}) of females in the Mediterranean varies generally between 30 and 36 mm CL (mean of 31.6 mm) while in the Atlantic the average size at maturity is lower at 25.6 mm CL (Orsi Relini et al. 1998). However, the value of L_{50} reported by Marano et al. (1998) for a deep-water *Nephrops* stock in the south Adriatic is 25 mm CL, and for the western and eastern North Aegean are 28.5 and 26.5 mm CL (Mytilineou et al. 1993b), respectively. These are within the range of values reported for the Atlantic.

Reproduction in the Mediterranean can be considered annual (Orsi Relini et al. 1998), except perhaps in the Catalan Sea, where Sardà (1985, 1991) reported that only 80-90% of mature females carry eggs, suggesting that spawning could be biennial for some females that did not synchronize the moult and gonadal maturity cycle.

Fecundity

The number of eggs carried increases with size (Orsi Relini et al. 1998, Mori et al. 1998, 2001, Abelló and Sardà 1982) (Table 5). The fecundity of the Mediterranean populations analysed showed great variability and no clear geographic trend. Lower fecundity values were associated with stocks which were subjected to high fishing mortality.

Habitat use and requirements by juveniles and adults

Sex ratio

In the Mediterranean juveniles are not captured effectively in the fishery probably due to low out-of-burrow activity (Gramitto 1998). Juveniles probably feed within their burrow (Gramitto 1998, Chapman 1980).

Females do not exit their burrow while berried (they can abstain from feeding for long periods, Farmer 1975). This behaviour affects the sex ratio of the catches. The sex ratio is equal between the periods of egg-hatching and egg-laying only. Males are more frequent in the catch in winter and spring (Sardà 1991).

Activity

In the western Mediterranean the activity of *Nephrops* was investigated with trawl gear in shallow (100 m) and deep (400 m) areas by Aguzzi (2002). Assuming that times of peak activity correspond to times of highest catch rate, this author found that in shallow waters *Nephrops* was active mainly at dawn and dusk, as in many Atlantic stocks (Farmer 1975). On the other hand, the activity of the deep *Nephrops* populations was centred at noon. These peaks also varied seasonally as a function of photoperiod (Aguzzi 2002).

Aguzzi (2002) also measured the heart rate, daily variations in glucose levels and oxygen consumption, and mobility patterns in animals kept in the laboratory and confirmed that the activity rhythms are endogenous (Chapman 1980).

Food and feeding

Nephrops forages for its food at certain times of the day. These periods of activity form a regular pattern, probably synchronised to changes in light intensity reaching the seabed (Farmer 1975). *Nephrops* may be an opportunistic feeder, taking available prey items from the sea floor near the burrow entrance. Bozzano and Sardà (2002) using submarine photography found that *Nephrops* feed in the vicinity of their burrows and their diet may consists of food falls or fishery discards, as observed by means of an underwater camera. Cristo and Cartes (1998) and Cristo (1998) made a comparative study of the feeding ecology of *Nephrops* in the Mediterranean (Alboran, Catalan, Ligurian, Tyrrhenian and Adriatic seas and Euboikos gulf) and the adjacent Algarve coast of Portugal. In accordance with previous studies in the Mediterranean and Atlantic, they found that *Nephrops* is a generalist feeder which actively captures prey or scavenges. Most of the prey items found in *Nephrops* stomachs were decapod crustaceans, euphausiids, peracarids and fish remains. No seasonal or geographic differences were reported.

Sardà and Valladares (1989) calculated the digestion rate in *Nephrops* experimentally reared in the laboratory and found that this species fully evacuated its stomach within 12 h and that long starvation periods induced cannibalism. Maynou and Cartes (1997), based on data in Sardà and Valladares (1989), calculated that the gastric evacuation rate for *Nephrops* is 0.179 h^{-1} at 13ºC, using an exponential evacuation model.

Recent studies showed that a high percentage of Nephrops in the Catalan Sea had empty stomachs (Aguzzi 2002). More than 50% of stomachs for both males and females in different seasons were empty. However, Cristo and Cartes (1998) reported a lower incidence of empty stomachs in other areas of the Mediterranean, with high seasonal variability. The percentage of empty stomachs was very high in the Catalan Sea and in the Euboikos Gulf in summer (*ca.* 50% both for males and females, Cristo and Cartes 1998). The variations in stomach fullness have been related to the peak of gonad maturity (Cristo and Cartes 1998) or to the period of egg bearing (Mytilineou et al. 1992). Evidence is inconclusive, however, as the percentage of empty stomachs is consistently high for both males and females.

Major predators

Farmer (1975, based on Gauss-Garady 1912, 1913) reported that *Lophius* spp., various sharks and rays, *Trigla* spp., *Scorpaena* spp. and *Merluccius merluccius* are major predators of *Nephrops* in the Adriatic Sea. Planas and Vives (1952) found that the poor cod (*Trisopterus minutus capelanus*) is a major predator of *Nephrops* on the Ebro delta continental shelf on the east coast of Spain. However, Macpherson (1977) studied the diet of more than 20 fish species of the Catalan Sea and did not find *Nephrops* remains in the stomachs anlaysed. Sartor (1993) studied the stomach contents of 14 demersal fish species in the Northern Tyrrhenian Sea and found *Nephrops* only occasionally. Quetglas et al. (1999) found *Nephrops* in stomach contents of the European flying squid (*Todarodes sagittatus*), although with very low incidence, off the Balearic islands.

On the other hand, there exist competitors for suitable burrowing substrate, such as other burrowing decapods (*Calocaris macandreae, Jaxea nocturna*, *Alpheus glaber*, *Callianassa subterranea*, *Goneplax rhomboides,* Farmer 1975) or fishes (some species of Gobiidae and Ophichthyidae, pers. obs.).

Relationship between stock and recruitment

Recruitment is annual since there is only one brood per year per female (Farmer 1975). Recruitment to the fishery occurs at 20 mm CL (2-3 years old, Farmer 1975). In the Mediterranean, the smallest sizes present in the catch are also 20 mm CL, except in the Ionian Sea, the Aegean Sea and the Euboikos Gulf where smaller individuals are routinely caught, probably related to the smaller mesh sizes employed (28-32 mm stretched mesh; Mytilineou et al. 1993a, 1993b, 1995, 1998c, Relini et al. 1999).

Larval ecology and larval settlement

Larvae occur between January and March in the Mediterranean (Lo Bianco 1909, Stephensen 1923, Santucci 1926, Karlovać 1953). The larval development period has been reported at 34 days in the Mediterranean (Sardà 1995), shorter than the *ca.* 50 days in the North Atlantic (Hill 1990).

The fishery

<u>Stocks: location and geographical extent</u>

A biometric analysis of 27 morphometric variables was performed on 6 stocks (one Atlantic: south of Portugal and 5 Mediterranean) by Castro et al. (1998). They concluded that the three western and central Mediterranean stocks (Catalan, Ligurian and Tyrrhenian Seas) showed the greatest overall level of similarity, while the two stocks at the geographical extremes of the study area, Algarve and Euboikos Gulf, were the most different.

The genetic structure of *Nephrops* stocks in the Mediterranean Sea was analysed by Maltagliati et al. (1998). They studied 15 enzyme systems for one Atlantic stock (Algarve) and eight Mediterranean stocks. This study showed only moderate genetic differentiation between geographic regions and no clear pattern of geographic stock structure. They further postulated that larval drift (assuming a planktonic lifetime of *ca.* 50 days as in the Atlantic, Hill 1990) is sufficient to offset genetic divergence in Mediterranean *Nephrops* stocks (Maltagliati et al. 1998). A study by Passamonti et al. (1997) characterising the genetic structure of Scottish and Aegean stocks of *Nephrops* based on allozyme analysis failed to reveal significant differences in those stocks.

The results of the biometric and genetic studies were not indicative of any clear geographical patterning of the populations studied, and stock identification cannot be based on morphometric or genetics at the present level of knowledge.

Although morphological and life-history variability between nearby populations may be significant it probably arises from phenotypic adaptations to local environmental conditions and fishing pressure rather than from genetic differences among populations.

Economic importance and overall volume of catches

Data series on economic yield of *Nephrops* stocks are generally available. It is known that the price is related to size (with larger sizes fetching higher prices) and inversely related to catch (or availability) because markets are local (Table 6).

Table 6. Unit economic value of Nephrops by region

Min €/kg	Max €/kg	Area	Source
18	27	Balearic islands	Merella et al. (1998)
12	31	Catalan Sea	Unpub. Data
14	35	Italy	Unpub. Data
4.5	16	Greece	Unpub. Data

In particular seasons (e.g. Christmas) large *Nephrops* (>45 mm CL) can reach up to €80 /kg.

Nephrops represents a small fraction of the total demersal landings in each country (FishStat 2000), from around 1-2% of demersal catches in Mediterranean Spain and Greece to around 10% in the Adriatic (Italy and Croatia). Its importance in economic terms is higher due to its high unit value. In Greece Nephrops represents 40% of the total mean annual economic yield of the crustacean official landings and 2.8% of the total official landings (Mytilineou et al. 2002).

Fishing methods

Nephrops is mainly caught by trawling in the Mediterranean, although set gears (traps and trammel nets) used by artisanal fishermen in the N. Aegean and the Adriatic Sea catch *Nephrops* in areas where trawling is prohibited. Around 7% of *Nephrops* production between 1990-1998 was obtained from nets in Greece (Mytilineou et al. 2002).

The trawl fleet targeting Norway lobster in the Mediterranean is composed of small to medium vessels (33-56 mean GRT for all areas studied in Sardà 1998b), but their engine power can be relatively large (as much as 1000 HP, clearly above the 500 HP legal limit for Mediterranean trawlers). This large engine power is used in reducing transit time from the port to the fishing grounds, and to ensure efficient use of large trawls. Additionally new technological improvements are continually being implemented, such as GPS navigation, acoustic gear-control devices, etc. The profile of the *Nephrops* fishing fleets by area can be seen in Table 7. Under the European Common Fisheries Policy, all trawls use a codend of 40 mm stretched mesh, except in Greece, where this policy has not yet been implemented and the mesh size is still 28 mm stretched.

The technical characteristics of the trawlers and the trawls can be found in Sardà (1998b). He reported the existence of three main types of trawls: a western (Portugal and Spain), a central (Italy) and an eastern (Greece) type. These three types of trawl differ mainly in overall proportions (length and mouth openings) and the size of otter doors. The Italian trawl is the smallest one and perhaps better adapted to the *Nephrops* fishery. In general, all these gear types have in common a small vertical aperture and the presence of chains between the wings, advanced with respect to the mouth opening and rolling over the sea floor. Hence, the impact of this fishing gear on the sea floor is significant.

Summary of fishing areas by country

South Portugal: The trawl fleet operating in south Portugal (Alentejo and Algarve) mainly targets a mixed decapod crustacean fishery at 200-600 m depth. The major fishing grounds are located in the SW and S Algarve coast (Sardà 1998a). *Parapenaeus longirostris* is caught at 200-300 m depth, while *Nephrops* is caught around 400 m depth and *Aristeus antennatus* in deeper waters. Thirty one licenses for crustacean trawling were issued in 1998 in this area. Twenty four of these vessels work exclusively on decapods.

Table 7. Profile of the fishing fleet by region

	ALGARVE	ALBORAN SEA	CATALAN SEA	W LIGURIAN SEA	N TYRRHENIAN SEA	C ADRIATIC SEA	IONIAN SEA (Greece)	AEGEAN SEA	N EUBOIKOS GULF
Number of vessels			280	5-12	15	120	35	290	23
Days of fishing trip				1	1-3	1	1-2	2-3	1
Number of hauls/day			2.5	2.5	2.5	6.5	1-3	1-3	2-6
average trawling hours/day	18	12	8	9	11	16	17.5	17.5	10
Number days/year									111
Average HP	280	250	500	290	470	300	360*	400*	360*
Average GRT	50	43	52	33	56	41	54	65	50
Average length			24				22	24	22
Average crew			5				4-5	4-5	4-5
gear used	trawl	trawl	trawl	trawl	trawl	trawl	trawl	trawl	trawl+nets
Multispecies fishery	yes	yes	yes	yes	yes	yes	yes	yes	yes
Targeted or by-catch	targeted	targeted	targeted	targeted	targeted	targeted	targeted	targeted	targeted
Other species			hake, monkfish, blue whiting, megrim		hake, blue whiting, greater fork-beard				hake, blue whiting, shortfin squid, monkfish
Technical fishing aids	GPS, Sounders, plotter	GPS, Sounders, plotter	GPS, Sounders, plotter	GPS, Sounder	GPS, Sounders, plotter	GPS, Sounders, plotter			GPS, Echosounder
Source:	Sardà (1998b)	Sardà (1998b)	Sardà (1998b)	Sardà (1998b)	Sardà (1998b)	Sardà (1998b)	Mytilineou (unpub. data)	Mytilineou (unpub. data)	Sardà (1998b), (Mytilineou unpub. data)

*registered, in reality it is around 500 Hp

Mediterranean Spain: Fisheries for *Nephrops* are mainly found in the Alboran and Catalan seas. Catches are around 200-300 mt annually. The catch in other Spanish Mediterranean areas is much less significant (Gil de Sola 1993).

Alboran Sea: The fisheries in this area were described by Gil de Sola (1993). *Nephrops* is caught in well-defined fishing grounds mainly between 200 and 270 m depth (although its depth distribution extends beyond 500 m in this area). Commercial yields are around 30 kg/day per boat.

Catalan Sea: The fishing grounds are located on the continental slope (between 200 and 500 m depth), with a peak catch at around 400 m. The yield in this area varies from 10-40 kg/day per boat. Additionally, *Nephrops* is caught in shelf depths (around 100 m depth) off the Ebro delta, at low densities.

Italy: In the west and south coasts of Italy *Nephrops* is abundant on bathyal fishing grounds from 200 to 700 m (Relini et al. 1999). It is caught in the eastern Ligurian Sea and northern Tyrrhenian, the south coast of Sardinia and the south coast of Sicily. In the northern Tyrrhenian Sea, on fishing grounds from 300-450 m depth, *Nephrops* is the most important target species all year round (Sartor et al. submitted). It is also present, though at lower densities, in the Ionian Sea and Gulf of Taranto.

Adriatic Sea: *Nephrops* is very abundant on shallow fishing grounds (10-50 m, Relini et al. 1999) in the northern and central Adriatic.

Greece: *Nephrops* is very abundant in the northern and central Aegean Sea from 200 to 500 m depth, with abundances of 9-10 kg/km^2 (data from MEDITS trawl surveys, Anon. 2000). Abundances in the Ionian Sea are between 2-9 kg/km^2.

Catchability

Diel changes in abundance.

The diel variation in catchability of *Nephrops* follows the rhythms of activity of this species (Farmer 1975). It is well known that *Nephrops* in shallow waters have peak emergence rates at sunrise and sunset (e.g. in the Adriatic Sea, Froglia 1972). However, in deep waters (400 m depth) the maximum catchability is around noon (Aguzzi 2002), confirming the hypothesis of Chapman et al. 1972, whereby a specific range of light intensities triggers activity in *Nephrops,* thus increasing availability to the fishing gear.

Seasonal changes in abundance

Nephrops catches are usually higher in late spring and summer for all stocks, when both males and females are available to the fishing gear (Sardà 1991). In autumn and winter, berried females remain in their burrows and are uncommon in catches. Consequently, the sex ratio changes seasonally in the catches from around 1:1 in late spring and summer to 4:1 in favour of males in autumn and winter (Farmer 1975, Sardà 1991, Mytilineou et al. 1993b, Aguzzi 2002).

In addition to the well-known seasonal patterns described above, Maynou and Sardà (2001) documented short-term spatio-temporal changes in catchability of Catalan *Nephrops* stocks. From the analysis of specifically designed log-books, these authors were able to recover a *ca.* 2-year daily series of catches and observations on environmental variables. The analysis of the data showed that atmospheric pressure, cloud cover, and sea state affected catch rates of commercial vessels. These changes took place over short time periods (a few days to a week) and were mediated by atmospheric conditions indirectly determining the light intensity reaching the sea floor.

Interannual changes in abundance

Table 8 shows the evolution of official landings of Mediterranean *Nephrops* stocks from 1970 to 1999. Notwithstanding probable increases in effort (poorly documented in the Mediterranean) it is apparent that the Ionian and the Adriatic stocks show large interannual fluctuation of catches. Furthermore, the two stocks seem to fluctuate synchronously, with peaks in 1977 and the early 1990s. Both stocks seem to be declining in the late 1990s. The Aegean stock seems to follow the same pattern although the fluctuations are smaller. The Balearic and Sardinia stocks show less interannual variability. The peak catches observed in the late 1980s for these two stocks coincides with the onset of the fishery in the Gulf of Lions.

Table 8. Landings (tons) of Nephrops norvegicus by region (in parentheses the main country(ies) contributing to the total catch). Source: FishStat (2000).

Year	Adriatic (Italy and Croatia)	Aegean (Greece)	Balearic (Spain and Algeria)	Gulf of Lions (Spain)	Ionian (Italy)	Sardinia (Italy)
1970	1142	475	348	0	147	504
1971	1175	496	436	0	239	528
1972	1267	534	526	0	243	640
1973	987	733	567	0	634	418
1974	976	651	525	0	986	449
1975	984	546	274	4	1100	434
1976	1247	575	825	0	1414	472
1977	1805	700	684	1	1767	432
1978	1250	879	579	0	1673	348
1979	972	729	552	1	1087	437
1980	814	692	517	1	750	441
1981	943	725	431	0	1023	357
1982	1113	656	470	0	1176	504
1983	959	720	514	0	1348	504
1984	1027	833	469	0	1447	660
1985	1909	813	642	0	1692	967
1986	1986	1.021	758	0	2314	1160
1987	1675	1.102	868	130	2188	1052
1988	2138	1.264	804	110	2685	839
1989	1767	1.173	593	90	2450	507
1990	1600	1.595	613	60	3314	432
1991	2024	934	602	45	3604	480
1992	2531	707	621	30	3152	648
1993	2493	796	620	25	2309	669
1994	2366	1.066	631	20	2846	749
1995	1811	1.075	594	20	2426	643
1996	2104	480	556	18	2764	736
1997	1964	313	490	11	2227	1160
1998	1341	435	605	12	1331	431
1999	951	241	533	12	1996	335

Selectivity

Studies on selectivity were conducted by Sardà et al. (1993), Stergiou et al. (1997) and Mytilineou et al. (1998b) for several Mediterranean stocks. These studies report that increases in mesh size from the current 40 mm (stretched mesh) to 50 or 55 mm would result in a size at 50% capture (L_{50}) of 31-32 mm CL. This size corresponds approximately to the L_{50} size of maturity in females and would allow a large proportion of recruits to escape. However, this measure would be unacceptable to fishermen, because in a multi-species fishery the yield of other species would also diminish. Politou et al. (1997) found that mesh sizes of 48 and 52 mm were more selective than a 40-mm mesh for *Micromesistius poutassou*, *Trisopterus minutus*, and *Lepidorhombus boscii* but they did not affect *Merluccius merluccius* and *Eutrigla gurnardus*. As discussed below, management measures other than selectivity seem more appropriate for *Nephrops* considering the current state of exploitation, because mesh size changes are not very effective for this species.

Impact of fishing gear on the habitat and recruitment

Specific studies on the impact of trawling on *Nephrops* habitat and recruitment are lacking in the Mediterranean. However, considering the close association of *Nephrops* populations to specific sea bottoms, it is reasonable to assume that heavy trawls may damage or degrade their habitat. A recent study by Sartor et al. (unpublished) on the *Nephrops* fishery of the Northern Tyrrhenian Sea showed that the majority of the biomass captured was by-catch characterised by a high species richness, due to poor selectivity of the bottom trawl gear. An important fraction of the by-catch was composed of commercial species, which were retained and provided an important added value to the landings. Annual average discards represented 20% of the total catch. No *Nephrops* were discarded. Discarding of commercial species was mostly due small size. Large numbers of non-commercial small fish and crustaceans were also discarded. The results seem to indicate that this kind of fishery achieves a fairly good compromise between efficiency of resource utilisation and impact on the demersal communities. However, Mytilineou et al. (1998c) found that discards amount to 40% of the total catch of trawl hauls on *Nephrops* fishing grounds in Greek waters.

Monitoring the fishery

Landings and effort

Reliable and long term data series on landings and effort are generally difficult to obtain for Mediterranean fisheries. The official statistics are often not accurate in the European Mediterranean and are very inaccurate in north African countries. *Nephrops* fisheries in the Mediterranean follow the general patterns of other fisheries in this area, i.e. they are multi-species, small-scale fisheries. *Nephrops* is a target species of mid to large otter trawlers, together with hake, monkfish and megrim. *Nephrops* is also caught by set gear (traps and trammel nets) in the Ionian and Aegean seas. It is mostly fished in deep waters (200-500 m), although fishing in shallow waters does occur on the continental shelves of the Ebro delta, Adriatic Sea and particular areas of the Aegean Sea. Personal observations indicate that a significant fraction of the *Nephrops* catch may be sold outside the official markets, at least in the Spanish Mediterranean and Greece. Sardà (1998a) reported that the official statistics of *Nephrops* landings are not generally reliable in the Mediterranean, with differences between official records and actual landings ranging between 10 and 50%. In Greece, the percentage of landings passing through the official markets increased in recent years, from 35 to 70% (Mytilineou et al. 2002). Smaller individuals are often sold in mixed-species consignments (Sardà 1993). The effort of the *Nephrops* fishery is also difficult to estimate due to the multi-species character of Mediterranean fisheries (Sardà 1993).

Italy, Greece and Spain have the highest landings in the Mediterranean at 3033, 243 and 448 mt respectively in 1999. Croatia with 245 mt is the only non-EU Mediterranean country with significant landings.

Since 1970 catches have increased markedly in the Ionian, and Adriatic and remained fairly constant in the Aegean Sea, Sardinia and Balearic regions. After a period of high catches in the late 1980’s and early 1990s, the current trend shows a decrease in catches in all stocks. Interestingly, trawl surveys conducted in the south Adriatic from 1985 to 1995 (Marano et al. 1998) showed increasing values of the abundance index from 1990 to 1995, closely matching the trend in landings observed in the Adriatic Sea.

Catch per Unit Effort

Figures on catch per unit effort from commercial fisheries are also difficult to obtain. Maynou and Sardà (2001) report 4-10 kgh^{-1} for commercial vessels working on the Catalan continental slope at 300-500 m depth and 0.5-1.0 kgh^{-1} for shelf stocks at 100 m depth. For shallow water north and central Adriatic stocks Piccinetti and Piccinetti-Manfrin (1994) report catches per unit effort of 0.5-1 kgh^{-1}. In Greek waters (200-500 m depth) the reported catch per unit effort ranges betweeen 3.5 and 14 kgh^{-1} in the North Aegean Sea (Papaconstantinou et al. 1993), 1 and 5 kgh^{-1} in the Gulfs of Chalkidiki (Papaconstantinou et al. 1994), 0.3-0.6 kgh^{-1} in the South Aegean Sea (Papaconstantinou et al. 1998). These yields are typically lower than for Atlantic stocks.

Abundance indices from trawl surveys in different regions is given in Table 9

Table 9. Abundance indices of Nephrops (kg/km^2) from experimental trawl surveys by region

Region	Shallow (10-200 m depth)	Deep (200-800 m depth)	Source
Ligurian and Central Tyrrhenian	0.85	8.10	Relini et al. [eds.] (1999)
Sardinia	0.00	9.70	Relini et al. [eds.] (1999)
South Tyrrhenian and Sicilian straits	0.02	4.07	Relini et al. [eds.] (1999)
Ionian Sea and South Adriatic	0.90	2.09	Relini et al. [eds.] (1999)
North and Central Adriatic	4.90	9.09	Relini et al. [eds.] (1999)
Catalan Sea off Barcelona: June 1991	0.00	14.70	Maynou et al. (1998)
Catalan Sea off Barcelona: Nov 1991	0.00	9.60	Maynou et al. (1998)
Catalan Sea off Tarragona: Apr 1994	2.90	9.10	Maynou and Sardà (1997)
North Aegean	0.51	9.38	Anon 2000
South Aegean	0	2.96	Anon 2000
Argo-Saronikos Gulf	0.67	3.29	Anon 2000
Central Ionian	0	1.79	Anon 2000

Discards

Generally there is no discarding of *Nephrops* in the Mediterranean. Even undersize or slightly damaged individuals are sold often in mixed consignments with other species.

Assessment of the impact of fishing on the population

Assessments of *Nephrops* stocks in the Mediterranean are still uncommon. Some studies include Froglia (1972), Sardà and Lleonart (1993), Abella and Righini (1995, 1998), Sardà et al. (1998) and Biagi et al. (1999).

Sardà and Lleonart (1993) analysed a *Nephrops* stock in the Catalan Sea by means of LCA and Y/R and concluded that it is not heavily overexploited and is stabilised near its equilibrium level. They also found that the stock is very sensitive to recruitment overfishing.

Sardà et al. (1998) assessed several stocks in the Mediterranean by means of LCA and Y/R analysis. They reported the current status of exploitation for several study areas and concluded that the Catalan, Adriatic and Tyrrhenian stocks are fully to slightly overexploited, while the Ligurian and the North Euboikos Gulf stocks are moderately exploited and the Alboran and Algarve stocks are lightly exploited.

Levels of fishing mortality from Abella and Righini (1998), Sardà et al. (1998) and Biagi et al. (1999) are presented in Table 10.

Table 10. Fishing mortality by region for male and female Nephrops.

Area	**F ($year^{-1}$): males, females**

Algarve	0.45, 0.5
Alboran Sea	0.30, 0.5
Catalan Sea	0.70, 1.0
W Ligurian Sea	0.40, 0.33
E Ligurian Sea	0.42, 0.21
N Tyrrhenian Sea	0.50, 0.45
Adriatic Sea	0.42, 0.80
Euboikos gulf	0.30, 0.50

It appears that females undergo heavier fishing mortality in all stocks, except for the Ligurian Sea and Northern Tyrrhenian Sea.

Sardà et al. (1998) also concluded that Mediterranean *Nephrops* fisheries are inefficient and a decrease in current effort levels or improved selectivity would result in future higher yields.

Sardà (1998c) reported that mean CL in the catches declined over time. This was later confirmed to be a general pattern for all Mediterranean stocks and gives an indication of the state of overexploitation of the stocks (Sardà 1998c).

Management of the fishery

Nephrops fisheries are not specifically managed as such in the Mediterranean. All trawl fisheries are managed according to technical measures and effort control regulations, which are not reviewed regularly. For *Nephrops* there is a specific minimum landing size of 20 mm CL (or 70 mm TL, EU regulation 1626/1994, 27 June 1994). Additionally, all trawl fisheries require a minimum mesh size of 40 mm stretched mesh and new trawlers are limited to 500 HP engines (EU regulation 1626/1994, 27 June 1994). At the level of local management, there are some restrictions on fishing time, e.g. existence of seasonal closures in Italy and Greece or limitation to 12 working hours a day in many ports of Catalonia. Note that these measures are applicable to all trawl fisheries of a given area. Measures in force are presented in Table 11. Additional information on the management of Mediterranean fisheries can be found in Farrugio et al. (1993) and Caddy (1993).

Table 11. Management measures applicable to Nephrops in the Mediterranean

	SPAIN	ITALY	GREECE
Minimum landing size	20 mm CL (70 mm TL)		
Sex restrictions	no		
Mesh regulation in trawls	40 mm stretched mesh		28mm stretched mesh
Trawl Exclusion Devices	no		
Engine power of new boats	500 HP		
Quota	no		
Seasonal closures	varies from year to year	varies for Maritime Districts	trawl prohibited from June to Sept in Greece, from April to Oct in specific areas

No take zones	no		areas prohibited to trawling or any fishing gear
Gear limitations	maintenance of the total GRT and HP of the trawl fishery. Prohibition of traps for Greece		
Management structures	Centralised-local	Centralised-local	Centralised

Conclusions

Except for the larval stages the biology and ecology of *Nephrops* is well known in the Mediterranean. The growth parameters show geographical variability (Mytilineou et al. 1998a), as in the Atlantic. The causes of growth variability are environmental factors such as substrate, temperature, food availability, etc., the exploitation sustained by each population (absence of older age groups), and biological factors (density, behaviour, moulting, etc.) (Mytilineou et al. 1998a).

The sizes at female maturity is generally larger in the Mediterranean stocks than in the Atlantic (30-36 mm CL in the stocks studied by Orsi Relini et al. (1998), and 23-31 mm CL in ICES areas). There is strong geographic variability, indicating that local factors together with the exploitation status of each stock may be of importance in determining the actual L_{50} (Orsi Relini et al. 1998).

Stocks are ill-defined at present and evidence from morphometric (Castro et al. 1998) and genetic studies (Maltagliati et al. 1998) do not point to clear geographic patterns. *Nephrops* populations are perhaps best viewed as a set of metapopulations that respond individually to environmental factors and fisheries pressure, but studies in this area are still lacking.

Official statistics on catch (landings) are not entirely reliable, but can be used as a qualitative tool to study trends in the *Nephrops* fishery. In the 1990s a general trend of decreasing landings was observed in all major stocks. Effort data are mostly lacking in the Mediterranean and only general considerations encompassing the entire trawl fleet can be made. In fact, these are issues concerning Mediterranean fisheries in general (Farrugio et al. 1993, Caddy 1993).

The assessments conducted on local populations showed that the state of exploitation varies across areas, from slightly underexploited populations to fully exploited populations (Sardà et al. 1998). The biology of *Nephrops* probably explains the resistance of this species to overexploitation, due to its burrowing behaviour, wide trophic spectrum and low incidence of juveniles in the catch. However, *Nephrops* is a sensitive species to trawl disturbance and management protection measures should work to minimize the impact of trawl gear on the bottom (Sardà 1993).

In order to improve the assessment and management of *Nephrops* fisheries in the Mediterranean, efforts should be directed at closing the life-cycle of this species (i.e., specific studies on larvae and larval distribution), improving the data collection systems (catch and effort) and implementing effective management measures of at effort reduction.

The biology and fisheries of *Nephrops norvegicus* in the Atlantic area

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Biological characteristics

Growth, maturity and length weight parameter estimates are presented in Table 1.

Fisheries

Otter trawls are the principal gear used to take *Nephrops* throughout its range (Table 2). Single rig trawls are most often used, but increasing proportions are taken by multi-rig (mostly twin) trawls, particularly in the Irish Sea and northern North Sea. Diamond meshes are used in most areas, but often combined with a square-mesh panel to promote escapement of young fish. Square meshes are considered to have improved selective properties for both fish and *Nephrops*, and there has been some use of these nets by Swedish vessels fishing in the Skagerrak and Kattegat. The extent to which *Nephrops* is the target species depends on the mesh sizes used and the area fished. Larger mesh trawls (≥100 mm mesh cod-end) are usually regarded as whitefish-directed, taking *Nephrops* as a by-catch, whereas a typical *Nephrops* trawl uses a 70-80 mm mesh cod-end. However, it is difficult to come up with definite rules for identifying *Nephrops*-directed fishing effort, as most relevant fisheries are to a greater or lesser extent mixed. Gadoid species, particularly cod, haddock and whiting, are the principal fish taken alongside *Nephrops* in the North Sea, west of Scotland and adjacent waters, and saithe, monkfish and some flatfish species are also important in some areas. Hake assumes a greater importance in westerly and southerly waters. Some Iberian stocks are exploited by fisheries directed primarily at hake and/or blue whiting, with *Nephrops* taken as a very small (~1% by weight) but valuable by-catch.

Creel (baited trap) fisheries directed at *Nephrops* exist in several areas. All landings from Faeroe Islands waters are now taken by creels. Almost 20% of Swedish *Nephrops* landings from the Skagerrak are taken in creels, and there is also a small Swedish creel fishery in the Kattegat. Historically there has been some trap fishing of *Nephrops* by Portugal, but these have been insignificant in recent years. Limited creel landings are taken from various areas around the British Isles, but this method of fishing is only really significant in the sheltered sea lochs of the west of Scotland. Around 10% of the total landings from the North and South Minch stock areas are taken by creels, and smaller quantities are taken in the Clyde Sea area. Creel fisheries take larger, higher value *Nephrops*, usually exported whole. A noteworthy feature of creel catches is that they include much larger proportions of ovigerous females than trawl catches, and thus have more potential to deplete spawning stocks than might be assumed from their contribution to overall landings.

The large UK markets for *Nephrops* are largely for tails, processed into ‘scampi’ (breaded tails). The other European markets are mostly for whole *Nephrops*, with a larger unit value. Discarding practices relate to these markets. According to official statistics, there is generally good compliance with the minimum legal sizes (MLS), although there may be some ‘black’ landings of small *Nephrops* in some areas. French vessels fishing in the Celtic Sea observe a minimum size of 35 mm CL which is much larger than the MLS of 25 mm specified by the EU. This is driven by the market for whole individuals, recognising that small *Nephrops* do not preserve well on ice during long fishing trips. Most discarding takes place at sea, and it is generally assumed that there is 25% survival of these discards (based on Guégen & Chareau, 1975). In some areas such as the north-east of England, discarding takes place in port, thus zero survival of discards is assumed. Very high levels of discarding are seen in the Skagerrak and Kattegat, driven by the large MLS of 40 mm CL. In contrast, there is effectively no discarding of *Nephrops* in the Iberian fisheries.

The UK, principally Scotland, accounts for more than half of all *Nephrops* landings outside the Mediterranean (Table 3), and it is now the most valuable fished species for this country. Much of these landings are taken from effectively national fisheries around the coast of Scotland and England and offshore in the northern North Sea, but the western Irish Sea is also of major importance, shared between UK (Northern Ireland) and Republic of Ireland fleets. France and the Republic of Ireland each take around 13% of the international *Nephrops* landings outside the Mediterranean. These include landings from some truly international fisheries in the Irish and Celtic Seas, but a major proportion of French landings are taken from the effectively national fishery in the Bay of Biscay. Danish fisheries are also significant, and have increased in recent years in offshore areas of the northern and central southern North Sea. Over the longer-term, Denmark has shared fisheries in the Skagerrak and Kattegat with Sweden. Spanish fleets are among the most wide-ranging, and contribute to *Nephrops* landings from the west of Ireland, around the Iberian peninsula and Morocco. Spanish landings from the last of these countries are variable but occasionally very significant. FAO statistics show 1,100 t of *Nephrops* taken by Spain from north African waters in the Atlantic in 1999, but only 3 t from this area in 2001.

Nephrops landings are taken from many separately identifiable stock areas. Table 4 lists 39 separate areas, and it is likely that a number of these areas comprise more than one stock units. The greatest landings taken from any single area are from the western Irish Sea, but in recent years this fishery is being overtaken by expanding offshore fisheries in the northern North Sea. The major Fladen Ground fishery has developed since the mid-1980s, and, although current landings are probably underestimated, there appear to be opportunities for further expansion, particularly in the relatively lightly exploited northern parts of the stock area. The Norwegian Deeps fishery, an extensive area to the west of Norway, is showing similar increases and scope for expansion. Further south, the Off Horn Reef stock in the southern North Sea has experienced greatly increased fishing activity since the early 1990s, principally from Danish vessels. Many fisheries, particularly those around the Scottish coast, have been relatively stable over the last 20-30 years. The biggest declines have been seen in the southern areas, particularly around the Iberian peninsula. A lesser decline has been seen in the large French Bay of Biscay fishery.

In many areas, *Nephrops* fisheries operate throughout the year, but there is much variation in seasonal patterns between areas and even between years. The Farn Deeps fishery off the north-east coast of England has traditionally been a mainly winter (October-March) fishery, with vessels switching to cod fishing during the summer. By contrast, the Irish Sea fisheries tend to concentrate on the summer months, and consequently take larger proportions of females in the catch owing to their greater availability at this time.

Landings and catch per unit effort (LPUE and CPUE) are very variable between fisheries (Table 2). This is probably due more to differences in gear, discarding practices, vessel power and seasonality of fishing than to major differences in *Nephrops* abundance. In the Bay of Biscay, improvements in gear efficiency and the ability to locate fishing grounds have led to stable or increasing LPUE whilst the stock has declined. Differences in units of measurement make some comparisons between areas difficult to make, but even taking this into account it is apparent that catch rates are very low for the Iberian stocks. This does appear to be a result of low *Nephrops* abundance, although it should be borne in mind that *Nephrops* is a by-catch in most of these fisheries.

Table 1. Biological characteristics of Nephrops norvegicus by stock. Growth parameters are for a von Bertalanffy growth function. Length is carapace length in mm. Weight is in g.

Stock	**Males and Immature Females**			**Female size at first maturity**	**Mature Females**			**Length-weight Parameters W = *a* CL ^{b}**			
	Growth parameters		***M***		**Growth parameters**		***M***				
	K	***L_∞***			***K***	***L_∞***		***a***	***b***	***a***	***b***
Moray Firth	0.165	62	0.3	25	0.060	56	0.2	0.00028	3.240	0.00074	2.910
Fladen Ground	0.160	66	0.3	25	0.100	56	0.2	0.00030	3.25	0.00074	2.910
Skagerrak and Kattegat	0.140	73	0.3	28	0.100	65	0.2	0.00045	3.113	0.00108	2.847
Firth of Forth	0.163	66	0.3	26	0.065	58	0.2	0.00028	3.240	0.00085	2.910
Farn Deeps	0.160	66	0.3	24	0.060	58	0.2	0.00038	3.170	0.00091	2.890
Botney Gut	0.165	62	0.3	27	0.080	60	0.2	0.00023	3.320	0.00080	2.950
North Minch	0.160	70	0.3	27	0.060	60	0.2	0.00028	3.240	0.00085	2.910
South Minch	0.161	68	0.3	25	0.060	59	0.2	0.00028	3.240	0.00085	2.910
Clyde	0.160	73	0.3	27	0.060	62	0.2	0.00028	3.240	0.00085	2.910
Eastern Irish Sea	0.160	60	0.3	24	0.100	56	0.2	0.00022	3.348	0.00114	2.820
Western Irish Sea	0.160	60	0.3	24	0.100	56	0.2	0.00032	3.210	0.00068	2.960
Aran Grounds	0.150	60	0.3	24	0.100	50	0.2	0.00032	3.210	0.00068	2.960
Porcupine Bank	0.140	75	0.3	24	0.100	56	0.2	0.00010	3.550	0.00010	3.550
Celtic Sea	0.170	68	0.3	31	0.100	49	0.2	0.00009	3.550	0.00009	3.550
Bay of Biscay	0.140	76	0.3	25	0.110	56	0.2	0.00039	3.180	0.00081	2.970
North Galicia	0.160	70	0.2	28	0.080	60	0.2	0.00043	3.160	0.00043	3.160
W Galicia & N Portugal	0.150	80	0.2	26	0.100	65	0.2	0.00043	3.160	0.00043	3.160
S & SW Portugal	0.200	70	0.3	30	0.065	65	0.2	0.00028	3.220	0.00056	3.030

Table 2. Recent landings (tonnes), landings per unit effort (LPUE) and catch per unit effort (CPUE) of Nephrops norvegicus by stock area, country and gear type. Unless otherwise specified the data are averages for 2000-2002, LPUE and CPUE are in units of kg/hour trawling. Shaded cells indicate sub-sets of preceding categories.

Stock	Country	Gears	Landings	LPUE	CPUE	Notes
Iceland	Iceland	Otter trawl (80+mm)	1403	45		Data for seasons 2000/01-2002/03 (September-August)
Faeroes	Faeroe Islands	Creel	64	120		Data for seasons 1995/96-1997/98, LPUE in g/pot day
Noup	UK	All trawls	284			
		Single otter (70+mm)	143	9		
		Multirig otter (80+mm)	34	83		
Moray Firth	UK	All trawls	1352			
		Single otter (70+mm)	876	25		
		Multirig otter (80+mm)	259	28		
		Creel	2			
Fladen Ground	UK	All trawls	5977			
		Single otter (70+mm)	2325	38		
		Multirig otter (70+mm)	1318	32		
	Denmark	Otter trawl (70-90mm)	113			
Norwegian Deep	Denmark	All trawls (mainly otter 70-90mm)	980	177		LPUE in kg/day
	Norway	Otter trawl	126			
	UK	All trawls (mainly otter 100+mm)	47			

Table 2 (continued)

Stock	**Country**	**Gears**	**Landings**	**LPUE**	**CPUE**	**Notes**
Skagerrak	Denmark	Otter trawl (70-90mm)	1782	114		LPUE in kg/day
	Sweden	All trawls	647			
		Single otter (70-90mm)	289	10	16	
		Twin otter (90mm)	240	8	12	
		Creel	144			
	Norway	Otter trawl	145			
Kattegat	Denmark	Otter trawl (70-90mm)	1384	94		LPUE in kg/day
	Sweden	All trawls	293			
		Single otter (70-90mm)	55	8	13	
		Twin otter (90mm)	188	8	13	
		Creel	5			
Firth of Forth	UK	All trawls	1546			
		Single otter (70mm)	1499	22		
		Multirig otter (100mm)	17	47		
		Creel	0			
Farn Deeps	UK	All trawls	2235			
		Otter trawl (70+mm)	2128	24	44	

Table 2 (continued)

Stock	Country	Gears	Landings	LPUE	CPUE	Notes
Clyde	UK	All trawls	3236			
		Creel	91			
Firth of Clyde		Single otter (70mm)	2478	26		
		Twin otter (80mm)	431	25		
Sound of Jura		Single otter (70mm)	81	21		
		Twin otter (80mm)	43	34		
Eastern Irish Sea	UK	Otter trawl (70+mm)	443	21		
	Republic of Ireland	Otter trawl (70-80mm)	114	48		
Western Irish Sea	UK	All trawls	4752			
		Otter trawl (70+mm)	4613	30	37	
	Republic of Ireland	All trawls (mainly otter 70-80mm)	2802	48		
NW Irish Coast	Republic of Ireland	All trawls (mainly otter 80+mm)	8			
Aran Grounds	Republic of Ireland	All trawls (mainly otter 80+mm)	981	37		
Porcupine Bank	Republic of Ireland	All trawls (mainly otter 80+mm)	380	33		
	France	Otter trawl (80mm)	334	16		
	Spain	Baca trawl	253	8		LPUE in kg/day *BHP/100
	UK	Otter trawl (80+mm)	139			
SW & SE Irish Coast	Republic of Ireland	All trawls (mainly otter 80+mm)	790	26		
	France	Otter trawl (80mm)	134			
	UK	Otter trawl (80+mm)	4			

Table 2 (continued)

Stock	Country	Gears	Landings	LPUE	CPUE	Notes
Celtic Sea	France	Otter trawl (80mm)	2778	13		
	Republic of Ireland	All trawl (mainly otter 80+mm)	1802	49		
	UK	All trawls (mainly otter 80+mm)	26			
Bay of Biscay	France	Otter trawl (70+mm)	3493	8		
Cantabrian Sea	Spain	All trawls	28			LPUE and CPUE data for 2000-2001 only, in kg/day *BHP/100
		Avilés trawl fleet		2	2	
		Santander trawl fleet		12	12	
		Traps	1			
North Galicia	Spain	Baca trawl	124	6	6	
West Galicia & North Portugal	Spain	All trawls	111			LPUE and CPUE in kg/trip
		Muros trawl fleet		3	3	
		Riveira trawl fleet		4	4	
		Marín trawl fleet		31	31	
		Vigo trawl fleet		35	35	
	Portugal	All trawls	6			
S & SW Portugal	Portugal	All gears	277	49	49	LPUE and CPUE in kg/day
Gulf of Cádiz	Spain	All gears	172			
Atlantic Moroccan grounds	Spain	All gears	166			Data for 2000-2001 only
	Portugal	All gears	83			
	Morocco	All gears	8			
	Greece	All gears	1			

Table 3. Total landings (tonnes) of Nephrops norvegicus by countries from all areas outside the Mediterranean during 1998-2002. Incomplete values are shown in parentheses. Shaded cells indicate sub-sets of preceding categories

Country	**1998**	**1999**	**2000**	**2001**	**2002**
Iceland	1420	1375	1240	1420	1550
Faeroe Islands	57	80	73	51	
Norway	275	358	327	252	242
Sweden	1319	1243	1197	1037	1032
Denmark	4978	5447	5068	4787	5442
UK Total	29159	31415	28518	28476	28397
Scotland	20102	21850	20632	20311	21223
Northern Ireland	6137	6392	5051	4782	4693
England and Wales	2903	3167	2834	3380	2481
Isle of Man	17	6	0	3	0
Germany	70	110	86	140	
Netherlands	694	660	577	863	971
Belgium	384	493	401	435	332
Ireland	7778	8169	7186	7040	7151
France	6445	6965	6340	6760	7318
Spain	1494	2230	1090	1040	(935)
Portugal	181	258	288	366	(363)
Greece	10	0	2	0	
Morocco	4	2	2	13	
Total	54270	58805	52394	52680	(53733)

Table 4. Total landings (tonnes) of Nephrops norvegicus by stock for all areas outside the Mediterranean during 1998-2002. 'Other' grounds are outside the main recognised Nephrops grounds.

Country	**1998**	**1999**	**2000**	**2001**	**2002**
Iceland	1420	1375	1240	1420	1550
Faeroes	57	80	73	51	
Noup	254	279	275	177	401
Moray Firth	1032	1008	1541	1403	1118
Other north-east Scotland	74	74	64	110	57
Fladen Ground	5136	6521	5570	5542	7182
Norwegian Deep	838	1129	1051	1192	1216
Other northern North Sea	94	175	81	103	163
Skagerrak	3248	3194	2894	2282	2977
Kattegat	1796	1749	1809	1773	1464
Firth of Forth	2145	2205	1785	1528	1327

Farn Deeps	2176	2401	2178	2574	1953
Other British east coast	278	401	391	633	637
Off Horn Reef	338	713	561	698	787
Botney Gut	1071	1185	1070	1329	1142
Other southern North Sea	238	307	349	402	489
North Minch	2441	3257	3246	3259	3416
South Minch	3730	4051	3952	3992	3280
Clyde	4843	3746	3417	3190	3373
Other west of Scotland	157	438	422	420	397
Eastern Irish Sea	389	625	567	532	577
Western Irish Sea	9145	10786	8370	7378	6914
Other Irish Sea	4	2	0	2	2
North-west Irish coast	78	16	9	2	14
Aran Grounds	1410	1140	880	913	1154
Porcupine Bank	2155	2132	872	1163	1282
South-west and south-east Irish coast	827	572	686	809	1288
Other west of Ireland	514	322	243	369	243
Celtic Sea	3835	3532	4579	4644	4603
Other south-west of Britain	144	146	56	37	144
Bayof Biscay	3226	3212	3069	3731	3681
Other south-west France	40	26	36	22	36
Cantabrian Sea	72	48	34	26	26
North Galicia	103	124	81	147	143
West Galicia	295	194	102	105	59
North Portugal	50	54	30	27	28
South and south-west Portugal	161	211	201	271	359
Gulf of Cádiz	89	123	92	178	247
Atlantic Moroccan grounds	297	1144	410	104	

Fisheries monitoring and assessment

Monitoring of *Nephrops* fisheries is very variable between areas, depending on available resources, sampling logistics and the historical importance of the fisheries. As a minimum, official landings statistics are available; despite doubts about reporting levels in some areas, these provide a basic indication of the past and present fortunes of a fishery. In EU waters, mandatory log-books provide information on fishing effort. Length-frequency distributions (LFDs) of landings are measured from onboard, market or port samples for most fisheries, and minimum levels of national sampling effort (number of samples and number of animals per sample) in different areas are set out in National Data Gathering Programmes established under EU data regulations (1639/2001). In most cases these minimum levels are exceeded, a typical example of sampling effort being 40-60 samples of around 200 animals from the Farn Deeps in 1999-2000. However, there is uneven geographical coverage of sampling effort, and some stock areas are only sparsely sampled. The large Fladen Ground fishery, for example, is sampled at low levels because of the logistical and resource difficulties of monitoring long offshore fishing trips. In some cases there is an uneven national coverage of some fisheries. For example, length sampling for the Botney Gut fishery is at present confined to Belgian vessels. Following the increase in UK and particularly Dutch fishing effort in this area, Belgian landings account for only a quarter of the total for the Botney Gut.

Sampling of *Nephrops* discards is an important element of fishery monitoring in many areas. LFDs and quantities of discards are measured on an annual basis for most of the large Scottish and Scandinavian fisheries. For the Farn Deeps fishery, where there is some uncertainty about real discarding practices, lengths are measured in unsorted catch samples and discarding is inferred by comparison of LFDs between catches and landings. In some areas, notably the French Celtic Sea and Bay of Biscay fisheries and the Belgian Botney Gut fishery, discard data have been collected in only a few years, as part of specific research projects (a new programme of regular discard sampling for the Belgian Botney Gut fishery was started in 2002). For the purposes of stock assessment, discard quantities in other years are estimated by application of a 'fishermen's selection curve' to landings data. Stock assessments based on data derived in this way tend to be misleading with respect to recruitment trends but otherwise reliable. No discard sampling is undertaken for Iberian *Nephrops* fisheries because all sizes of animals are retained in the landings.

Nephrops fishery monitoring is supplemented by fishery-independent surveys in some areas. Trawl surveys have not seen wide application, because daily, seasonal and sex-related patterns in catchability make catch rates difficult to interpret. However, some use has been made of Spanish and Portuguese research trawl survey data in assessing Iberian *Nephrops* stocks. Some of these surveys are directed at other species, e.g. to monitor hake recruitment. *Nephrops* catch data from French hake surveys in the Bay of Biscay has also been integrated into a stock assessment.

The main fishery-independent survey method for *Nephrops* is underwater TV (UWTV) surveys of burrows. This method was pioneered for Scottish stocks in the 1970s (Chapman, 1979), developed into a standard stock assessment technique (Tuck *et al.* 1997) and has been regularly applied to most of the main Scottish stocks since the early 1990s and to the Farn Deeps stock since the mid-1990s. Trials in the eastern Irish Sea proved unsuccessful, owing to the number of burrows of other species that could be confused with *Nephrops* (notably the angular crab *Goneplax rhomboides*). The method involves towing a sledge-mounted underwater television camera over the ground and counting the number of burrow systems in a given area. The principal output is a measurement of burrow density, which can be converted into stock abundance given data on the area of suitable mud habitat. Biomass estimation is also possible, although there are problems stemming from the difficulty in obtaining an unbiased estimate of mean individual *Nephrops* size on the ground. UWTV surveys are now the principal method of stock assessment for the poorly sampled Fladen Ground stock. The method has recently been trialled successfully on the Aran Grounds and in the western Irish Sea.

Another approach to fishery-independent assessment is to measure the abundance of larvae in the water column and convert to an estimate of the size of spawning stock based on information about fecundity and the survival rates of larvae. Given the availability of plankton survey data from a study of fish egg production in 1995, this method was applied to *Nephrops* in the Irish Sea in 1995. Extensive laboratory studies were taken to estimate effective fecundity and the survival and development rates of eggs and larvae, and the resulting biomass estimate was comparable to that obtained from analytical assessments of fishery data (Allen *et al.*, 1999). The high input of resources and research effort means that larval production surveys are unlikely ever to be a routine method of stock monitoring, but they provide a useful calibration and validation of other methods.

Despite the increase in importance of UWTV and other fishery-independent survey methods for *Nephrops*, fishery data still forms the principal source of information on the status of stocks. In its widest sense, *Nephrops* stock assessment involves examining trends in landings, fishing effort, LPUE and CPUE, mean size and sex ratio. Considering the importance of catchability patterns, some of these indices are examined for quarterly time periods and for the sexes separately (e.g. ICES, 2003). For many stocks, however, analytical assessments provide a more formal analysis of stock trends and state of exploitation. These are generally applied to males and females separately because of differences in catchability between the sexes. Exploitation rates are generally higher on males than females, and assessments of males are usually regarded as being more reliable because males are more heavily represented in the landings data. The length-based method of length cohort analysis (LCA) has been extensively applied to *Nephrops*, using average LFDs of fishery removals to estimate fishing mortality and generate a yield per recruit analysis (Jones, 1979). This method suffers the drawback, however, that its valid application is restricted to stocks at equilibrium; results of LCA can be misleading when applied to a declining stock. Dynamic age-based methods of the virtual population analysis (VPA) type are most commonly applied when there is a sufficient time-series of data. The ICES Working Group on *Nephrops* stocks most commonly uses the 'extended survivors analysis' (XSA) variant of this method, involving 'tuning' against CPUE data (Shepherd, 1999). Most often commercial CPUE data are used for this purpose, since, unlike the case with many fin-fish assessments, suitable survey data are rarely available.

The principal difficulty in applying XSA and other VPA-type methods to *Nephrops* stocks is in obtaining catch age composition data. The ICES Working Group use von Bertalanffy growth parameters (see Table 1) to 'slice' a length-composition deterministically into age-groups. This ignores variation in growth rates between years and between individuals, the effect of which is to smooth out the year-class distinctions in the data and in the resultant estimates of stock biomass and recruitment. Various alternative approaches have been attempted, such as resolving LFDs into mixtures of normal distributions (e.g. Castro, 1995) or applying age-length keys (Caramelo, 1995). However, the problem of age-determination remains central to *Nephrops* assessments. The standard XSA approach currently applied appears to give reliable indications of average stock biomass and overall trends, but probably underestimates variability between years. This is most particularly a problem when examining stock-recruitment relationships and using assessment outputs as a basis for obtaining biological reference points. For the future, dynamic length-based methods hold some promise (e.g. Dobby, 2003). There has been some success in applying catch-survey analysis (CSA – also known as Collie-Sissenwine Analysis) (Mesnil, 2003). This has given results equivalent to XSA whilst requiring only the distinction between recruits and older individuals.

The results of XSA and other analytical assessments provide information on trends in stock biomass, recruitment and fishing mortality. These results are often used to generate yield per recruit analyses and stock projections, but these are used mostly as part of an overall appreciation of stock status rather than in a strict quantitative management context. In the case of Icelandic stock assessments, however, stock projections are used to estimate appropriate catch levels based on a yield per recruit reference point.

A summary of assessment methods applied to each stock is given in Table 5, together with recent estimates of average fishing mortality. Note that the fishing mortality is generally much higher in males than females, except in the summer fisheries in the Irish Sea.

Table 5. Recent stock assessments of *Nephrops norvegicus*: **X**, principal method; x, secondary method; (x), trial application or previously assessed by this method; VPA, virtual population analysis based on catch at age data; LCA, length cohort analysis based on catch at length data; UWTV survey, underwater television counting of burrows. Mean *F* is from VPA or LCA and is an arithmetic average fishing mortality for a reference group of ages or lengths.

	Stock Assessment Methods					**Mean *F***	
Stock	**VPA**	**LCA**	**UWTV survey**	**Larval production**	**Trawl survey**	**Males**	**Females**
Iceland	**X**					0.17	
Noup			(x)				
Moray Firth	**X**	(x)	x			0.47	0.17
Fladen Ground	(x)	x	**X**			0.31	0.25
Skagerrak & Kattegat	**X**	(x)				0.25	
Firth of Forth	**X**	(x)	x			0.95	0.25
Farn Deeps	**X**	(x)	x			0.49	0.12
Botney Gut	**X**	(x)					
North Minch	**X** (trawl)	**X** (creel)	x			0.58 (trawl) 0.33 (creel)	0.20 (trawl) 0.08 (creel)
South Minch	**X** (trawl)	**X** (creel)	x			0.52 (trawl) 0.17 (creel)	0.13 (trawl) 0.01 (creel)
Clyde	**X**	(x)	x			0.77	0.18
Eastern Irish Sea	**X**	x	(x)	(x)		0.60	0.48
Western Irish Sea	**X**	(x)	(trial in 2003)		(x)	0.57	0.75
Aran Grounds	x	**X**	x			0.59	0.42
Porcupine Bank	(x)	**X**				0.27	0.13
Irish coastal stocks		(x)					

Table 5 (Continued)

	Stock Assessment Methods					**Mean *F***	
Stock	**VPA**	**LCA**	**UWTV survey**	**Larval production**	**Trawl survey**	**Males**	**Females**
Celtic Sea	**X**	(x)				0.54	
Bay of Biscay	**X**	(x)			(x)	0.55	
Cantabrian Sea	**X**	(x)			x	0.18	0.07
North Galicia	**X**	(x)			x	0.42	0.14
W Galicia & N Portugal	**X**	(x)			x	0.58	0.26
S & SW Portugal	**X**	(x)			x	0.53	0.24

Assessing the impact of fishing on the population

Many *Nephrops* fisheries are considered to be at least 'fully' exploited, in the sense that yield per recruit (a proxy for yield, in the absence of information on recruitment) is often close to its maximum value in males. For stocks north of the Bay of Biscay recruitment estimates tend to be fairly stable over time. Lower availability of females to fishing gear is thought to be a partial safeguard for spawning stocks. There is no hard information on thresholds for recruitment overfishing, but declines in recruitment have been seen in the Bay of Biscay and Iberian stocks over recent years. In the case of the Bay of Biscay, it is thought that reductions in fishing mortality and improvements in the fishery selection pattern will reverse the trend of stock decline. For the Iberian stocks, however, only zero fishing mortality seems likely to have any effect in halting or reversing stock declines. It is suspected that environmental changes may have caused recruitment failure in these shelf-edge stocks, although a fishery impact cannot be ruled out.

The major problem facing fisheries on northern stocks at present is not the impact of fishing on *Nephrops* stocks but the contribution of *Nephrops* fishing to mortality of other species, specifically those for which recovery plans are in operation (cod and hake).

Fisheries management

Various technical measures are in operation for *Nephrops* fisheries. MLS for *Nephrops* vary from 20 mm CL (70 mm TL) in the Irish Sea, west of Scotland and southerly waters, 25 mm CL (85 mm TL) in most other areas and 40 mm CL (130 mm TL) in the Skagerrak and Kattegat. In most cases these MLS are well observed, and are unlikely to have a dramatic effect on the fisheries or stocks. The regulations on gear and mesh specifications are too complex and extensive to summarise here, but in most cases 70 mm or 80 mm meshes are specified for cod-ends, with square-mesh panels to allow escapement of young fish. Much of the gear regulation reflects measures to protect fish stocks. The primary tool used to manage *Nephrops* fisheries is the Total Allowable Catch (TAC).

ICES assessment and advice for *Nephrops* is based on small Management Areas (MAs), comprising one or more stock units (Functional Units). Current EU management is based on aggregating these MAs into TAC areas, which often are much larger. Current (2003) TACs are 16,623 t for the EU zone of ICES Sub-Area IV, 11,340 t for ICES Division VIa, 17,790 t for ICES Sub-area VII, 3,000 t for ICES Divisions VIIIa and VIIIb, 180 t for ICES Division VIIIc and 600 t for ICES Division IXa. TACs for other EU areas are set at zero to prevent misreporting. Advice on TACs is based on recent landings that have been seen to be sustainable rather than as an analytical output of assessment. In the case of declining Bay of Biscay and Iberian stocks, TAC advice has been informed by stock projections, indicating levels of landings under which increasing stock trends are expected. No biological reference points or formal management objectives are defined. In the case of the Fladen Ground, where UWTV surveys indicated scope for increased landings, the TAC advice was based on the UWTV estimate of stock biomass combined with the lower end of the range of harvest ratios (landings/stock biomass) observed for other, sustainably fished stocks.

Agreed TACs tend to be higher than those advised, particularly when restrictive management is proposed. The fact that TAC areas are larger than MAs can lead to difficulties in specific areas. For example, uptake of TAC on the expanding Fladen Ground fishery can lead to problems in quota availability for winter fisheries off the north-east of England. Recent cuts in TACs in IV and VII have been imposed in an attempt to reduce by-catch fishing mortality of cod.

Iceland sets its own national TAC for September-August fishing seasons. Stock projections based on VPA are used to determine levels of landings corresponding to $F_{0.1}$ (the level of fishing mortality at which the slope of the yield per recruit curve falls to 10% of its value at the origin – close to, but precautionarily less than the fishing mortality at maximum yield per recruit).

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The Biology and Fisheries for Palinurus elephas (Fabricius, 1787) and Palinurus mauritanicus (Gruvel, 1911)

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Introduction
Two species of spiny lobster (Family: Palinuridae) inhabit European waters. *Palinurus elephas* is the most abundant and accessible and has traditionally been the target of fisheries off Ireland, the UK, France, Portugal, Spain, Italy, Greece, Tunisia and adjacent southern Mediterranean waters. *Palinurus mauritanicus*, has a deeper distribution and is fished in the Eastern Central Atlantic (mainly off Mauritania), where it reaches its highest densities. There is no targeted fishery for *P. mauritanicus* in European waters although it is captured as a by-catch in some fisheries targeting *P. elephas*. *P. elephas* also commands higher prices than *P. mauritanicus* in European markets. Neither species has been extensively studied probably because of the high costs of the animals that reduce the possibilities for sampling and experimental work. Their high unit value also makes the fisheries economically feasible despite low yields and is responsible for the overfished status of their populations. More is known about the biology, ecology and fisheries of *P. elephas* than of *P. mauritanicus; c*onsequently, *P. mauritanicus* is only treated briefly in this paper

Description
The taxonomic position of Palinurus spp. is as follows : Class: Crustacea, Infra class: Malacostraca, Order: Decapoda , Sub order: Reptantia, Family: Palinuridae , Division: Stridentes, Genus: *Palinurus*

In Europe the species may have the following common names
P. elephas (Fabricius, 1787)
Danish: languster, langust – **Dutch**: langoesten, hoornkreeft - **English**: spiny lobster, rock lobster, sea crayfish, thorny lobster, crawfish, crayfish - **Finish**: languisti – **French**: langouste rouge – **German**: Languste, Panzerkrebs, Heuschreckenkrebs – **Greek**: astakos – **Icelandic**: huma – **Italian:** aragosta, aragusta, arigosta, aligusta, aliusta – **Norwegian**: languster - **Portuguese**: lagosta-castanha - **Spanish**: langosta – **Galician**: Langosta – **Catalan**: llagosta – **Basque**: otarrain – **Swedish**: languster

P. mauritanicus (Gruvel, 1911)
English: pink spiny lobster - **French**: langouste rose, langouste de Mauritanie –**Spanish**: langosta mora, langosta africana - **Galician**: langosta mora - **Catalan**: llagosta rosa – **Basque**: otarrain mairua - **Portuguese**: lagosta rósea.

Spiny lobsters can easily be distinguished from clawed lobster by the absence of claws, and from slipper lobsters by their long whip-shaped antenna. *P. elephas* and *P. mauritanicus* can be distinguished from one another by their coloration. *P. elephas* is red-brick and mauve and *P. mauritanicus* has a pink colouration. The concavity of the anterior margin between the supra-orbital spines is larger in *P. elephas* which also has an antero-lateral spine at the extremity of the first walking leg, a pair of symmetric pale spots on each of the first five abdominal segments and longitudinal pale stripes on the walking legs. Both species may also be confused with *Palinurus charlestoni* but this is endemic to the Cape Verde Islands (Latrouite and Alfama, 1996).

Geographic Distribution
Palinurus elephas is distributed in the Eastern Atlantic from Norway to Morocco and also in the Mediterranean, except in the extreme eastern and south-eastern regions (Holthius, 1991). It previously occurred in greatest quantities around the western Mediterranean islands of Corsica

(Marin, 1987), Sardinia (Santucci, 1926, 1928), Sicily (M. Gristina, personal communication), the Balearic Archipelago, the Columbretes and islands off the north coast of Tunisia (Quetglas et al. in preparation).

The pink spiny lobster *Palinurus mauritanicus* occurs in the Eastern Atlantic from western Ireland to southern Senegal and in the Western Mediterranean to western Sicily, west of 16ºE (not in the Adriatic) (Holthius, 1991).

Ecology and Habitat

Palinurus elephas lives between 0-160 m depth (Holthius, 1991). It is found on rocky and coralligenous substrates where micro-caves and natural protective holes are numerous (Ceccaldi and Latrouite, 2000). In the Western Mediterranean post larvae settle during the summer in holes and crevices at 5-15 m depth (Diaz et al., 2001). Early juveniles leave the protective crevices to forage at night (Diaz et al., 2001). Off the Columbretes Islands (Western Mediterranean) juveniles move to deeper waters as they grow and small adults concentrate below 50 m depth, while the oldest lobsters tend to reach greatest abundance at shallower locations (Goñi et al., 2001b). Little is known about the preferred habitat of juveniles but observations of juveniles off Ireland by Mercer (1973) indicate that they occur in groups and tend to inhabit crevices. In contrast with this observation, Marin (1987) reported large quantities of late juveniles (modal size 60 mm CL) in experimental trawls over *Posidonia* beds at 15-25 m off Corsica.

According to Mercer (1973) and Ansell and Robb (1977) *P. elephas* undergoes a pre-reproductive spring onshore migration and a reverse post-reproductive offshore migration in late autumn in the Atlantic. A similar behaviour has been postulated for *P. elephas* off the Columbretes Islands (western Mediterranean) (Goñi et al., 2001b). The movements of adults are generally limited and seem motivated by foraging, change of shelter and reproduction. Its activity is mainly nocturnal. Tag-recapture studies conducted both in the Atlantic and the Mediterranean indicate that adults exhibit limited movements with most animals showing displacements of less than 5 km and exceptionally up to 20 km after 1 to 8 years at large (Hepper, 1967; 1970; Marin, 1987; Goñi et al., 2001b). Nevertheless, two reports of movements of 50 and 70 km have been made in the Mediterranean (Cuccu et al., 1999; Relini and Torchia, 1988).

P. elephas preys nocturnally on a variety of benthic organisms. Mercer (1973) and Goñi et al. (2001a) describe quantitatively the natural diet of *P. elephas* off Ireland and the Western Mediterranean respectively. *P. elephas* is highly omnivorous and predates on hard–shelled bottom dwelling organisms, principally molluscs, echinoderms and crustaceans. It is also a generalist, opportunistic feeder that changes its food preferences as a function of the abundance of benthic organisms. While molluscs and sea urchins are the most important prey in the diet of the species, other prey such as decapod crustaceans, ophiuroids or coralline algae are consumed in certain areas and not in others (Goñi et al., 2001a). In common with other spiny lobsters, *P. elephas* appears to be a key benthic predator and its selective predation can have important effects on the composition and size structure of benthic communities.

P. mauritanicus occurs at depths of 40-600 m, but occurs in highest densities between 200-400 m (Postel, 1966). Sex and size appear to vary with depth. Males are more abundant in the 150 to 250 m depth range while large females and juveniles predominate between 250-300 m (Maigret, 1978). They inhabit the continental shelf's edge, especially the canyons, and show preference for muddy and coralligenous substrates near rocky outcrops (Postel, 1966). They have been observed sheltering at the entrance of circular holes dug at the base of compact mud cliffs (Latrouite et al., 1999). Migrations are apparently linked to moulting and reproduction. Large groups concentrate in autumn at the edge of canyons and then spread onto the shelf. Off Mauritania, the mean size of *P. mauritanicus* in the fishery is smaller north of Cape Blanc (20°45) than in the south which could indicate that the north of this area is a nursery resulting from a northward drift of larvae due to bottom currents and that adults migrate southward (Maigret, 1978). It appears that groups of mainly females undergo migrations in late autumn, probably linked to reproduction, that increase their catchability in bottom trawls (Maigret, 1978).

Off West Africa *P. mauritanicus* feed primarily on dead fishes, live molluscs (bivalves and gastropods), crustaceans, polychaetes and echinoderms (ophiuroids and echinoids) (Maigret, 1978).

Life History

Biometry of P. elephas

Total length / carapace length

Total length (TL) measured from the tip of the rostrum (medial spine between the eyes) to the posterior end of the telson has in the past been used as the reference for minimum legal size (MLS) and some authors have used it in scientific publications. However, carapace length (CL), measured from the tip of the rostrum to the posterior margin of the cephalothorax, is now more commonly employed. The following equations relate TL to CL:

Atlantic Ocean (Brittany) (Latrouite and Noël, 1997):

Males TL(mm) = 2.32* CL(mm) + 44.2 (n= 65, range 86-203 mm CL)
Females TL(mm) = 2.65* CL(mm) + 27.1 (n= 69 ,range 93-148 mm CL)

Western Mediterranean (Corsica): (Campillo and Amadei, 1978):

Males TL(mm) = 2.47* CL(mm)+ 22.07 (n = 417, range 45-175 mm CL)
Females TL(mm) = 2.77* CL(mm)+ 6.38 (n = 278, range 50-160 mm CL)

At any given total body size females have larger abdomens than males.

Carapace Length / Body Weight

The following equations relate carapace length to body weight (W):

Atlantic Ocean (Brittany) (Latrouite and Noël, 1997):

Males: $W(g)= 0.0013*CL(mm)^{2.856}$ (n= 65, range 86-203 mm CL)
Females: $W(g)= 0.0026*CL(mm)^{2.726}$ (n= 70, range 94-148 mm CL)

Western Mediterranean (Corsica) (Campillo and Amadei, 1978):

Males: $W(g)= 0.0008*CL(mm)^{2.966}$ (n= 417, range 45-175mm CL)
Females: $W(g)= 0.0009*CL(mm)^{2.942}$ (n= 278, range 50-160 mm CL)

At equal body size males are heavier than females.

Biometry of P. mauritanicus

Total Length / Carapace Length

The following equations relate TL to CL:

Northeast Africa (Mauritania) (Maigret, 1978):

Males: TL(mm) = 2.15* CL(mm) + 24.1 (n= 131, range 30-175 mm CL)
Females: TL(mm) = 2.33* CL(mm) + 15.2 (n= 135, range 35-170 mm CL)

At any given total body size females have larger abdomens than males.

Carapace Length / Body Weight

The following equations relate carapace length to body weight:

Northeast Africa (Mauritania) (Boitard, 1981):

Males: $W(g)= 0.001826*CL(mm)^{2.756}$ (n= 160, range: not indicated))

Females: $W(g)= 0.002156*CL(mm)^{2.729}$ (n= 140, range: not indicated)

At equal body size males are heavier than females.

Growth

P. elephas

The moulting process in *P. elephas* is similar to that of other Palinurids. Mercer (1973) describes it as follows: 'the intersegmental membrane jointing the cephalothorax and abdomen swells and ruptures dorsally. The carapace tilts forward and the cephalothorax is withdrawn antennae first followed by the legs. The abdominal segments are then freed by a series of violent jerks'. It takes about fifteen minutes to complete ecdysis; the animal then remains under cover and does not feed for 7 to 19 days by which time the new shell has almost hardened (Karlovac, 1965). The intermoult stage, when increase in weight ceases, is attained 3-5 weeks after moulting (Mercer, 1973). Mature females moult in April-May in the Mediterranean (Marin, 1987) and in June-August in the Atlantic (Latrouite and Noël 1997), always prior to mating. In the Mediterranean, mature females are berried from mid summer to late winter (Goñi et al., 2003a) and moult 1-2 times per year (Marin, 1987). In the Atlantic mature females are berried from mid-autumn to late spring and appear to moult only once per year (Mercer, 1973). According to Mercer (1973) mature males follow the same pattern but with a more extended moulting season. Observations by Marin (1987) in Corsica showed that the number of moults per year is related to size. After sexual maturity it decreases faster for females than for males. Juveniles usually moult 2-3 times per year (Marin, 1987) but up to 5 times (Corral, 1968; Cuccu et al., 1999).

Growth studies of *P. elephas* in nature have been conducted by means of mark-recapture experiments. Growth increments reported in different studies are difficult to interpret because of the varying size of the lobsters involved, the different times at large and the different growth conditions experienced. Common to all growth studies based on mark-recapture is that growth rates will tend to be underestimated as lobsters moulting more often will be more likely to loose their tags and not be recaptured (Hepper, 1970). Furthermore, no or even negative growth increments are not rare in this type of studies.

Marin (1987), using tag-recapture experiments studied the growth of *P. elephas* off Corsica in nature. The growth per moult of males 55-100 mm CL and of females 55-130 mm was arithmetic (according to Kurata terminology) for both sexes, and larger for males than for females

Males: $CL_1 = 0.99\ CL_0 + 6.97$ (mm) (n= 21)

Females: $CL_1 = 0.99\ CL_0 + 5.68$ (mm) (n= 27)

The parameters of the von Bertalanffy growth equation of *P. elephas* from Corsica estimated by Marin (1987) are

Males: $CL_\infty = 166$ CL (mm), $K = 0.151$, $t_o = -0.348$

Females: $CL_\infty = 136$ CL (mm), $K = 0.189$, $t_o = -0.342$

The life span of *P. elephas* has been estimated at about 15 years by Marin (1987) but unpublished data by Goñi et al. suggest that males could reach 20-25 years. A mark-recapture study of large-sized *P. elephas* by Hepper (1970, 1977) off Cornwall indicated mean moult increments <2 mm CL even after more than 2 years at large, while field observations by Mercer (1973) off Ireland yielded much larger growth increments (about 12 mm CL for both males and females). On the basis that it takes 1 year from the first larval stage to reach a juvenile size of 35 mm CL and the juveniles moult at least twice per year up to the size at first maturity, Mercer (1973) proposed the following estimation of size at age for *P. elephas* off Ireland:

Age	Male (CL-W)	Female (CL-W)
2-3 years	87 mm – 0.455 kg	86 mm – 0.510 kg
5-6 years	123 mm – 1.245 kg	122 mm – 1.225 kg
8-9 years	160 mm – 2.680 kg	158 mm – 2.350 kg

According to the above data from Marin (1987) and Mercer (1973), growth appears to be faster in the Atlantic than in the Mediterranean. *P. elephas* also attains larger sizes in the Atlantic than in the Mediterranean as estimated maximum sizes are

- Western Mediterranean: 175 mm CL (n= 417) and 160 mm CL (n= 278) for males and females off Corsica (Campillo and Amadei, 1978).
- Atlantic: 200 mm CL (n= 65) and 170 mm CL (n= 70) for males and females off Brittany (Latrouite and Noël 1997); 190 mm CL (n= 298) and 153 mm CL (n=586) for males and females off Ireland (Mercer, 1973).

It is not easy to interpret the differences in maximum sizes observed in different areas and years, specially if we consider that maximum size of lobsters in an exploited population can depend on the exploitation pattern (see below) and that observed values may be influenced by a variety of factors, such as sample size, sampling method, season, and depth.

Comment [DL1]: I would prefer « can » to « will » because some very large (maximum) individuals can escape to fishermen even if the probability to catch a big one decreases.

Moult increments of lobsters in captivity from the Atlantic studied by Mercer (1973) indicated little or no growth, while Hepper (1977) observed small increments. Unpublished data of Goñi et al. from the Western Mediterranean lobsters in captivity show growth increments per moult around 0-2.5mm and 0-4 mm CL for females and males respectively, while Karlovac (1965) indicates increments per moult of 0-5.5 mm CL and 0-8 mm CL in captive females and males from the Adriatic.

P. mauritanicus

Little is know about the growth of *P. mauritanicus*. According to Maigret (1978) who studied this species off the Mauritanian coast, there is only one moulting period, from September to December, and one annual moult for both males and females. Moult increments, as deduced from recapture of a few tagged males of initial size 25-27 cm TL, were 3-4 cm TL. Vincent-Cuaz (1966) estimated a moult increment of 3 cm and divided the composition between 27 and 49 mm TL into 9 age groups (ages 9-16) for both males and females. Maigret (1978) estimated that *P. mauritanicus* could live for 21 years. Using Maigret's (1978) data, Boitard (1981) proposed the following growth parameters for female *P. mauritanicus*:

CL_∞ = 202.8 mm CL, K = 0.169, t_o = -0.227

Reproduction

P. elephas

Mercer (1973) described the mating process in *P. elephas* as follows: 'stridulation by female attracts males from distances of at least 15 meters. Courtship starts when antennal contact is made and continues with rubbing and waving with the antennae and antennules. After a final stimulus, apparently triggered by a pheromonal release from the female, the male endeavours to overturn the female. Copulation occurs, sternum to sternum, between intermoult individuals. The male deposits two spermatophores of a milky-white gelatinous texture on the two sides of the female's sternum, below the genital openings'.

In the Atlantic**,** mating is reported to occur between June and September depending on the region (De Vascondellos, 1960; Gibson and O'Riordan, 1965; Mercer, 1973), a few weeks after the annual female moult. In the Western Mediterranean females bearing spermatophores occur between July to September (Marin, 1985; Goñi et al., 2003a). Oviposition takes place shortly after mating (i.e., 2 days, Mercer, 1973; 5-10 days Ansell and Robb 1977). The spermatophores of *P. elephas* do not harden to form a permanent tar-spot as in other Palinurids and disappear after a maximum of 10 days; thus they are infrequently observed (Hunter et al., 1996; Goñi et al., 2003a). Eggs are shed across the spermatophoric mass while the female scratches it with the 5th walking leg and the eggs are fertilised; egg extrusion normally takes place in less than two hours (Mercer, 1973). Egg laying peaks in September in the Western Mediterranean (Gamulin, 1955; Campillo and Amadei, 1978; Marin, 1985; Goñi et al., 2003a) and in September-October in the Atlantic (Mercer, 1973; Hunter et al., 1996; Latrouite and Noël, 1997). In Greece, females with eggs have been observed from August to November (Moraitopoulou-Kassimati, 1973). Incubation lasts 4-5 months in the Western Mediterranean (Campillo and Amadei, 1978; Marin, 1985; Goñi et al., 2003a) and 6-9 months in the Atlantic (Mercer, 1973; Latrouite and Noel, 1997; Hunter, 1999). Hatching occurs in January-February in the Mediterranean (Gamulin, 1955; Campillo and Amadei, 1978; Goñi et al., 2003a) and in March-June in the Atlantic (Mercer, 1973; Hunter et al., 1996; Latrouite and Noël 1997). Hatching is normally completed in 24h (Mercer, 1973) but in aquarium may extend up to 8 days (Karlovac, 1965).

In Brittany, mean size of functional maturity (ability to mate and lay eggs) of female *P. elephas* was estimated at around 95 mm CL (Latrouite and Noël, 1997; smallest berried: 92 mm CL). In Ireland**,** Mercer (1973) assessed female physiological maturity by the presence/absence of ovigerous setae and the size at which 50% of animals were mature was 82 mm CL. He estimated males' 50% maturity at 84.5 mm CL.

In the Western Mediterranean**,** a recent study of the reproductive biology of a protected *P. elephas* population concluded that both physiological and functional maturity of females was attained simultaneously at a mean size of 76-77 mm CL (or 4 years of age, Marin, 1987), while males physiological maturity was attained at a larger size (82.5 mm CL) but at the same age (Goñi et al., 2003a). However, Marin (1987) observed a 1-year lag between female physiological maturity (ovary maturation) and functional maturity. On the basis of the relationship between testis weight and body size Marin (1987) estimated male mean size at physiological maturity of 76 mm CL. Discrepancies between the maturity estimates provided by different authors are difficult to explain. However, it is well known that estimates of size-at-maturity differ depending on the maturity criteria used as well as the sampling period, number and size range of the specimens (Chubb, 2000). Furthermore, factors such as food availability, population density, or water temperature are known to influence growth rates and thus size at maturity (Goñi et al., 2003a).

P. elephas is less fecund than other commercial lobsters of the family Palinuridae such as the genus *Jasus* or *Panulirus*. Fecundity of *P. elephas* from the Atlantic was studied by Mercer (1973) and the relationship of number of eggs laid and body size was described by the linear equation: $F = 2552 * CL - 165602$ (n = 254, range: 80-154 CL mm). He estimates egg loss during incubation at 10%.

In the Western Mediterranean the fecundity-body size relationship of *P. elephas* has been studied in the exploited population off Corsica and in the protected population of the marine reserve of Columbretes Islands:

Corsica: $F= 3003 * CL – 229\ 809$, $R^2= 0.97$, n= 24 (Campillo, 1982)

Columbretes Islands: $F= 2428 * CL – 148988$, $R^2= 0.85$, n= 70 (Goñi et al. 2003a).

Absolute fecundity increases with body size up to the maximum size and thus senescence of large females has not been observed. However, maximum relative fecundity in the Western Mediterranean is reached at intermediate sizes (100-110 mm CL) (Campillo, 1982; Goñi et al., 2003a). Factors such as increased variation in fecundity among larger females and small sample sizes (in the case of Campillo's sample) complicate attempts to compare size-specific fecundity among populations (Somers, 1991). Egg loss during incubation of 26-28% was estimated in Western Mediterranean *P. elephas* by Marin (1985) and Goñi et al. (2003a). The lower egg loss estimated by Mercer (1973) in the Atlantic may be due to the influence of lower water temperature and the fact that the animals were collected by hand rather than by nets.

P. mauritanicus

Information on reproduction in *P. mauritanicus* is sparse. According to Maigret (1978) and Boitard (1981) the pink lobster reproduces in late summer and fall. Mating takes place shortly after moulting in the manner described in other Palinuridae and spawning shortly after mating. Egg incubation lasts about three months. Mean female physiological maturity deduced from the gonadal index occurs around 90 mm CL (Boitard, 1981). The smallest berried female observed by Maigret (1978) was 250 mm TL (or 101 mm CL). Although berried females can be found throughout the year, the main spawning season extends from August to January. The fecundity of *P. mauritanicus* appears to be low as Maigret (1978) reported 60 000 eggs in females of 340-380 mm TL (or 140-157 mm CL). Hatching in captivity has been observed to last 14 hours (Maigret, 1978).

Population size and sex structure

P. elephas

Information on population structure is available from data of commercial or survey catches carried out in different regions since the early 1950s. Traditionally *P. elephas* was captured by means of traps/pots and sometimes diving (Hepper, 1977). A major change in the exploitation strategy took place during the 1960s and 1970s with the progressive introduction of trammelnets, which virtually replaced other fishing methods. This change in fishing strategy had an impact not only on exploitation levels, demography and sex ratio of the exploited populations (e.g. Hunter, 1996; Goñi et al., 2003b), but also on the data that may be obtained from the population by sampling commercial catches. Catches are strongly influenced by the selectivity of the gear and gear-related catchability (Goñi et al., 2003b). This together with the discontinuous and scattered nature of the available data hampers temporal and spatial comparisons of populations' size or sex structures.

In Corsica, Campillo (1982) was the first to study the size composition in commercial catches through a sampling programme in 1977. The maximum sizes observed in trammelnet caught females was 160 mm CL and in males 175 mm CL. The mean modal size of females was 95.6 mm CL and that of males 103.7 mm CL. The size composition of the trammelnet catches in Corsica was again established through a two-year sampling program in 1983-1984. Results indicate a strong mode around 75 mm CL in both males and females and a maximum size of 120 mm CL for females and 140 mm CL for males (Marin, 1987). Although Campillo (1982) acknowledged that in 1977 the fishery already showed signs of overexploitation, it seems that until then most of the fishing had been done with traps, and that fishing with trammelnets during the late 1970s and early 1980s had reduced the number of large lobsters in the population. In a study of the selectivity and catchability of *P. elephas* in traps and trammelnets Goñi et al. (2003b) showed that traps used in the Western Mediterranean exclude and thus protect large *P. elephas* (mostly males). The size structure of a population of *P. elephas* 10 years after the establishment of the marine reserve of Columbretes Islands (Western Mediterranean) presented modes around 100 mm CL for females and 100 and 130 mm CL for males. The maximum sizes were 148 in females and 173 mm CL in males (Goñi et al., unpublished) that resembled those of Campillo (1982).

The earliest published data on the structure of Atlantic populations comes from Portugal and dates back to 1958 (de Vasconcellos, 1960). The large size of the lobsters caught was striking, the modal size of males and females was 120 mm CL and the maximum sizes were 190 and 180 mm CL respectively. In 1965-1975 Hepper (1977) conducted a study of the size structure of the commercial catches of pot, divers and trammelnets from Cornwall, where fishing was mostly conducted by pots. Male lobsters caught in trammelnets had mean lengths of 145-160 mm CL (maximum 182 mm CL; max. 195 mm CL in Hepper, 1970) and females 122-134 mm CL (maximum 152 CL, max. 168 mm in Hepper, 1970). Ansell and Robb (1977) also found similar maximum sizes in lobsters caught off Scotland during 1972-1975. However, field observations by Hunter et al. (1996) during 1993-1994 off Cornwall show that the size structure of the Cornish *P. elephas* populations has altered dramatically since Hepper's (1977) study. While the mean size of males had declined to 125.6 mm CL, the females' mean size had not changed (132-135 mm CL). A comparison of the Cornish with the less exploited Welsh populations and with Hepper's (1977) data from Cornwall led Hunter et al. (1996) to conclude that the reduction in the male mean size was due to the change in exploitation pattern brought about by trammelnets replacing pots during the 1970s. In Brittany, no regular sampling has been carried out but available data indicate that few individuals smaller than 100 mm CL are caught, the modal size is 120-140 mm CL and the maximum sizes of females and males were 170 mm and 200 mm CL, respectively (Latrouite and Noël 1997). These large maximum sizes contrast with the overexploited status of the populations in the area.

<u>P. mauritanicus</u>

Size structure data of *P. mauritanicus* commercial or survey catches are rare. The study of commercial landings conducted by Maigret (1978) during 1972-1974 off Mauritania**,** indicated modal sizes of 96 and 119 mm CL (maximum: 217 mm) for males and 83 mm CL (maximum: 195 mm) for females. Experimental catches sampled in 1975 indicated a size range between 77 and 198 mm CL in males and 75-197 cm CL in females. Boitard (1981)**,** who sampled French landings from Mauritania**,** indicated a maximum size of 170 mm CL in males and 155 mm CL in females.

No sampling has been done of the catches resulting from sporadic net fishery off Brittany in the Biscay Bay but commercial data indicates that over half of landings were in the category >2 kg, and that some males were as big as 7 kg corresponding to CL of 155 mm and 245 mm respectively.

Larval ecology and larval settlement

<u>P. elephas</u>

As in all Palinurids, the larvae of *P. elephas* is a leaf-like, transparent planktonic zoea called a phyllosoma which is adapted to a long offshore, drifting life. It is a poor horizontal swimmer, although it is capable of making vertical migrations. During the day the phyllosomas are found in intermediate waters while at night they gather near the surface (Corral, 1968). *P. elephas* larvae at hatching measure 2-3mm TL (Mercer, 1973; Kittaka, 1988) and are carried offshore where they develop through moulting through nine phyllosoma instars of similar morphology (Bouvier, 1914). In the following two moults the larvae undergo metamorphoses, the first of which results in the puerulus that has a well developed abdomen, a translucent exoskeleton and is able to swim. The puerulus migrate inshore with the aid of currents and possibly also by winds (Mercer, 1973). The peurulus moults to the benthic post-puerulus, which measures around 20 mm total length (Santucci, 1926). This is the first juvenile stage and has the appearance and habits of the adult (Hunter, 1999). The duration of the pelagic larval life is about 5-6 months in the Mediterranean (Marin, 1985) and 10-12 months in the Atlantic (Mercer, 1973), although it can be as short as 3-4 months in captivity (Kittaka, 1988).

According to Mercer (1973)**,** eggs hatch inshore where the early larval stages are common. Late larval stages may be found offshore at variable distances (up to 100 miles) and metamorphosis to the natant stage often occurs at a considerable distance from the shore. The post-puerulii are again found inshore. Since the larvae are not capable of swimming large distances, it is thought that water movements control their movements. Mercer (1973) hypothesizes that off Ireland early larvae are carried offshore and caught up in a series of circular slow-moving currents, where larval development continued, and the late larval or puerulus stages are returned by offshoots of the main currents to coastal waters. Considering the ecology of *P. elephas* larvae, it is not surprising that observations of phyllosomas, in particular of the most advanced stages, are rare. In the Atlantic early stages (I-III) have been observed from June and later stages (VII onwards) from July (Mercer, 1973). In the Adriatic different stage phyllosomas have been recorded from December to March (Gamulin, 1955) and in the Western Mediterranean from January to March (Hunter, 1999) and in June (off the Balearic Islands, R. Goñi, unpublished data). Few records of *P. elephas* puerilii exist (Hunter, 1999). Most specimens have been identified in stomach samples of fish predators and the few that have been fished were found in mid water (Bouvier, 1914; Hunter, 1999). From late June to August many hundreds of small juveniles (20-50 mm CL) laying in crevices off Ireland were reported by Mercer (1973). In the North-western Mediterranean, settlement of puerulii takes place in limestone rocks from June to July, a few weeks after sea surface temperature starts to rise. Juveniles concentrate in shallow depths (10-15 m preferentially) and move to deeper waters as they grow (Díaz et al., 2001). Goñi et al. (2001b) postulated that a migration of juveniles takes place from the shallow settlement habitats to deeper habitats, presumably during winter or spring. Apart from these few accounts, the life of post-larvae and juvenile *P. elephas* through adulthood remains almost entirely unobserved.

Comment [DL2]: ?

P. mauritanicus

Maigret (1978) collected one phyllosoma of *P. mauritanicus* in December off Mauritania. It was a stage I larva and measured 2.9 mm TL. The almost total absence of larvae of this species in the plankton during the months of January to April (reproductive period: August-January) suggests that phyllosomes are probably offshore from the continental shelf. Maigret (1978) reports that fishermen have observed phyllosomes hanged on their pots and he suggests that the larvae could possibly develop near the bottom. No studies have addressed the settlement of *P. mauritanicus*.

Natural mortality

<u>P. elephas</u>

As with many other species of lobster, the natural mortality of *P. elephas* is probably caused primarily by predation, in particular during moulting and during the juvenile stages (Marin, 1985). Both the octopus (*Octopus vulgaris*) and the dusky grouper (*Epinephelus marginatus*) are known predators of *P. elephas* in the Western Mediterranean (Quetglas et al., 2001). Other known fish predators in the region are *Labrus* spp., *Scorpaena* spp., and *Serranus* spp. (Marin, 1987). A study of *P. elephas* diet did not reveal cannibalism in natural conditions (Goñi et al., 2001a) although it has been observed in captivity (Marin, 1987). Based on knowledge of the life cycle of the species – slow growth, large size – Marin (1987) estimated the coefficient of natural mortality of *P. elephas* to range between 0.15-0.3. Hepper (1977) estimated the instantaneous coefficient of natural mortality of *P. elephas* in the Atlantic by mark-recapture experiments at 0.11. Estimates of natural mortality in the protected population of the Columbretes Islands derived from length data and the growth parameters in Marin (1987) suggest higher natural mortality rates in females than in males (Goñi et al., unpublished data).

<u>P. mauritanicus</u>

There is no information available.

Fisheries

FAO statistics for the period 1984-1996 register landings specifically for *P. elephas* and *P. mauritanicus* only in France (and they are underestimated). In all other European and African countries where landings of those species are given, they are registered as « Palinurus spp ». These cumulative annual landings range between a maximum of 8710 t and a minimum of 4242 t and show a decline between 1988 to 1996. Unfortunately, no confidence can be afforded to any of these figures, which may be overestimated (rarely), underestimated, irregularly reported (most countries) or absent (several countries). Published information on *P. elephas* fisheries is scarce. Thus, we present summaries of the information, published and unpublished, available to the authors on some national *P. elephas* fisheries. There may be other fisheries of some biological or socio-economic importance that have not been studied and that are not covered here. Despite the lack of reliable data series, all evidence indicates that *P. elephas* populations declined rapidly during the 1960s to 1980s and that now most, if not all, are overfished or depleted (Massuti, 1973; Marin, 1985; Petrosino et al., 1985; Latrouite and Noel, 1997; Hunter, 1999; Gristina et al., 2002; Quetglas et al., in preparation).

French fisheries before 1960

According to several authors (Dupouy, 1920; Postel, 1962; Gloux and Manach, 1976), while *Palinurus elephas* was appreciated and marketed in France for several centuries, directed fisheries really started at the end of the 19th centrury when a small specialised fleet developed in Brittany and fished grounds around the islands of Sein, Belle Isle and Houat in Britanny, Yeu and plateau de Rochebonne in Biscay Bay. In the beginning of the 20th century this fleet progressively expanded to distant waters: Scilly Islands (SW England) after 1901, off the Iberian Peninsula (Atlantic coast) after 1906, Berlingues Island and rocky grounds between Figueira and Saint Vincent Cape off Portugal after 1910, Ireland and Scotland after 1919, and Atlantic Morocco later. In 1935, fishing moved also to Tunisia (plateau de la Galite). In most areas, they also caught clawed lobster *Homarus gammarus*. In the Western Mediterranean, a small-scale fishery also developed around Corsica at the end of the 19th century and accounted for 215 boats (landings 140 t) in 1900 and 331 boats (landings 229 t) in 1948 Marin (1985).

Figures issued by the Administration and/or Industry report national landings for both Atlantic and Mediterranean fisheries of over 1000 tons of *P. elephas* in the 1920-1925, a maximum of 2678 tons in 1947 and a continuously decreasing production thereafter with a mean of 867 tons in the 1950's. Landings for the periods 1906-1914 and 1926-1937 were around 1500 t and 2200 t respectively (max 3230 t in 1928) but they include both *P. elephas* and *H. gammarus.* Data on fishing effort for the period are incomplete and imprecise. In Brittany, the main port for spiny lobster, Camaret, harboured a dedicated fleet of 170 boats in 1914 and 209 in 1937, fishing from May to November (largest boats started in February) with string of pots. In some ports (Roscoff, Santec, Moguériec) of North Brittany a restricted fleet targeting spiny and clawed lobsters appears to have used nets after 1920 and, according to Gloux and Manach (1976), this gear was qualified as « devastating gear which seem to have largely contributed to the depletion of stocks ».

French fisheries after 1960

In the Atlantic, due to the closure of some foreign zones and to an impoverishment of the stocks of both *P. elephas* and *H. gammarus*, most vessels (Brittany) shifted in the 1960's from lobster to crab (*Cancer pagurus* and *Maja brachydactyla*) fishing. Currently *P. elephas* is primarily a by-catch, while economically important, for some 150 boats (mean length 11.8 m, mean power 152 HP) netting for monkfish (*Lophius piscatorius),* rays (*Raja spp.*), turbot (*Psetta maxima)* and brill (*Scophtalmus rhombus)* with trammelnets of 240-320 mm stretched mesh (inner panel). Catches from potters (1%) and trawlers (<5%) are incidental. Landings occur all year round but 80% occur between April and November. The only regulation specific to *P. elephas* is a minimum landing size (MLS) of 95 mm CL (EC regulation). There is also a 10 km limit per boat on the length of nets in Brittany.

Comment [rg3]: Is this correct? Is there a closed season during the winter?

In the Mediterranean, introduction of more efficient fishing methods in the 1960's (ecosonders, net-haulers, nylon trammelnets) led to a substantial effort increase (Giménes, 1969) which was accompanied by a sharp decline in catches (minimum of 45 t in 1965). According to Marin (1987), 165 boats (average 4 GRT and 49 HP) were devoted to lobster fishing in 1985. Presently there are about 200 boats in the fishery. These have a mean length of 8 m and a mean power 80 HP and operate within 3 miles of the coast with trammelnets, locally called "bistinari", of 125-160 mm stretched mesh (inner panel). A few larger vessels occasionally fish for lobster in deeper waters. The MLS is 80 mm CL, the fishery is closed from September to March and eight sanctuaries covering a cumulated area of about 80 km^2 are distributed around the island.

Official figures for national landings from Atlantic and Mediterranean fisheries report an average of 520 tons in the 1960's, 360 tons in the 1970's, 290 tonnes in the 1980's, 160 tons in the 1990's, 60 t in 2000 and 70 t in 2001. Reliability of those data is probably very poor. In Corsica Marin (1987) estimated annual landings of 154-222 t in 1983-1984 while official statistics reported 83-88 t, 127 t in 2000 and 117 t in 2001 (according to Industry figures). No detailed estimates of landings are available for the Atlantic fisheries but probably were around 100 t in the mid 1990s, falling to 50-60 t in 2002.

The collapse of the fisheries linked to excess fishing effort, especially with nets, directed or not, is evident and any recovery will have to go through a series of strict measures including global and zoned limits on nets. The current mean price of *P. elephas* is around 35 € /kg.

Spanish Fisheries

Lobster fishing also has a long tradition off the Atlantic and Mediterranean coasts of Spain (Von Salvador, 1895; Iglesias et al., 1994). Presently, *P. elephas* fisheries are mostly restricted to the Mediterranean while in the Atlantic the species is caught as bycatch in finfish gillnet fisheries. In the Spanish Mediterranean, over six hundred artisanal vessels and some 1100 fishermen engage in lobster fishing every year (Alarcón, 2001). The fishery is regulated by an annual 6-month closure during the egg bearing period (September to February), a MLS of 80 mm CL and a ban on catching berried females.

Massuti (1973) collected catch and effort data of the lobster fishery in the Balearic Islands from 1940-1970. Mean annual catches in the period 1940-1945 were around 90 t and declined to 40-50 t in the period 1950-1955 and to 20 t in the period 1965-1970 while fishing effort tripled. As trammel nets replaced traps at the end of that period catches increased. It is suspected that fishing mortality rates have increased in all grounds and that most fisheries are overexploited (Quetglas et al., in preparation). As no reliable fishery statistics are available, it is not possible to estimate exploitation levels. However, the high recapture rates of lobsters (up to 61%) released in grounds near the Columbretes Islands (Western Mediterranean) suggest high rates of fishing mortality in that area (Goñi et al., 2000).

Trammel nets are soaked 48 hours (weather permitting) preferably between 50-100 m of depth. Trammel nets are set in gangs of 10-12, 50-m long and 1.7-m high net pieces. The mesh size of the inner panel is about 80 mm. In Spanish *P. elephas* fisheries, trammel nets have replaced traps in most areas, as nets are able to catch more fish, which compensates for declining lobster yields. A relict lobster trap fishery remains in traditional lobster fishing grounds of the Balearic Islands.

By-catch and discards rates are lower in trap than in trammel net lobster fisheries (Goñi et al., 2003c). The most common by-catch species in the Mediterranean trammel net fisheries are scorpionfish (*Scorpaena scrofa*), rays (*Raja* spp.), and dogfish (*Scylliorhinus canicula*) (Quetglas et al., in preparation). Lobster under the size limit (<80 mm CL) make up 24-46% of the catch (in number) and are usually returned to the water in good condition (Quetglas et al., in preparation).

Official landings in 2000 amounted to some 2 t in the Atlantic and around 98 t in the Mediterranean. However, ongoing studies of some local fisheries in the Mediterranean indicate that official landings underestimate lobster catches because significant but variable portions of the catch are sold directly to consumers (mostly restaurants) and go unreported. Use of correction factors developed for particular locations suggest that annual *P. elephas* landings in Spain reach at least 200 t, which at the price of 42 € /kg, first sale, amount to €8.5 million per year to the fishers. Additionally, a similar amount may be earned annually by the middlemen and the tourist industry (restaurants) together.

Greek Fisheries

An important artisanal fishery currently exists in Greece (about 18,000 small coastal fishing boats; CENSUS-Ministry of Greek Agriculture, February 2001). However, the number of vessels involved in the lobster fishing activity is not known. In Greek waters, *P. elephas* is caught together with *H. gammarus* mainly by nets (trammel nets or gill nets) (66% of the catch) (Mytilineou et al., submitted). Lobsters are also caught by trawlers as bycatch (32%) and traps are no longer used. The mesh size of the inner panel of trammelnets is 34-40 mm (or 36-45 mm in the protected area of the Alonissos National Park). The gill nets, more resistant than trammel nets and providing fewer by-catch specimens, are primarily used in the Alonissos National Park fishery and have a minimum mesh size of 110 mm. The maximum length of nets per boat is about 9000 m (8000m in the Alonissos Park). Depending on the area, the nets remain in the water 2-3 days; in the Alonissos National Park the nets remain in the sea only one night (Mytilineou, pers. comm.). The fisheries are regulated by a MLS of 85 mm CL, the prohibition of landing berried females and a 4-month closed season from September to December (or September to March in the Alonissos National Park). Undersized and berried lobsters are to be returned to the water although often this regulation is not respected (C. Mytilineou, pers. comm.).

The landings of lobsters from the Greek waters include *P. elephas* and *Homarus gammarus* in a proportion of about 80% and 20% respectively and are higher in the Aegean than the Ionian Sea (Mytilineou et al., submitted). The greatest landings occur off the Spodares Isl., Corfu Isl. and Cyclades Isl. The mean annual landings for the 1990’s have been estimated at 200 t (Mytilineou et al., submitted). For the same period, the official figures are 23 t, indicating that a large amount of lobsters goes directly to the consumers or restaurants (Mytilineou et al., submitted). The mean annual price of lobsters in the wholesale market showed a positive trend in the 90s’, reaching €12 in 1999 (Mytilineou et al., submitted) and €21 in 2001 (C. Mytilineou pers. comm.).

Italian Fisheries

No information is available on *P. elephas* fisheries at the national level. However, fishing for *P. elephas* is very important in Sardinia where the fishery started at the end of the 19th century. At the beginning, fishing was carried out mainly by traps and since then spiny lobster catches have continuously increased. Presently about 253 artisanal boats exploit this resource with trammels nets at depth of 50-200 m. Only two fishermen still use traps for *P. elephas* fishing in the island. The boats are small (7-10 TRB). During the 1970s increased fishing effort led to a depletion of stocks and at present mean yields are lower than those recorded in the 1920' and 1970's.

In Southern Italy (Golfo di Taranto and Sicily) *P. elephas* were caught exclusively with traps until the 1950s when they were replaced by trammelnets (Petronsino et al 1985; Gristina et al., 2002). Nets are left in the water for 2-3 days and maximum yields are found at around 90m depth. According to old fishermen from the Egadi Islands, in the 1950s *P. elephas* was very abundant and trap yields were large. Presently trap yields are almost zero.

The minimum landing size in Italy is 300 mm TL (or 107 mm CL), the fishery is closed from January to April and berried females are returned to the water. (Gristina et al., 2002) although compliance with these regulations may be poor (Petrosino et al., 1985; M. Gristina, pers. comm.). There are no limits on the length of nets. *P. elephas* is sold at 50 € / kg. According to Petrosino et al. (1985), the technical innovations introduced in the 1960s have led to overfishing of the *P. elephas* stock off the Ionian coast.

Tunisian Fisheries

In Tunisia the production of *P. elephas* comes mainly from the fishing grounds of La Galite and the Esquerqis and secondarily de L'Estafette and from Cap Serrat and Cap Blanc (Tijani, 2000). At present the Tunisian lobster fleet is composed of 56 vessels (mean: 14m long; 149 HP). Lobster used to be fished with traps but now trammelnets -75 mm-stretched mesh size (inner panel) – are used. The fisheries take place at 20-170 m depth and preferentially at 70–80 m (Quetgals et al., in preparation). The lobster fleet grew rapidly between 1990 and 1995, when over 80 vessels fished lobster, and declined afterwards to 60 boats in 1998–1999. The number of days at sea also increased between 1990 and 1995 with a peak in 1993 and have remained constant at about 3000 days since then. Annual landings in the period 1990–2002 peaked in 1993 with a maximum 74 tons. Since then, lobster catches have decreased progressively to a minimum in 2002 when only about 33 tons were landed (Tijani, 2000). Lobster fishing is regulated by an annual closure from mid September to February, a MLS of about 200 mm TL, a prohibition of landing berried females (Tijani, 2000). In terms of weight *P. elephas* fishing constitutes only 1% of the total landings but its economic value approaches 10% of the Tunisian total (Tijani, 2000). The populations are considered overexploited and protective measures - such increases of the MLS, extending the closed season and reintroduction of traps – are being proposed (Tijani, 2000).

Croatian Fisheries

In the eastern Adriatic *P. elephas* is found at depths of 20-120 m. The most important fishing areas are in the southern sides of offshore islands (Soldo et al., 2001). High product value, small catches and multiple fishing gears characterize the commercial lobster fishery in the area. Historically, *P. elephas* was caught using lobster pots and gillnets. In recent years, and due to deficient legislation, new fishing gears have been introduced in the fishery and lobster gillnets with 240 mm mesh size were replaced by 120 mm mesh gillnets, originally employed for fishing cartilaginous fishes, and by trammel nets of 80 mm mesh in the inner panel (Soldo et al., 2001). According to the legislation, the lobster fishery is open from May to September and the minimum landing size is 240 mm TL (88 and 84 mm CL in males and females). Additionally, berried lobsters must be returned to the water regardless of the size (Soldo, in prep.) Reported landings were highest in 1953 at 83 t, while in the period of 1985-1998 annual landings ranged from 23 to 43 t. Although in the last decade official landings have not declined, all evidence (fishermen, inspections, market) indicated that the lobster resource is heavily exploited and that total catches, average length and CPUE have declined considerably (Soldo, in prep.).

British Fisheries

In the UK, targeted *P. elephas* fisheries are restricted to Cornwall and the west coast of Wales with occasional catches from the Scottish Western Isles (Hunter, 1999). In common with fisheries elsewhere, the species was traditionally fished with pots (and diving), and although traps are still used in some areas, tangle and trammel netting is now the principal means of capture. Pot CPUE declined steadily during the period 1979 to 1997 and the populations are depleted (Hunter et al., 1996).

Irish fisheries

P. elephas is fished in Ireland between May-September. Presently approximately 20-25 vessels target this species although by-catch in static net fisheries and to a lesser extent in trawls also occurs. As in other countries a major change in the fishery occurred during the 1970s in the change over from traps to trammel nets. This lead to a depletion in stocks and a very significant reduction in mean size. Annual official landings between 1990-2000 ranged from 33-175 tonnes. Landings have declined continuously during the period. MLS is currently 110 mm CL and there are 2 areas closed to fishing with nets. Attempts are being made by the authorities to revert to fishing with pots. Unit price at first sale varies seasonally but on average is about €30/kg.

Fisheries for P. mauritanicus

The main commercial fishery for *P. mauritanicus* is off northwest Africa. At its inception, this fishery was mainly operated by Spanish and Portuguese boats trawling for fish but catching *P. mauritanicus* on grounds as shallow as 40 m depth. In 1955 a French dedicated fishery developed along the Mauritanian coast and in the first years of the 1960s more than 40 boats (length 25-38 m, TRB 100-390, HP 500) from Brittany were fishing with cylindrical baited traps and with bottom trawls that served both to catch fish bait and lobsters (Maigret, 1978). Most fishing took place on the continental shelf edge at 150-300 m and occasionally down to 600 m. French landings peaked at 3600 t in 1961 which corresponds to a total catch of 4000 t when onboard storage mortality is included. CPUE dropped quickly and fishing grounds shrank substantially due to, according to Maigret (1978), both overfishing and habitat deterioration by trawlers. In the following years, the fishery collapsed despite a reduction in fishing effort, and French landings declined to 200 t in 1970 (Maigret, 1978). In the 1970s the stock recovered somewhat and in 1986 French landings reached 900 t (10 boats), which were in accordance with the calculated maximum sustainable yield (Boitard, 1981). Allocation in 1987 by the European Commission of fishing rights to Portuguese boats for lobster netting (in the form of direct agreements with the Mauritanian authority) and the development of poaching led rapidly to a new collapse and French boats left the fishery. No recovery has occurred in recent years.

Off Brittany, in the Bay of Biscay, sporadic *P. mauritanicus* netting occurs by one or two boats on coral grounds at 300-400 m depth but good grounds are very limited and a rapid decrease in catch rates occurs. Trawlers also occasionally land *P. mauritanicus* as bycatch.

In the western Mediterranean, the commercial importance of the species is not very high and it is regularly taken by bottom trawlers as bycatch (Holthius, 1991). It is also occasionally targeted with trammel nets; however, high yields followed by low catches characterize this fishery. It is marketed together with *P. elephas* but it commands lower prices. No catch statistics are available for this species and the figures given for *Palinurus* spp. in the FAO yearbook of Fishery Statistics correspond to mixed catches.

Recruitment

P. elephas

A virtual population analysis carried out by Marin (1987) indicated that in the trammel net fishery off Corsica *P. elephas* recruited at 40 mm CL (or age 2) and that by 70 mm CL (or age 3), just before maturity, lobster were fully recruited to the fishery. He estimated the number of recruits at 458 000-801 000. Estimates on *P. elephas* recruitment are not available for other areas.

P. mauritanicus

Maigret (1978) estimated that *P. mauritanicus* recruited to the fishery off Mauritania at 73-82 mm CL (or age 5 for males and 6 for females).

Catchability and selectivity

P. elephas

Virtual Population Analysis (VPA) results by Marin (1987) indicated that in the trammel net in the Corsican fishery, mature females were less catchable than mature males and that their catchability decreased with size. This reduction in catchability of females was attributed to either a sharp increase in natural mortality of females after maturity or more probably a change in behaviour associated with reproduction. However, in a comparative study of the catchability of *P. elephas* in traps and trammel nets, Goñi et al. (2003b) demonstrated similar catchability of males and females in trammel nets and reduced catchability of large males in traps. Thus, the reduced catchability of mature females in the trammel net fishery observed by Marin (1987) could be associated with a higher natural mortality of females after maturity relative to males.

Comparing selectivity of traps and trammel nets, the same study indicated that while *P. elephas* <70 mm CL are poorly retained in traps, large (>130 mm CL) specimens are less likely to enter traps due to behavioural factors, physical limitations or because they are able to feed without entering (Goñi et al., 2003b). Since recruits and large specimens would suffer lower fishing mortalities in traps than in trammel nets, the study concluded that traps are a preferable means of capture from the point of view of conservation. Ongoing studies also demonstrate that by comparison with traps, trammel nets have poor selectivity with higher by-catch rates and much greater negative impact on lobster habitats through the incidental catch of structure forming species, such as sponges, bryozoans, corals and coralline algae (Goñi et al., 2003c).

<u>P. mauritanicus</u>
No information is available.

Discussion

The high unit value together with the biological and ecological characteristics of *Palinurus* spp. in the Eastern Atlantic and Mediterranean indicate that they are highly vulnerable to fishing. *P. elephas* is slow growing, has a long life-span and low fecundity by comparison with most other commercial spiny lobsters. Adults movements are small in scale. These biological characteristics make *P. elephas* prone to local overexploitation. Although nothing is known about the stock-recruitment relationship in either *P. elephas* or *P. mauritanicus*, the pelagic larval stage of *Palinurus* spp. is long and dispersal by ocean currents may be extensive. As recruitment may occur far from the parental grounds, decoupling between local spawning stock biomass and recruitment is likely.

These statements are supported by the current status of the fisheries. Targeted fisheries in the Atlantic have largely disappeared and the stocks are overfished in the Mediterranean. The poor status of *P. elephas* fisheries may be traced back to the 1960s-1970s, when fishing effort increased dramatically coincident with the replacement of pots (and diving) by trammel nets and the introduction of hauling gear and other technological advances. Although the lack of historical catch and effort data means that this hypothesis cannot be tested all circumstantial evidence point to the greater efficiency of nets in catching lobsters, to excess fishing effort and to the poor selectivity of trammels nets relative to pots, as the main causes of the collapse in these fisheries. The problem is exacerbated by the fact that lobsters are also a substantial by-catch in nets targeting monkfish, rays, turbot, brills, etc. Recent and ongoing studies indicate that trammel nets catch a greater proportion of large lobsters than pots and that their impact on lobster habitats and benthic communities is far greater. Palinuridae species in Europe are fished by a large number of artisanal vessels typically distributed in many ports along the coastline. Thus, at-sea effort control of *P. elephas* fisheries is difficult and in general, the limits on net length per boat are usually exceeded. Additionally, while pots had to be hauled every day to restock the bait, trammel nets are left in the water for 2 or more days. Due to bad weather conditions, nets are often soaked for longer periods resulting in loss of catch and return of undersized specimens to the water in poor condition.

The minimum landing size of *P. elephas* in Mediterranean fisheries is just over the size of physiological maturity. A recent study of the reproductive potential of a protected population of *P. elephas* shows that such MLS protects only about 1% of the potential population egg production (Goñi et al., 2003a). Lacking estimates of fishing mortalities, and thus a full assessment of the impact of various MLS on the reproductive potential of *P. elephas* populations, the study points to the need to increase the MLS to allow specimens to reproduce a minimum of once or twice before becoming susceptible to fishing. However, larger MLS in some fisheries (eg. Croatia) alone does not appear to have protected the populations from overfishing. Similarly although the MLS in France is above the size at maturity stocks have not recovered. The recently introduced high MLS in Ireland has not yet had time to have effect on recruitment to the fishery. Certainly a larger MLS may be a necessary technical measure in the Mediterranean and in areas there it is below size at matirity but this alone is insufficient to protect stocks. As the relationship between local spawning stock and recruitment is probably decoupled by the long dispersal phase expectations of postive impact of improved regulations may not be realised. More stringent regulations need to apply consistently over large areas of the distribution to optimise the possibility of local and regional improvements in recruitment.

The lack of data prevents discrimination between increased fishing mortality resulting from greater fishing effort associated with trammel netting and the ensuing changes in size and sex related catchability as the factors responsible of the depleted status of *P. elephas* fisheries. As a high value commodity, *P. elephas* continues to be pursued despite low yields and rapidly growing prices maintain viable but depleted fisheries. Because of that, fishermen are requesting managers to impose more restrictions to help rebuild the stocks (Hunter, 1996) and additional measures, such as closed areas (Goñi et al., 2001b), areas open only to pots and programmes to promote the reintroduction of pot fishing should and are being considered in some areas (e.g. Balearic Islands and Ireland.

Much less information is available on the the biology and fisheries for *P. mauritanicus*. However, its high unit value and the history of depletions of the fisheries off West Africa suggest low resilience. Its distribution over muddy bottoms, despite the greater depths where it occurs, and the rapidly declining catch rates, suggest high catchability in both trawls and tangle nets.

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The biology and fisheries for Palaemon serratus and Palaemon adspersus

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Description

P. adspersus and *P. serratus*

Mature specimens of *P. adspersus* have a mean length of 58 mm (females) and 52 mm (males). The average size for both sexes according to FAO is around 60 mm. The species is characterised by a rostrum with 5-6 dorsal spines and 4 or rarely 3 dorsal. The number of the dorsal spines is a classification characteristics for the species *Palaemon adspersus*. The colour of the shrimp body is grey-pink with brown or red lines on the carapace and dots on the abdomen.

Sexual dimorphism is not clear. In general, the sexes can be separated by observing typical anatomical features such as the presence of "appendix masculine" in the males and the position of the gonad duct on the base of the 5th or 3rd walking leg.

Mature female *P. serratus* can attain a total body length of 110 mm. The rostrum has a distinct upward curve with a normally bifid tip and 6 dorsal teeth and 4-5 ventral teeth. The rostral features are diagnostic for specimens over 25 mm in length.

Comment [DL4]: according to Campillo : 7 to 11 dorsal teeth and 4 to 6 ventral ; rostrum is relatively longer for males than females.

Distribution

Four species of *Palaemon* (Suborder Natantia, Infraorder Caridea, Family Palaemonidae) occur in the north east Atlantic and Mediterranean ; *P. elegans*, *P. serratus*, *P. longirostris* and *P. adspersus* (Smaldon et al 1993). *P. serratus* and *P. longirostris* have a more southern distribution than *P. adspersus* and *P. elegans*. The former 2 species reach their northern distribution limits in Ireland and Britain while the latter 2 species are common in south west Norway and the North Sea. Maximum lengths vary from 63 mm in *P. elegans* to 110 mm in *P. serratus*.

The geographic distribution limits of *P. adspersus* are : the Black Sea and Mediterranean coasts from the east, the Atlantic coasts of Europe down to Morocco to the west, the 54th parallel (South England and Denmark) to the north and the north African coasts to the south. The species is endemic within this geographic region.

The species inhabits brackish waters as well as hyper-saline waters in lagoons and river deltas/estuaries. It prefers mud bottoms in which it can burrow. The larval stages are found in waters with variable salinity and prefer high temperatures. The salinity tolerance of the species is between 4-6‰ as well as open sea water salinity (>33‰). The shrimp prefers shallow coastal waters down to 5m depth even though in the Atlantic region, it can be found in deeper waters.

P. serratus ranges from the Danish coast in the north Sea southwards to the Mediterranean, Black sea and coast of Mauritania. In Britain and Ireland it is most abundant on south and west coasts although it has become increasingly common in the Irish Sea and North Sea.

Palaemon spp

Palaemon spp. live in shallow water from the intertidal zone to 60 m depth. The habitats they occupy is dependent to some degree on the presence of congeneric species. *P. adspersus* and *P. serratus* in particular can displace *P. elegans* from seagrass meadows and *Fucus* habitats in the shallow sublittoral. *P. adspersus* occurs mainly in seagrass (*Zostera marina* in northern Europe and *Cymodocea nodosa* in the Mediterranean and is associated with estuarine conditions. *P. serratus* is less tolerant of low salinities and occurs generally in brown algal belts (*Fucus* and *Laminaria*) and in sea grass in tidal areas with high salinity. At higher latitudes some species at least undertake small scale offshore migrations in winter. These migrations may be to avoid low winter temperatures and are also linked to the reproductive cycle whereby a move to deeper water and more stable temperatures reduces egg development times and allows the larvae to be released in open water avoiding exposure to fluctuating salinities.

Spatial segregation of year or size classes occurs to some extent in *Palaemon* spp. Post-larvae settle into intertidal areas and undergo seasonal or shorter term migrations to deeper water. Migration to deeper water in *P. serratus* begins with the onset of maturity. Mean size can vary over small spatial scales and depths due to local aggregation of particular size groups in specific habitats. Local habitat quality may have an effect on the migratory behaviour and average size of shrimp.

Growth and reproduction

Palaemon species are relatively short lived having a life span between 1-4 years depending on latitude or environmental temperature. The timing of key events in the life cycle varies with latitude. Growth rates depend mainly on environmental temperature and probably food availability. Growth is faster and life span is shorter at lower latitudes. Males grow more slowly and reach smaller size than females. The intermoult duration is linearly related to pre-moult size at a given temperature and is related as a negative power function to temperature at any given size. Large female size is a trade off between increased risk of predation and higher fecundity. Males remain smaller to reduce the risk of predation and energetic costs of locomotion.

P. adspersus

Most biological information on this species originates from Messolonghi-Etolikon lagoon in west Greece. The species is not found in the Ionion sea except in certain areas with muddy sediments in estuaries of large rivers. In addition information has been derived by experimental rearing in laboratory installation of the National Centre for Marine Research (Athens).

The total length-weight relationships for males and females respectively, are:

$$W=0.000004\ TL^{3.20},\ r^2=0.996$$

$$W=0.000005\ TL^{3.12},\ r^2=0.991$$

Growth is extremely fast and the longevity of the species is no longer than 36-45 months. The length attained by males and females in 6 month increments is summarised in Table 1.

Table 1. Growth rate at age of male and female P. adspersus in Greek waters.

Age (months)	Males	Male daily rate of growth (mm/day)	Females	Female daily rate of growth (mm/day)
6	21	0.12	21	0.12
12	24	0.07	24	0.07
18	36	0.06	39	0.07
24	39	0.05	42	0.06
30	45	0.04	51	0.06
36	48	0.04	54	0.05
42	52	0.03	60	0.04

In the literature 5 gonad maturity stages have been described. However, ova development is continuous and does not occur in phases. The stages are: immature (ovaries like transparent threads), under development (3 lobed ovary covers the 1/5th of the carapace and is transparent), pre-mature individual (green ovary large covering ¾ the dorsal part of the body), mature

Comment [DL5]: 5 stages (not 6) are listed below.

individual (the ovary is green and covers the whole body as well as covers the front part of the stomach) and spent individuals (indiscernible gonads, slightly larger than immature gonads).

The annual sex female to male sex ratio has been calculated at 1.08.

Comment [DL6]: male / female ?

P. serratus

Mating takes place after moulting when the female is soft shelled. Eggs are dark green in colour when spawned. In northern Europe spawning occurs in late autumn and early winter although the timing is size related, large females spawn earlier than small females and depends on location. The rate of egg development is temperature dependent and is 3.5 months at 12C (Phillips 1971). Larvae are released from April –September with a peak in abundance in July and August and occur in coastal surface (<0.5 m) waters (Figueras 1987). Females moult after the eggs hatch and may produce 2-3 broods per year. Settlement onto the shore occurs from July to September at a total length of 9 mm. Considerable growth occurs in the first summer and a proportion of this cohort enters the fishery as 0+ shrimp in their first autumn. Growth during winter may cease or continue at a low rate depending on location. During the second summer growth is higher in non-reproducing 1+ females than in those that attain maturity. Shrimp not maturing until they are 2+ have larger clutches. There is a trade off between early maturation, increased risk of predation, overwintering mortality but higher future fecundity for survivors. In the Mediterranean growth rates can be double those in northern Europe and maturity can occur during the first year (Rodriguez 1981).

Comment [DL7]: m ?

In northern Brittany the largest males weigh 7 g and females 15 g. Females have larger moult increments. Von Bertalanffy growth function where Lc is the carapace length from tip of rostrum is in Table 2. The number of eggs at stage 1 (short after spawning) is related to carapace lenght (Table 2).

Comment [DL8]: something missing ?

Environmental constraints on survival

The northern limit of *P. serratus* is probably limited by temperature. Tolerance to low temperature is significantly affected by acclimation temperature (Richard 1978) and increases with increasing body size. Acclimation at temperatures near the lower limits of tolerance however confers no advantage when exposed to even lower temperatures. Low winter temperatures in particular may therefore be lethal to postlarvae and the 0+ age group which are distributed in the littoral and shallow sublittoral in autumn and early winter. Growth of small shrimp is particularly affected by low temperature. Optimum temperature for growth is 22^{o}C (Richard 1978) which is considerably higher than average summer temperatures in northern Europe. Low salinity combined with low temperatures may be particularly lethal as osmoregulation in low salinity is impaired by low temperature. Metamorphosis is possible over a salinity range of 13-43 gL^{-1} between temperatures of 17-25^{o}C (Yagi and Ceccaldi 1984, 1985). *P. serratus* can grow and reproduce in salinities ranging from 40-45 gL^{-1} and at temperatures of 15-25^{o}C (Rodriguez 1981). The data above do not include the possibility of genetic adaptation by some populations to local conditions.

Population structure

Berglund and Lagercrantz (1983) found evidence for restricted gene flow *in P. adspersus* and *P. elegans* suggesting population differentiation at regional if not local scales. Larval dispersal can promote gene flow. Larvae, however, are distributed in coastal embayments and appear to be neustonic. This vertical distribution may be an adaptation to promote onshore drift by taking advantage of summer sea breezes and so limit alongshore dispersal and loss of larvae to oceanic waters. Adults undertake limited migrations to deeper waters during winter in northern Europe but mixing of populations is probably limited. The duration of the larval phase depends on temperature.

Table 2. Biological characteristics of Palaemon serratus by region

	REGION						
STATISTIC	**south Ireland**	**west Ireland**	**N Wales**	**Plymouth, England**	**Cadiz, SW Spain**	**Ria de Vigo, NW Spain**	**France**
Size-Weight Relationship (M&F)	y=-12.55+3.14x	y=-4.9966+3.0829x			y=-4.9309+2.9146x *	NA	
Size-Weight Relationship (M)	NA	NA			y=-5.0215+2.9618x*	NA	$W = 446*10^{-6}L_{ct}^{2.48}$
Size-Weight Relationship (F)	NA	NA			y=-4.7626+2.8174x*	NA	$W = 177*10^{-6}L_{ct}^{2.82}$
Von B (M)	NA	NA			NA	97.84(1-e^-0.73(t+0.05)) *	$Lc = 45.52[1-e^{-0.66(t+0.37)}]$
Von B (F)	NA	NA			NA	137.40(1-e^-0.48(t+0.09)) *	$Lc = 56.44[1-e^{-0.545(t+0.20)}]$
Von B (M)	NA	NA			NA	5.41(1-e^0.73(t+0.05))^2.58 *	
Von B (F)	NA	NA			NA	21.58(1-e^0.48(t+0.09))^2.92 *	
Other Growth Models	NA	NA			NA	NA	
Moult Increment	NA	NA			NA	NA	
Natural Mortality	NA	NA			NA	NA	
Size-Fecundity	NA	1950-3530		1500 -4300	NA	NA	$F = 0.1185 Lc^{2.747}$
Size-Maturity (F)	60-70 mm TL	81 mm (TL)			82 mm (TL)	NA	
Age at Maturity	Mostly 1+	NA			1+	NA	
Egg Incubation Season	Oct to July	Oct-June	April-July	Dec-July	Dec to Feb	NA	
Egg Incubation Period	Nov to April	4 months **	2.5 M	4 Month@ 9-11 C	NA	NA	
Hatching Season	Summer	April to May		July	Mar to ?	April to Sept	
Longevity	Usually 2+	2,3	4-5 Years	2+	NA	3	
Main Growth Period	July-Nov	NA		July to November	May to Oct	NA	
Reference	Fahy & Gleeson (1996) Fahy *et al*. (1998)	Browne (2000)	Cole (1958)	Forster (1951 & 1959)	Rodriguez (1981)	Figueras (1986 & 1987)	
Notes	* Lt/Wt is Logged	* Lt/Wt is Logged		* After 2nd Summers growth	* Lt/Wt is Logged	* t=years; Wt=Gr; Lt=mm	Campillo(1984)
		*Wet Wt used			* Lt-Wt made from original data in paper		
		** De Bhaldraithe (1971)					
		*** Mc Padden (1976)					

Table 2b. Biological characteristics of Palaemon adspersus by region

STATISTIC	west Greece	Spanish Med	NW Spain	Denmark
Size-Weight (M&F)				
Size-Weight (M)	0.000004*TL^3.20 (r2=0.996)	y=-12.3114+3.1981x *		
Size-Weight (F)	0.000005*TL^3.12 (r2=0.991)	y=-12.6841+3.3210x *		
Von B Length (M)	Lmax=78.286(1-e^0.272(t+0.57))^3.19	K (per annum)=1.9	Lt=44.91(1-e^-1.64(t+0.07))	
Von B Length (F)	Lmax=104.81(1-e^0.216(t+0.45))^3.12	K (per annum)=1.8	Lt=68.19(1-e^1.07(t-0.05))	
Von B Weight (M)	Winf=43.4g		Wt=0.92(1-e^-1.64(t+0.07))^2.95	
Von B Weight (F)	Winf=54.3g		Wt=4.00(1-e^-1.07(t-0.05))^3.17	
Growth(mm/day) (M)	G=0.0010+2.08199/L			
Growth(mm/day) (F)	G=0.0213+1.62417/L			
Pauly's Mortality (M)/(F)	0.18/0.11			
Size-Fecundity	900-1100			y=1183+0.6683(x-1369)*
Sex Ratio (M:F)	50:50	40:60 (Jan-July)		1:9
Age at Maturity		1 year (Females)		
Egg Incubation Season	March-September	Jan-Sept		June-August
Egg Incubation Period	22-25 days @ T=20 C; 42-47 days @ T=13 C			
Hatching Season			June, July & August	
Appearance & TL of 0-Group (Postlarvae)	10mm TL at settlement	Summer+Autumn		
Longevity	36-45 months	M=13; F=20 months		
Reference	Conides *et al*. (Year?)	Guerao and Ribera (1995)	Figueras (1986&1987)	Jensen (1958)
Notes		*TL(mm)/Wet Wt(g). Is logged		

Larval biology

The number of larval stages prior to metamorphosis varies by species. Fincham and Figueras (1986) reared all stages of larvae for all 5 species in the laboratory and give diagnostic descriptions of all stages. There is a progressive reduction from the 8-9 zoeal stages in *P. serratus* to only five in *Palaemonetes varians*. Larval staging is difficult especially for later zoea because the number of zoea is not fixed even with species. Size is not diagnostic as larvae at higher latitudes (and lower temperatures) are larger at any given stage.

Larvae are planktonic and occur predominantly in the surface 0.5 m of water (Figueras 1987). Larval distribution tends to reflect that of the adult population although the capacity for dispersal is high. Their surface distribution infers that wind and tide induced drift are important in determining their distribution. Post-larvae settle in intertidal areas or in the shallow sub-littoral. As zoeal stages are distributed in coastal water generally settlement may depend on onshore drift of larvae. This drift may be facilitated by onshore sea breezes during summer months.

Metamorphosis to the post-larvae and settlement occurs in late summer. Post-larvae use the pleopods to swim. These are not functional in the zoeal stages which use the exopods of the thoracic appendages to swim.

Fisheries

Fisheries for *P. serratus* occurs on the west and south coasts of Ireland (landings in Figure 1) and U.K., in coastal waters in France and in northern Spain. A fishery for *P. adspersus* previously existed off the Danish coast (Jenkins 1958). This species continues to be fished in the Mediterranean. A small fishery for *P. longisrostris* exists in France, specialy in the Gironde (Garonne + Dordogne estuary), where 25 small boats pot for it from June to October.

In northern Europe shrimp are usually captured by traps in shallow inshore waters by vessels less than 10 m in length. The can also be captured by beam trawling over sandy substrates with sea grass cover. In Ireland the fishery for *P. serratus* began in the mid 1970s and continued at a low level until 1989. In 1990 and 1991 landings tripled to 333 tonnes fell back in 1992 but increased annually up to 1999 when 547 tonnes were recorded. This substantial increase in landings has been due to both an increase in fishing effort of individual boats and a longer season. The fishery is characterised by local failure and subsequent recovery. The causes of this are unknown.

In France about 370 boats fish *P. serratus* with traps along the Atlantic coast (mainly) and the English-French Channel. Most are 6-10 m in length and the average characteristics are 8.2 m, 73.5 kw, 5.30 GT. The season extends from August to March and shows a north-south time lag with maximum in September-October in English-French Channel and in November-December along the Atlantic coast. According to official statistics since 1960 annual landings are generally between 300-600 t (probably slightly underestimated). Most of the production comes from the Atlantic coast.

Landing fluctuations from one year to the other are rather important and probably reflect annual variations in recruitment as well as variation in environmental conditions (hydrological and meteorological conditions) in winter time during fishing season. Fishermen report that *P. serratus* catchability is correlated with sea conditions catches being higher after periods of high sea swell.

Fisheries Management

In Ireland the fishery for *P. serratus* is managed using a closed season between May and August inclusive. This is designed to protect growth of juveniles in early summer and to optimise yield per recruit. The extension of the season to May does not conserve mature berried females which have overwintered. In many areas however no fishing occurs after February. The species is characterised by spatial variability in population size structure and possibly growth rate and mortality. Management measures may need to be designed specifically for local populations. Minimum landing size measures are possibly not effective as sorting on board is difficult and discard mortality may be high. Natural methods of sorting using appropriate mesh sizes in store boxes may have some value. Measures to increase survival during live export are required in order to optimise the value of the fishery. Prices in Ireland range from €12-25 per kg. Live catch achieves a higher price.

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Biology and fisheries for Carcinus meanas (L.)

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Introduction

The shore crab *Carcinus maenas* (L.) is among the most characteristic and successful crustacean that inhabits European coastal waters. Its wide geographical distribution and local high abundance place *C. maenas* as a species of prime ecological importance. The crab's ubiquity, ease of capture and suitability for laboratory studies have made the shore crab one of the most extensively studied marine invertebrates in the world, and its biology is better understood than any other European crustacean. However, the fishing activity for shore crabs is limited relative to other European decapods, and commercial shore crab fisheries are found only in southern Ireland, France, Portugal and in Italy, where the crab is of socio-economic importance locally.

The present review focuses on life history characteristics and processes that may be important from a management perspective of *Carcinus* species in Europe. For that purpose mainly European studies will be included in this review. Yamada (2001) presents a more extensive, recent review on the biology of *Carcinus maenas,* including also the global invasion by *C. maenas*.

Taxonomy

The shore crab, or European green crab, is a Brachyuran crab belonging to the family of swimming crabs, Portunidae. *C. maenas* is typically olive green or red in colour, and has five evenly spaced sharp spines, or teeth, on each side of the anterior-lateral margin of the carapace, or shell (Fig. 1). Its size ranges from up to 70 mm carapace width (CW) in females and over 90 mm in males (Crothers 1967).

Two closely related species are thought to exist in the genus *Carcinus* Leach: *C. maenas* (Linnaeus, 1758) that occurs from the Scandinavian Peninsula to Mauritania, and *C. aestuarii* Nardo, 1847 (formerly known as *C. mediterraneus* Czerniavsky, 1884), which is found throughout the Mediterranean, including the Black Sea (Crothers 1968, d'Udekem d'Acoz 1999). The two species are distinguished by the shape of the male copulatory organs, or pleopods, and by the shape of the lobes between the eyes (see Yamada 2001 for descriptions). However, the decision to distinguish the two morphological forms at the species level has been challenged because the two forms interbreed (Démeusy 1958), because of the occurrence of populations with intermediate morphological characters between the two typical forms (Almaça 1960), and because of low levels of genetic differentiation among populations (Bulnheim & Bahns 1996).

Distribution

Carcinus maenas typically forms large populations in estuaries and shallow coastal lagoons, but it may also be found in sheltered and semi-exposed sandy and rocky shores down to depths of about 40 m. Juvenile shore crabs are mainly found in the intertidal zone, on mudflats and in shallow soft sediment bays. As crabs mature, they move into the subtidal zone, but many return to forage in the intertidal at night during high tide. The oldest crabs often live permanently subtidal and many display a characteristic red coloration of crabs in late intermoult (Crothers 1968, Kaiser et al. 1990, Hunter & Naylor 1993). These "red" crabs are competitive dominant over "green" crabs, but less tolerant to low salinity or low oxygen concentrations, and are restricted to deeper more saline and cooler coastal regions (McGaw & Naylor 1992, Legeay & Massabuau 2000, see Reid et al 1997 for review). During the winter months, most crabs, particularly in estuaries, migrate to deeper waters (Edwards 1958, Naylor 1962, Rasmussen 1973, Gomes 1991a).

The natural range of *C. maenas* extends from 70° N in Norway to 22° N in Mauritania, including Iceland, the Faroe Islands, the British Islands and the western part of the Baltic Sea (Almaça 1962, Crothers 1968; see map Fig. 2). *C. maenas* has been accidentally introduced into several parts of the world during the last two centuries, including the Northwest Atlantic, Northeast Pacific, South Africa and Australia (Cohen et al. 1995 and references therein) where it presently is threatening native species and shellfish fisheries (Grosholz & Ruiz 1995, Lafferty & Kuris 1996, see Yamada 2001 for review).

Reproduction

The shore crab can reproduce repeatedly during its 3 to 5 years life span. It reaches maturity one to two years after settlement, and can reproduce two times per year at lower latitudes (Démeusy 1958, d'Udekem d'Acoz 1993).

Shore crabs have internal fertilisation and can only copulate directly after female moult, when the exoskeleton is soft and the genital pores are open. Female moult and copulation usually occur during summer and fall. To guarantee that a male is present at the right moment, a pre-copulation period precedes mating, where a male carries the female underneath. Females approaching moult release a pheromone, or chemical messenger, that attracts males (Bamber & Naylor 1997). A receptive female will respond passively to touch from a male, allowing him to clasp her, using his walking legs, with her dorsal side against his ventral side. This pre-copulatory embrace may last for several weeks while he waits for her to moult. After the female moult, while the exoskeleton is still soft, the male turns the female over and transfers the spermatophors to the female spermathecae, or sperm storage pouches, where they can be left for several months before fertilising the eggs. The male continues to carry the female underneath until her carapace hardens to protect her from male competitors and predators (Crothers 1967). The mechanism of partner selection appears to be very efficient in *C. maenas* because nearly all adult females of a population are fertilised (Broekhuysen 1936).

Once a female has mated, she can produce one or more broods with the sperm in her spermathecae. The eggs are fertilised as they descend the reproductive tract, and are subsequently attached to the feather-like appendages, or pleopods, under her abdomen, where they are carried during embryonic development (Crothers 1967, Rasmusen 1973). A female may produce about 50 000 to 200 000 eggs per brood, depending on her size (Broekhuysen 1936, Henrique Queiroga *unpublished data*). The egg laying usually occurs several months after copulation, generally late in the fall or during the winter. The embryonic development is controlled by temperature and may take up to 6 months at temperatures between 5 and 7°C, and about 1 month at 16-17°C (Broekhuysen 1936). However, *C. maenas* appears not to be able to breed at temperatures above 18°C (Naylor 1965). Reduced salinity, particularly in combination with low temperature, may prevent development, and at least 20‰ at 16-17°C or 26‰ at 10°C are required for normal development (Broekhuysen 1936). Ovigerous females therefore seek stable temperature and salinity conditions, and undertake seasonal migrations into deeper water during the winter (Rasmusen 1973, Dries & Adelung 1982).

At the end of the embryonic development, the shore crab larvae hatch from the eggs still attached to the female abdomen, and are released as planktonic larvae. Larvae start hatching when water temperature exceeds 10°C (Dawirs 1985). Most larvae therefore hatch during spring and early summer. In tidal areas larvae hatch almost exclusively during night time ebb tides, which is thought to facilitate the dispersal of larvae and reduce predation pressure on both larvae and females (Queiroga et al. 1994). The female is thought to induce the hatching of larvae by vigorously pumping with her abdomen and piercing the eggs with her periopods at regular intervals (Zeng & Naylor 1997).

The larval phase

Carcinus maenas has a planktotrophic larval phase, comprising 4 zoeal stages and a megalopal (postlarval) stage that settles on the bottom and metamorphoses into the first benthic crab stage. The different larval stages are well described (Rice & Ingle 1975, see also Yamada 2001) and can be readily identified in field samples. Larvae appear well adapted to natural shortage of food, and most zoea stage 1 larvae (zoea-1) will successfully moult into zoea-2, also when starved for over 50% of the normal stage duration (Dawirs 1984). The natural diet of shore crab zoea includes small animal and algal plankton, bacteria and detrital particles (Factor & Dexter 1993, Kumulu & Jones 1997). Larval development in *C. maenas* may take 3 -10 weeks, depending on temperature and availability of food (Dawirs 1984, 1985, Mohamedeen & Hartnoll 1989, Nagaraj 1993). At 20°C, the duration of the different larval stages increases from 3 days in zoea-1 to 5 days in zoea-4, and the megalopal stages last 9 to 10 days. At 15°C, the zoeal stages require 5 to 8 days to moult, and the megalopae over 14 days (Mohamedeen & Hartnoll 1989). At 6°C shore crab larvae are unable to moult. Starvation may also delay larval development, and starved zoea-1 larvae required 9 days more than fed larvae to moult into zoea-3 (Dawirs 1984). Considering the larval development times, the potential dispersal radius of *C. maenas* larvae under the influence of coastal and oceanic circulation ranges from tens to hundreds of kilometres (Palumbi 1995, Queiroga 1996).

Larval behaviour and dispersal

Recent studies of the *C. maenas* larvae from tidal areas suggest that larvae may use "selective tidal stream transport" to control both the dispersal of zoea larvae from the coast (Queiroga *et al.* 1994, 1997, Zeng & Naylor 1996a, 1996b, 1996c, Duchêne & Queiroga 2001), and the return of the megalopal stage back to the coast and nursery areas (Queiroga *et al.* 1994, Zeng & Naylor 1996d, Queiroga 1998). Selective tidal stream transport is thought to involve a vertical migration behaviour where the larvae swim close to the surface during a certain phase of the tide and near the bottom during the opposite phase, resulting in a net horizontal transport since tidal currents are always stronger closer to the surface due to bottom friction (see Forward & Tankersley 2001 for review).

The zoea-1 larvae from Wales and Portugal hatch almost exclusively during night time ebb tides. Hatching in the laboratory, in constant conditions, occurs with circatidal and circadian periodicity, implying an endogenous control of the hatching process (Queiroga et al. 1994, Zeng & Naylor 1997). Newly hatched larvae show vertical migration rhythms synchronised with the tidal cycle so that the larvae are consistently closer to surface during ebb than during flood tides, resulting in a seaward transport and subsequent offshore dispersal (Queiroga *et al*. 1994, 1997, Zeng & Naylor, 1996a). This behaviour is under endogenous control (Zeng & Naylor 1996a, 1996b, Duchêne & Queiroga 2001) and is inherited, *i.e.* it occurs even in larvae that were never subjected to tidal influences during embryonic and ontogenetic developments (Zeng & Naylor 1996c).

The distribution of shore crab larvae appears to be restricted to shelf waters (Rees 1955, Roff et al. 1986, Lindley 1987, Queiroga 1996). In a study conducted on the north-west Portuguese shelf, the distribution of shore crab larvae extended from the surface to a depth of approximately 60 m, and was confined to the inner and middle shelf with a gradual ontogenetic displacement to deeper waters throughout larval development (Queiroga 1996).

Shore crab megalopae from Portugal and Wales are more abundant in coastal surface waters during night flood tides than during ebb tides (Queiroga et al. 1994, Zeng & Naylor 1996d). The vertical migration of the megalopa is not endogenously controlled, but appears to result from exogenous cues, possibly chemical cues present in estuarine waters in combination with light and with tidal changes in hydrostatic pressure and salinity (Zeng & Naylor 1996d, Queiroga 1998).

Interestingly, along the Swedish Skagerrak coast, where tidal currents are very weak and unimportant for the water circulation, *C. maenas* larvae do not migrate in phase with local tides. The first zoea larvae do not display an endogenous tidal rhythm under constant conditions in the laboratory. Instead, both zoeal and postlarval stages swim in the surface water only at night, irrespectively of tidal conditions (Queiroga et al. 2002). The settlement behaviour of postlarvae is also not affected by the tidal conditions, but by the light intensity, and settlement occurs mainly during daylight (Moksnes et al. *submitted*). These studies also demonstrate that only first stage zoeae and late stage megalopae were abundant close to the shore, indicating an offshore-onshore transportation of larvae during development.

These results suggest that *C. maenas* from the tidal areas and the microtidal Skagerrak have adapted differently to their tidal environment, and that some other, unknown, larval dispersal mechanism is controlling the transport of shore crabs along the Swedish west coast. Because the endogenous tidal migration behaviour in British larvae was demonstrated to be inherited, these results suggest that larval dispersal and gene flow are limited between the British Isles and the Swedish Skagerrak. Thus, although the potential dispersal radius of *C. maenas* larvae could be hundreds of kilometres per generation, isolated populations may occur within northern Europe.

Very little is known regarding the larval behaviour and dispersal of *C. aestuarii* in the microtidal Mediterranean. A recent study carried out off the Catalan coast in Spain, suggested that *C. aestuarii* megalopae are dispersed well off shore, but restricted to shelf waters. Densities of megalopae in the neuston were highest at night, indicating a nocturnal vertical migration. However, moderate numbers were found in surface waters also during the day (Abelló & Guerao 1999).

Larval mortality

Direct *in situ* estimates of larval mortality are not available for *C. maenas*. An indirect estimate of the larval mortality can be obtained by using data on settlement and post-settlement mortality to back calculate how many individuals need to settle per female for two offspring to survive to reproduction. This number of settlers can then be compared to the average number of larvae produced per female, and the duration of the larval stages, to calculate the average mortality rate during the planktonic phase. Reliable estimates of settlement and early juvenile mortality are available for Swedish shore crabs (see below) allowing for such a comparative calculation in the Swedish system. Assuming that an average female shore crab in Sweden reproduces twice in her life time and the first time about 23 months after settlement, and by using field estimates of settlement and juvenile mortality from the literature for the first 5 months of benthic life (see Table 1 for references), and a conservatively low mortality rate (50% mortality year^{-1}) for the following 18 months before reproduction (where no data is available), we calculated that at least 22 000 megalopae need to settle per female and year for one offspring to survive to reproduction. Assuming that 100 000 larvae hatch from an average female (Crothers 1967, Henrique Queiroga *unpublished data*), this estimate suggests that 78% of these larvae perish during the 40 days larval phase, equivalent to an average instantaneous larval mortality rate of approximately 4% day^{-1} (Table 1).

Another indirect estimate may be obtained from data on abundance of zoea-1 and the megalopa larvae in a Portuguese estuary, where the plankton was intensively sampled during two periods of one month. Average abundance of zoea-1 was 2.0 m^{-3}, contrasting to a megalopal abundance of only 0.03 m^{-3} (Queiroga 1995). Assuming that the sampled zoea-1 larvae and the megalopae came from the same larval population, this data indicates a total mortality of 98.5% during the larval phase, equivalent to an instantaneous mortality rate of 11% day^{-1} if the larval phase lasts 35 days. Although these two mortality models are simplistic, they present rough estimates of larval mortality in shore crabs that are within the range of *in situ* estimates of larval mortality in decapod zoea larvae (1.6 to 22%; mean 6.9% mortality d^{-1}; Rumrill 1990).

Table 1. Model to estimate the average daily mortality rate during the larval phase for Swedish shore crabs using field estimates of mortality rates during settlement (including the first instar stage) and the young juvenile stages from the literature, and assuming that 100 000 larvae hatch from a female crab, that the larval phase last 40 d, that mortality rate during the last 15 months before reproduction is 50% yr^{-1}, and that one crab should survive to reproduction. The number of crabs surviving at the end of each stage, and the average mortality and the proportion of all mortality occurring during each stage are also presented. Daily mortality rate is estimated from $M_d = 1-e^{ln(St)/t}$, where M_d = proportional mortality rate per day, S_t = proportional survival after t days (modified from Krebs 1994).

Life-history stage	Mort. d^{-1}	Duration (d)	No. at end	Mort. stage^{-1}	Prop. of all mort.
Larval	0.037	40	22134	0.78	0.78
Settlement	0.15 [1]	7	7096	0.68	0.15
Young juvenile	0.05 [1,2,3]	153	3	0.9996	0.07
Juvenile - adult	0.0019	536	1	0.64	0.00002

Nursery areas and habitats

Young juvenile shore crabs are mainly found in shallow (< 1 m depth), soft sediment areas (Klein Breteler 1976a, Reise 1985, Pihl 1986) or in the upper intertidal zone in areas protected from waves (Zeng et al. 1997), suggesting that *C. maenas* preferentially settles in shallow water, sheltered from high energy waves. A recent field experiment using artificial settlement collectors demonstrated over 30 times higher settlement at the surface compared to at 9 m depth, supporting that shore crab megalopae actively select to settle at shallow depth (Moksnes et al. *submitted*). Suction sampling performed in shallow kelp habitats on exposed rocky shores along the Swedish west coast demonstrated very low densities of young juvenile shore crabs (Thomasson 1997), suggesting that settlement or survival there are low.

Within shallow soft sediment areas, young juveniles are concentrated in several structurally complex habitats, primarily in blue mussel beds (*Mytilus edulis* L.) and shell debris, but also in seagrass beds (*Zostera marina* L.) and in filamentous macroalgae (*Cladophora* spp., *Enteromorpha* spp.) whereas very low densities are found on adjacent open sand habitats (Klein Breteler 1976a, Eriksson & Edlund 1977, Scherer & Reise 1981, Pihl & Rosenberg 1982, Baden & Pihl 1984, Isaksson & Pihl 1992, Thiel & Dernedde 1994, Moksnes et al. 1998, Almeida 2001, Moksnes 2002).

Habitat selection by megalopae and juvenile crabs

Laboratory and field experiments performed on the Swedish west coast have demonstrated that megalopae avoid open sand habitats and actively select mussel shell, eelgrass or algal habitats at settlement (Hedvall et al. 1998, Moksnes 2002, Moksnes et al. *submitted*). This habitat selection is very efficient over small spatial scales (1 to 10s of meters), and result in 10 to 50 times higher densities in the structurally complex habitats compared to open sand or mud, also when the direct effect of predation is removed (Moksnes 2002). The settlement of shore crabs appears not to be affected by settlement of benthic shrimp, suggesting little interspecific competition at settlement (Moksnes 2002).

The selection of structurally complex habitats by megalopae appears to be an adaptation to reduce predation during settlement since these "nursery habitats" provide refuge from predators compared to open sand habitats. Both laboratory mesocosm experiments and field tethering experiments have demonstrated significantly higher mortality rates for postlarvae and young juvenile crabs in open sand habitats compared to mussel, eelgrass and filamentous algal habitats (Moksnes et al. 1998). Young juvenile crabs are very mobile within shallow nursery areas and constantly migrate between habitat patches where they show a preference for mussel habitats. This migration results in a redistribution from the initial settlement pattern of high densities of megalopae in several structurally complex habitats, to a concentration of juvenile crabs in mussel and shell habitats (Moksnes 2002).

In northern Europe, most juvenile crabs migrate from the shallow nursery areas in late fall to spend the winter in deeper waters (Rasmusen 1973, Pihl & Rosenberg 1982, Thiel & Dernedde 1994) whereas some hibernate in shallow waters (Klein Breteler 1976b, Eriksson & Edlund 1977). Migrating crabs return to shallow nursery areas in the spring as the surface temperature increases (Rasmusen 1973, Pihl & Rosenberg 1982), but gradually disperse to deeper subtidal areas as they reach maturity (Klein Breteler 1976a, Pihl & Rosenberg 1982, Beukema 1991).

Juvenile mortality

The shore crab is one of few European decapods for which natural mortality during juvenile stages has been directly measured in the field. Conservative estimates from the Swedish west coast, based on experiments using cages and small bays as mesocosms (where migration was accounted for), suggested that predation mortality is over 15% d^{-1} on average during settlement and the first crab stage, and 5 to 10% d^{-1} for the second to third crab stage (Moksnes 2002). Field experiments where juvenile crabs were tethered within grass beds demonstrated that the relative predation mortality decreased from 50 to 10% d^{-1} from the first to the seventh crab stage (Moksnes et al. 1998). These results suggest that settlement and young juvenile stages represent a bottleneck in survival during the life-history of shore crabs, also when compared to larval mortality (Fig. 3, Table 1). High juvenile mortality is also supported by several studies of juvenile shore crab populations that have demonstrated sharp declines in abundance after peak settlement events (Klein Breteler 1976a, Eriksson & Edlund 1977, Pihl & Rosenberg 1982, Beukema 1991). Klein Breteler (1976a) followed cohorts of juvenile shore crabs on a mud flat in the Dutch Wadden Sea over several years, and estimated a decrease in crab densities between 2 and 7% d^{-1} during the first 4 months after settlement, likely caused by predation mortality. Losses of 0-group crabs from the nursery area over the 4 months winter period varied between 70 and 98%, being substantially higher on late settlers (Klein Breteler 1976a).

In the Swedish system the dominant predators on young juvenile crabs are cannibalistic larger juveniles and small benthic shrimp (*Crangon crangon* L. and *Palaemon* spp.) and to a lesser degree gobid fishes (*Pomatoschistus* spp.; Pihl & Rosenberg 1984, Moksnes et al. 1998, Moksnes 2002). Larger juvenile crabs (> 5 mm CW) are eaten by 1-group cod *Gadus morhua* L. and by cottid fishes (*Myoxocephalus scorpius* and *Taurulus bubalis* Euphrasen; Pihl 1982, Isaksson et al. 1994, Gibson et al. 1998). On tidal flats in the Dutch and German Wadden Sea juvenile crabs are preyed upon by adult *C. maenas*, shrimp, fishes, wading birds and gulls (Dernedde 1993, Thiel & Dernedde 1994). The herring gull *Larus argentatus* is also an efficient predator on adult crabs (Crothers 1968, Dernedde 1993, Dumas & Witman 1993). In the Tagus estuary, Portugal, *C. maenas* is the preferential prey (both in number and weight) of the Lusitanian toadfish (*Halobatrachus didactylus* Bloch & Schneider), a benthic fish species that occupies a top position in the estuarine food web (Costa et al. 2000). In the Lagoon of Venice, Italy, the benthic fish *Gobius ophiocephalus* is though to be the main predator of *C. aestuarii* (Varagnolo 1968).

Regulation of the juvenile recruitment

The demonstrated high predation rates on young juvenile crabs suggest that settlement and young juvenile stages represent a critical phase in the life-history (see Fig. 3), and that survival may be dependent on finding a nursery habitat that provides shelter from predators. In areas where the supply of larvae is high, these habitats may become saturated with young crabs resulting competition over space and food, or cannibalism between juveniles. Such interactions can create density-dependent mortality that may regulate the recruitment of juveniles, and decouple the relationship between larval supply and juvenile abundance.

Laboratory and field experiments carried out in Sweden have identified several strong density-dependent processes operating in young juvenile crabs at naturally occurring densities. Interference competition between juvenile crabs over space within the nursery habitats resulted in reduced feeding and growth, and density-dependent emigration from the refuge habitats, even though food was available in excess (Moksnes *submitted*). Moreover, juvenile shore crabs are cannibalistic on smaller conspecifics (Klein Breteler 1975a, Scherer & Reise 1981, Moksnes et al. 1998), and laboratory experiments demonstrated that juvenile cannibals fed proportionally more on smaller crabs at high prey densities, resulting in density-dependent mortality on prey crabs. Moreover, prey crab mortality also increased with cannibal densities resulting in a negative correlation between late and new cohorts in the field (Moksnes *submitted*). These studies suggest that several density-dependent mechanisms, acting within the species, regulate the population size of juvenile crabs in relation to available nursery habitats. The results also indicate that nursery habitats may be a limiting resource for the recruitment in shore crabs.

Habitat limited recruitment was supported in a large-scale study along the Swedish west coast where larval supply was continuously measured during the recruitment season over a 4-year period in six small nursery areas, and compared to the recruitment patterns of juvenile shore crabs at the end of the season (Moksnes 1999). This study showed no positive relationship between larval supply and the abundance of juvenile shore crabs, despite a 10 fold difference in relative larval abundance between populations. Instead a significant correlation was found between the local abundance of nursery habitats and the juvenile recruitment (Moksnes 1999). Thus, in Sweden the recruitment of juvenile shore crabs appear, in general, to be limited by the availability of nursery habitats, and not by the supply of larvae.

Growth

Carcinus maenas is estimated to have about 18 benthic crab stages (Crothers 1967). The young juvenile crabs moult every 6 to 10 days and grow from 1.5 to over 10 mm CW in less than 2 months under optimal conditions (Mohamedeen & Hartnoll 1989). The moult increments decrease from 35 to 40% in the first 10 crab stages to around 30% in the last few moults before puberty (Klein Breteler 1975a, 1975b, Mohamedeen & Hartnoll 1989). The growth increments for adult crabs are similar in males and females, and are around 30% under ideal conditions, and 20-23% under marginal conditions (Broekhuysen 1936, Adelung 1971). A tagging study in the Ria de Aveiro estuary, Portugal, showed an average growth increment of 23% in adult crabs (Gomes 1991a). The intermoult periods are also similar in males and females, but increase consistently with age, from under 10 days in the smallest crabs to over a year in large adults (Mohamedeen & Hartnoll 1989; see Table 2).

The growth rate is strongly affected by temperature and crabs stop moulting when temperature drops below 10°C (Berrill 1982). Laboratory studies with individually reared crabs demonstrated that the intermoult period is shorter at higher temperatures, but that the growth increment per moult is lower when the temperature is higher. At 20°C, juvenile crabs moulted every 6 to 20 days, and reached sexual maturity after 12 moults and 173 days. At 15°C, the intermoult period lasted 9 to 32 days, but sexual maturity was attained after only 11 moults and 208 days (Mohamedeen & Hartnoll 1989). Food availability also has a large effect on growth and may increase the time to complete the first 6 moults by about 50% and decrease the size by 25% when restricted (Klein Breteler 1975b). Intraspecific interactions may also affect growth, and small crabs have been reported to delay moult in the presence of larger individuals (Bückmann & Adelung 1964, Adelung 1971). Juvenile shore crabs are agonistic to each other, and these interactions negatively affect their feeding at high natural densities and result in a density-dependent reduction in growth, also when presented with an excess of food (Moksnes *submitted*).

C. maenas normally attains sexual maturity after the 11th or 12th moult, at a carapace width between 20 and 35, and 25 and 33 mm, for females and males, respectively (Broekhuysen 1936, Démeusy 1958, 1963, Mohamedeen & Hartnoll 1989). In the Dutch Wadden Sea, the average size of ovigerous females was around 38 mm CW (Broekhuysen 1936). The female puberty moult is characterised by a broadening of the abdomen, by an enlargement of the pleopods, and by loss of the locking mechanisms of the abdomen. Puberty moult in the males is less evident and concerns mainly a modification of the chelipeds allometry, which become proportionally larger and longer than in the juvenile and the female. The shore crab can grow to over 80 mm CW and live over 4 years (Broekhuysen 1936, Crothers 1967, Yamada 2001). One of the largest shore crab specimens ever recorded was a male of 100 mm CW caught by a creel fisherman at 60-70 m depth on the Swedish west coast (Per-Olav Moksnes 2000, *personal communication*).

Latitudinal variation in life-history characteristics

The reproductive season of *C. maenas* is affected by water temperature, and larval release and settlement therefore occur later at higher latitudes and after cold winters (Pihl & Rosenberg 1982, Beukema 1991). At higher latitudes the spawning season is more concentrated and occurs mainly in late spring and early summer, whereas spawning can occur year around close to the southern limit of the distribution of the species (see Table 2 for summary).

Table 2. Biological characteristics of Carcinus maenas in different regions in Europe. All sizes refer to carapace width (mm) and weight refers to ash free dry weight (mg). M denotes males, F denotes females. Superscript numbers denote references: (1) Pihl & Rosenberg 1982, (2) Eriksson & Edlund 1977, (3) Klein Breteler 1975c, (4) Munch-Petersen et al. 1982, (5) Cruz 1989, (6) Mohamedeen & Hartnoll 1989, (7) Moksnes unpublished data, (8) Klein Breteler 1975a, (9) Beukema 1991, (10) Queiroga 1993, (11) Broekhuysen 1936, (12) Naylor

1962, (13) Crothers 1967, (14) Almaça 1962, (15) Gomes 1991a, (16) Rasmussen 1973, (17) Queiroga 1987, (18) Marques & Costa 1983, (19) Gonçalves 1991, (20) Paula 1993, (21) Queiroga 1995, (22) Moksnes 1999, (23) Klein Breteler 1976a, (24) Almeida 2001.

Life cycle parameter	Skagerrak-Kattegat	Wadden Sea	Southern Britain	Portugal
Size (L) - weight (W) relationship **Juveniles** log W = a * log L +log b	a = 1.255[1], 2.568[2] b = 4.400[1],0.0963[2] r = 0.975[1], 0.986[2]	a = 2.8573[3] b = 0.0555 r = 0.992		
Adults W = a * L^3	a_M = 0.221[4] a_F = 0.232			W_{M+F} = 0.00031* $L^{2.91}$ [5]
VonB growth parameters (Ford-Walford Method) **Males**				L_{inf} = 59.9528 [5] k = -0.4099 t_o = -1.56
Female				L_{inf} = 71.8607 [5] k= - 0.2233 t_o = -1.87
Intermoult period (I, days) - size (L) relationship. log I = a * L + b **15° C**		a = 0.973[6] b = 0.0222 r = 0.992		
20° C		a = 0.799[6] b = 0.0243 r = 0.981		
Size: average (maximium)				
Juveniles by first winter (early settlers)	5-10[1,2] (20[7])	10-15 (20)[8,9]	-	30[10]
Adults	M ≈ 45-60[4] (100[7]) F ≈ 35-47[4] (61[4])	M ≈ 45 (68)[11] F ≈ 39 (58)[11]	M = 63[12] (86)[13] F = 58[12] (70)[12]	M = 30-47[14] (87[15]) F = 25-35[14] (56[15])
Age (years) at first mating	1-2*	0.5-1[11]	0.5-1*	0.5-1*
Generation time (years)	2-3*	1-2*	1-2*	1-2*
Life-history periods (peaks)				
Mating	Aug-Sept[16]	July-Sept[11]	March-Nov (Aug-Sept)[12,13]	March-July [5] May-Oct[5,17]
Ovigerous females	May-July (June)[16]	Feb-June[11]	Jan-June (March-April)[12,13]	Nov-May (Jan-March)[5,18,19]
Hatching	-	May-	spring[13]	Feb-July[19,20,21]
Megalopal settlement	July-Sept[22]	June-Oct[23]	-	(March-July[24])
Young juveniles	Aug-Sept[1,2]	June -Oct[23, 9]	July-Sept[13]	April-Aug (May-July)[10,19]
Larval behaviour	Nocturnal[a]	-	Tidal[a]	Tidal[a]

In Skagerrak and Kattegat (north-eastern part of the North Sea), the surface water temperature is below 10°C from November to April in most years (Eriksson & Edlund 1977, Pihl & Rosenberg 1982), and the reproductive period is concentrated in the few months of favourable growing temperature. In the Danish Isefjord, mating occurs from August to September, ovigerous females are found mainly from May to July, and young juvenile crabs occur mainly in August and September (Rasmusen 1973). Along the Swedish Skagerrak coast, the daily abundance of shore crab megalopae was assessed using artificial settlement substrates (see Moksnes & Wennhage 2001 for methods) from June to October during a 4-year period. This study demonstrated that late stage megalopae were present in the water column on a daily basis from early July to the end of September each year, with peak settlement occurring from mid July to mid September (Moksnes 1999). This settlement period corresponds well with the peak abundance of young juvenile crabs in shallow nursery habitats, which usually occurs in August to September in the same area (Eriksson & Edlund 1977, Pihl & Rosenberg 1982, Moksnes 2002). Because of the short growing season in this area, female crabs will attain sexual maturity and mate at the earliest in the fall about one year after settlement, and hatch their larvae the following spring. Most females will likely hatch their first larvae about 2.5 years after settlement. Thus, generation time for *C. maenas* in Skagerrak and Kattegat is 2 to 3 years.

In the southern North Sea, the water temperatures are higher, the growing season longer, and the reproductive season occurs earlier and is more extended over the year. The female moult and mating occur from March to November, and ovigerous females and larvae are found in almost every month of the year (Crothers 1967 and references therein). In the Wadden Sea, copulation occurs mainly from July to September, most ovigerous females are found from February to June (Broekhuysen 1936), and young juveniles are found from June to November, with a peak in abundance generally occurring from July to September (Klein Breteler 1976a, Scherer & Reise 1981, Jensen & Jensen 1985, Beukema 1991). In south-west Britain, most ovigerous females are found from January to June, the zoea larvae are found mainly in the spring, and most young crabs occur from July to September (Naylor 1962, Crothers 1967 and references therein). Because of the higher water temperatures and longer growing season, sexual maturity may occur already at the second summer, and the generation time is likely 1 to 2 years.

In Portuguese estuaries, the reproductive season of the shore crab is not the same in the southern and northern parts of the country. In the Tagus estuary and the Ria de Aveiro lagoon (northwest Portugal) female moult and copulation occur from May to October, whereas copulation mainly occurs from March to July in the Ria Formosa lagoon (south Portugal; Queiroga 1987, Cruz 1989). In northwest Portugal, ovigerous females are encountered throughout the year, but most are found from November to May (Marques & Costa 1984, Cruz 1989, Queiroga 1995). In this area, hatching and high abundance of the first larval stage are found from February to July (Gonçalves 1991, Paula 1993, Queiroga 1995). In the Ria Formosa lagoon, larval hatching occurs from October to May, with peak abundance of first stage larvae recorded from November to March (Sprung 2001). In northwest Portugal, settlement occurs from late winter to early summer with peaks found from mid March to July (Almeida 2001). High number of young juvenile crabs on tidal flats has been found from April to August, with maximum numbers occurring from May to July (Queiroga 1993, 1995, Almeida 2001).

Ecological importance

The shore crab is an opportunistic omnivore that feeds on various benthic organisms as well as on plant material and detritus (Ropes 1968, Eriksson et al. 1975). It is considered to be an important predator that can control the distribution, abundance, size and morphology of prey populations and species composition of soft-bottom and rocky shore communities (Klein Breteler 1976a, Reise 1977, Pihl & Rosenberg 1982, Reise 1985, Johannesson 1986, Janke 1990, see Yamada 2001 for review). In shallow soft sediment areas, juvenile shore crabs are thought to play a key role in structuring the benthic community since they occur at very high densities, and can regulate or locally eliminate newly recruited prey populations (Scherer & Reise 1981, Jensen & Jensen 1985, Reise 1985, Beukema 1991).

The impact of shore crabs on their prey populations is particularly well documented in areas where it is not a native species (see Yamada 2001 for review). After its introduction on the North-American Atlantic coast, the shore crab is thought to have caused the collapse of the soft shell clam fisheries in northern New England and Nova Scotia (Ropes 1968, Cohen et al. 1995 and references therein). There is therefore great concern about the recent establishment of shore crab populations in northern California (Cohen et al. 1995, Grosholz & Ruiz 1995) where they presently threaten oyster cultures and crab fisheries estimated to be worth more than 40 million U.S.$ annually (Lafferty & Kuris 1996).

The fisheries

Although the shore crab is very abundant throughout most of its range in Europe, the fishing activity for this species is limited relative to other European decapods. Official statistics suggest that less than 2 000 tons of *C. maenas* and *C. aestuarii* are landed annually in Europe, which is an order of magnitude less than the average annual landings of, for example, the edible crab *Cancer pagurus* (FAO 1999). In southern Europe, several small *Carcinus* fisheries exist, which are of socio-economic importance locally. In Northern Europe a commercial fishery exists in Ireland where since 2001 approximately 300 tonnes have been landed annually. This is exported frozen to France. Part of the fishing activity is directed and commercial and some is designed as a predator removal exercise from mussel beds. Some crabs are used as bait in pot fisheries in Ireland.

In England and Wales, landings of *C. maenas* have been recorded since 1995, but the official landings are very low (0-5 tons year^{-1}; Steve Lovewell 2000, CEFAS, UK, *personal communication*). Still, soft-shelled *C. maenas* (peeler crabs) is a very popular bait among coastal sport fishermen in northern Europe, and peeler crabs are collected and sold locally for the sport angling market. This cottage industry could be locally important because of the high unit value of peeler crabs (up to 2.5 € crab^{-1} in England; Steve Lovewell 2000, CEFAS, UK, *personal communication*).

In Sweden, Denmark and southern Norway *C. maenas* can be extremely abundant in shallow (< 10 m) waters, but is considered a nuisance by coastal fishermen (Rasmussen 1973). For example, eel fishermen using fyke nets often find their traps filled with shore crabs, which can cause substantial damage to the equipment and catch (Per-Olav Moksnes 2000, *personal communication*). This by-catch of shore crabs is dumped back into the sea since no market exists in the Nordic countries for *C. maenas*. However, in recent years a limited market for ovigerous female shore crabs has developed, which are caught in spring and early summer and sold directly to fish restaurants (Per-Olav Moksnes 2000, *personal communication*).

In the Basin of Arcachon, southern France, *C. maenas* is traditionally fished by a small number of fishermen using baited crab pots. From 1980 to 1992 this fishery was practised by 4 to 5 fishermen that landed 300 to 400 tons crab year^{-1}, constituting a value of approximately €0.3 to 0.4 million year^{-1}. This fishery has declined in recent years because of a reduction in demand, and at present only one boat remains fishing, with landings below 80 tons crabs year^{-1} (Isabelle Auby 2000, IFREMER, France, *personal communication*). The majority of the crabs are sold to canneries manufacturing "Bouillabaisse". This is also the destination for the Irish landings.

In Portugal there is an old and traditional small-scale fishery for *C. maenas* in coastal lagoons that originally was used to fertilise agricultural land. With the development of chemical fertilisers and with an increasing interest by the Galician shellfish conserve industry of low cost crustacean species, the fishery transformed and expanded rapidly in the 1980´s. Nowadays around 1 000 tons shore crabs are landed each year in Portugal, worth about €0.3 million (Manuel Sobral 2000, IPIMAR, *personal communication*), which are exported to Galicia, Spain, where they are processed by the industry and also consumed by the local population (Sobral 1985, Gomes 1991a, 1991b). The *Carcinus* fishery in Portugal is not managed or regulated, and there are no official records or regular statistics. However, due to its local economic importance, the Portuguese Fisheries Research Institute (IPIMAR) devoted some research effort to it (Sobral 1985, Gomes 1991a, 1991b). Port samplings and a survey of export logbooks resulted in landings, effort, size and sex composition data for the period of 1980 to 1988, and the Portuguese authorities are preparing some specific legislation to apply to this fishery in the near future.

In Portugal the shore crab fishery is primarily carried out in the Ria de Aveiro lagoon (north western Portugal), but also in the Tagus estuary, Sado estuary (Setúbal), and Ria Formosa lagoon (Algarve - South Portugal). In the Ria de Aveiro, where a large majority of the shore crab landings in Portugal occur, the *Carcinus* fishery plays an important socio-economic role in the local fisheries. In the 1980's about 50 fishing boats took part in the *Carcinus* fishery in the Aveiro lagoon (Sobral 1985), and at present about 15 boats are fishing for shore crabs (Manuel Sobral 2000, IPIMAR, *personal* *communication*). The fishery is artisanal and most fishermen also have other sources of income, either from other fishing activities, agriculture or industry.

The fishing is carried out from small (5-7 m) wooden boats locally named "bateiras", using small (40 cm) hoop nets baited with sardines. Each “bateira” has 1 to 2 fishermen which set 40 to 50 hoop nets in a long line and fish them in half hour intervals for approximately 4 to 5 h per day. The fishing occurs all year around, 6 days per week (Manuel Sobral 2000, IPIMAR, *personal communication*). The CPUE (number of individuals per hoop net and h) was about 100 crabs/net h (approx. 1.6 kg/net h) in 1986, but declined to about 50 crabs/net h in 1989 (Gomes 1991b). Catches are sold to the intermediaries at several small ports for around 0.25 € kg^{-1}. The industry imposes a 50 mm CW minimum size of the crabs, and the catch is sorted at port resulting in an estimated annual discard of 50 to 75% of the catch (Gomes 1991b). The management value of the minimum size regulation is negligible since most of the discards are left on land to die.

In the Gulf of Venice (north eastern Italy) there is an old and traditional fishery of the Mediterranean shore crab, *Carcinus aestuarii*, which has been carried out since the 18th century. The crabs are collected and held until moulting to produce soft shelled crabs named "molecche" (or "moeche"), a local delicacy valued up to €50 kg^{-1} at wholesale. The fishing is carried out between March and November using long fyke net traps, locally called "cogòlo". In the 1960’s, about 400 fishermen took part in the *Carcinus* fishery in the lagoon of Venice, fishing about 50 traps each per day. Annual landings of “molecche” from the Gulf of Venice between 1946 and 1965 were 100 to 260 tons (Varagnolo 1968). A recent estimate suggests that the production of “molecche” involves about 220 employees, only in the province of Venice, with a production of over 100 tons $year^{-1}$ at a value around 2.5 million € (ASAP 1995). Research is being performed to control the crab's moult cycles and reduce the seasonal phases of the production, as well as investigating the possibilities of deep-freezing the product in order to free it from market fluctuations (ASAP 1998).

Fisheries Management: Implications of the life-history characteristics

None of the present fisheries for shore crabs in Europe are managed or regulated. However, most of the fisheries are small-scale and artisanal, and the risk of overfishing may be small in most regions. One possible exception is the fishery in the Ria de Aveiro lagoon, Portugal, where the decreased catch per unit effort in the late 1980's might have indicated overfishing. The lack of official records or regular statistics in the shore crab fisheries poses a serious impediment for the development of effective management measures of the fisheries. However, the broad understanding of the general biology of the different life stages in *C. maenas*, unmatched for any other European decapod, provides an unique opportunity to explore the management implications of the specific life-history characteristics in the shore crab. Specifically, the comprehension of the early benthic processes in *C. maenas* may provide valuable information for fishery managers.

Understanding whether local populations are limited by the number of larvae that reach the population, or regulated by post-settlement processes is critical for assessment and management of marine species with pelagic larvae. If a population is generally limited by larval supply, effective management necessitates identification and regulation of the larval source populations, to ensure that recruitment overfishing does not occur. On the other hand, if the larval supply is generally high, and local populations are regulated by density-dependent processes after settlement, the populations may be better managed by protecting important nursery areas.

The demonstrated high mortality rates in young juvenile crabs suggest that settlement constitutes a bottleneck in the life-cycle of the shore crab, when survival may be dependent on finding a habitat that provides refuge from predators. In Swedish Skagerrak, larval supply was demonstrated to be sufficiently high to over-saturate available refuge habitats, resulting in density-dependent mortality of juvenile crabs, and a habitat limited recruitment. These results suggest that, in eastern Skagerrak, moderate variation of adult populations sizes (e.g. stocks) will have little effect on the recruitment of juveniles since spatio-temporal patterns of egg production and larval supply are decoupled during young juvenile stages. The dynamics of local populations should instead be very sensitive to variation in the distribution of nursery habitats. Natural or anthropogenic changes of shallow nursery areas, such as the recent increase in distribution of filamentous algal mats on the Swedish west coast (Pihl et al. 1999), should therefore have a large effect on the populations of shore crabs. This is supported by an apparent consensus among coastal fishermen in Sweden that the by-catch of adult shore crabs has increased dramatically in the last decades, with negative effects on equipment and catch (Per-Olav Moksnes 1999, *personal communication*), corresponding to the increase in algal mats in this area (Pihl et al. 1995).

Although the relationship between larval supply and juvenile recruitment has not been assessed in other parts of Europe, several studies indicate that the juvenile habitat plays an important role in the population dynamics of *C. maenas*. In the German Wadden Sea, a long-term increase in adult populations of shore crabs was associated with increases of green algal mats and mussel cultures on the mudflats (Reise et al. 1989, Thiel & Dernedde 1994).

Thus, it appears to be critical to include juvenile processes and the availability of nursery habitats when developing a management strategy for shore crabs. A crucial part still lacking in our understanding of the shore crab is how larvae disperse and connect subpopulations within and between regions. To identify possible source- and sink-populations within a fishery is imperative for effective management, and represents a big challenge for ecologists and fishery scientists.

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The Biology and Fisheries of the genus *Plesionika* Bate, 1888.

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Introduction

The genus *Plesionika* Bate, 1888 is widely distributed throughout the world and in Europe is mainly distributed in Mediterranean waters and French-Portuguese Atlantic waters (Crosnier and Forest, 1973; King, 1981; etc.). *Plesionika* spp shrimps are mainly deep-water species with a nektobenthic behavior feeding on pelagic and benthic resources. Despite their wide distribution, high abundance, high biomass and the important ecological role they play on their habitats, the life histories of all the species of the genus are practically unknown, and just some studies have been carried out on biogeographic aspects. Fishery studies have not been carried out at present, although all the species of this genus are found on the fishery markets as a by-catch species. However, and depending on the region, only two or three species of this genus, from a total of eight species, have economic importance on the fishery markets of certain countries.

In this paper, we present an overview of the information available (published and unpublished data) on this genus in the European waters focusing particularly on its distribution, biology, ecology and fishery.

Taxonomy

The taxonomic position of the genus Plesioniak is: Subclass Caridea, Superfamily Pandaloidea Haworth, 1825, Family Pandalidae Haworth, 1825, Genus *Plesionika* Bate,1888. There are 8 species: *Plesionika antigai* Zariquiey Alvarez, 1995, *Plesionika gigliolii* (Senna, 1902), *Plesionika heterocarpus* (Costa, 1871), *Plesionika martia martia* A. Milne-Edwards, 1883, *Plesionika narval* (Fabricius, 1787), *Plesionika acanthonotus* (S.I. Smith, 1882), *Plesionika edwardsii* (Brandt, 1851), *Plesionika ensis* (A. Milne-Edwards, 1881).

Description, habitat and distribution

The genus *Plesionika* are small or medium size species of shrimp. The rostrum is long or very long, bearing teeth on the ventral and/or dorsal sides. The carapace is smooth or covered with a thin surface of minute scales. The claws of the first pair of pereiopods are microscopic or absent. The carpo of the second pair of pereiopods is subdivided in many articles. The 3rd maxilipede bearing an exopodite (Holthuis, 1987).

There seems to be a clear species-size and species-depth segregation of *Plesionika* species (Thessalou-Legaki *et al*.,1989;Thessalou-Legaki, 1992; Company, 1995; Company and Sardà, 1997; Carbonell and Abelló, 1998). Oceanographic features such as submarine canyons or frontal systems are considered to play a role in the distribution and ontogenic migrations of these species (Cartes 1993b; Cartes *et al*., 1994; Puig *et al*., 2001).

There are eight species of the genus in the European waters, which can be easily distinguished based on rostrum length, carapace length and density of rostrum teeth (Holthuis, 1987). For each species the body size, the habitat and distribution are given below.

<u>Plesionika antigai</u>

Size: Maximum body length (excluding rostrum): 25 mm approximately [CL:16.9 mm (males); 17.5 mm (females)]. *Habitat*: Deep-water, on muddy and muddy-sandy bottoms (Pérès and Picard, 1964), at depths between 120 and 800 m, especially from 330 to 370 m (Holthuis, 1987).

Distribution: This Atlanto-Mediterranean species is known from: 1 - Atlantic ocean: Eastern Atlantic, from Mauritania to Gibraltar straits (Maurin, 1962, 1963, 1968; García Raso, 1996), Atlantic coast of France (Lagardère, 1973); 2 - Mediterranean basin: Western Mediterranean (García Raso, 1981, 1982, 1996; Zariquiey Alvarez, 1968, 1955; Holthuis, 1987), Central Mediterranean (Manning and Froglia, 1982; Franceschini *et al*., 1993; Pipitone and Tumbiolo, 1993; Politou *et al*., 2000), Adriatic Sea (Froglia, 1972; Stevcic, 1990), Eastern Mediterranean (Koukouras *et al*., 1998; Politou *et al*., 1998, 2000).

<u>Plesionika gigliolii</u>
Size: Maximum body length: 62 mm, usual 40-50 mm. *Habitat*: Deep-water, on muddy bottoms (Pérès and Picard, 1964; Carpine, 1970), at depths between 100 and 800 m, mostly from 330 to 370 m (Holthuis, 1987). *Distribution*: This Atlanto-Mediterranean species is known from: 1 - Atlantic ocean: Eastern Atlantic from Maroc, Sierra Leone, Azores, Madeira (Fransen, 1991; Martins and Hargreaves, 1991; Biscoito,1993); 2 - Mediterranean basin: Western Mediterranean (Senna, 1903; Zariquiey Alvarez, 1968; Lagardère, 1971; García Raso, 1981, 1982, 1996; Holthuis, 1987), Central Mediterranean (Arena and Li Greci, 1973; Franceschini *et al*., 1993; Pipitone and Tumbiolo, 1993; Politou *et al*., 1998, 2000), Eastern Mediterranean (Koukouras *et al*., 1998; Politou *et al*., 1998, 2000).

<u>Plesionika heterocarpus</u>
Size: Maximum total length (from rostrum to telson): 88 mm (males), 106 mm (females), usually from 50 to 80 mm. *Habitat*: Deep-water, on muddy bottoms (Pérès and Picard, 1964; Carpine, 1970), between 10 and 850 m, mostly from 300 to 500 m (García Raso,1981; Holthuis, 1987). *Distribution*: This Atlanto-Mediterranean species has been reported from: 1 - Atlantic ocean: Eastern Atlantic from Angola to the Gulf of Gascon (Maurin, 1963, 1968; Lagardère, 1971;Grosnier and Forest, 1973; Anadon, 1981; Sardà *et al*., 1982; Neves, 1987; Rodríguez-Marin, 1993; García Raso, 1996; Fariña *et al*., 1997); 2 - Mediterranean basin: Western Mediterranean (Forest, 1965; Zariquiey Alvarez, 1968; García Raso, 1981, 1982, 1996; Moncharmont,1979; Holthuis, 1987), Central Mediterranean (Heldt and Heldt, 1954; Forest and Guinot, 1956; Pastore,1976; Franceschini *et al*., 1993; Pipitone and Tumbiolo, 1993; Politou *et al*., 1998, 2000), Adriatic Sea (Froglia, 1972; Stevcic, 1990), Eastern Mediterranean (Ostroumoff, 1896; Adensamer, 1898; Lewinsohn and Holthuis, 1964; Koçatas, 1981; Katagan *et al*., 1988; Koukouras *et al*., 1992; Galil and Goren, 1994; Koukouras *et al*., 1998; Labropoulou and Kostikas, 1999; Politou *et al*., 1998, 2000).

<u>Plesionika martia martia</u>
Size: Maximum total length: 169 mm, usually between 70 and 120 mm. *Habitat*: Deep-water, on muddy bottoms (Pérès and Picard, 1964; Carpine, 1970), at depths between 190 and 1215 m, mostly from 200 to 700 m (Grosnier and Forest, 1973; Holthuis, 1987). *Distribution*: This Atlanto-Mediterranean species was reported from: 1 - Atlantic ocean: Eastern Atlantic, from Angola to Ireland (Kemp, 1910; Holthuis, 1951; Maurin, 1968; Lagardère, 1971; Sardà *et al*., 1982; Neves, 1987; Martins and Hargreaves, 1991; Biscoito, 1993; García Raso, 1996), Western Atlantic from Brasil to Bermudas (Grosnier and Forest, 1973); 2 - Mediterranean basin: Western Mediterranean (Zariquiey Alvarez, 1968; García Raso, 1981, 1982, 1996; Holthuis, 1987), Central Mediterranean (Arena and Li Greci, 1973; Franceschini *et al*., 1993; Pipitone and Tumbiolo, 1993; Politou *et al*., 1998, 2000), Adriatic (Froglia, 1972; Stevcic, 1990), Eastern Mediterranean (Adensamer, 1898; Koçatas, 1981; Holthuis, 1987; Katagan *et al*., 1988; Koukouras *et al*., 1992; Koukouras *et al*., 1998; Politou *et al*., 1998, 2000).

<u>Plesionika narval</u>
Size: Maximum body length (excluding rostrum): 95 mm, usually from 50 to 120 mm (total length from rostrum to telson). *Habitat*: Deep-water, on muddy, sand-muddy, rocky bottoms and in submarine caves from 10 to 910 m, mainly from 200 to 400 m (Holthuis, 1987; Chan and Grosnier, 1991). *Distribution*: This cosmopolitan species has been reported from: 1 - Red Sea

(Chan and Grosnier, 1991); 2 - Western Indian Ocean (Chan and Grosnier, 1991); 3 - Atlantic ocean: the Eastern Atlantic, from Angola to North-West coast of Spain (Lagardère, 1971; Chan and Grosnier, 1991; Fransen, 1991; Martins and Hargreaves, 1991; García Raso, 1996); 4 - Mediterranean basin: Western Mediterranean (Heldt and Heldt, 1954; Zariquiey Alvarez, 1968; Arena and Li Greci, 1973; Moncharmont, 1979; García Raso, 1981, 1982; Holthuis, 1987; Chan and Grosnier, 1991), Central Mediterranean (Chan and Grosnier, 1991), Adriatic (Pesta, 1918; Stevcic,1990), Eastern Mediterranean (Drensky, 1951; Holthuis, 1987; Thessalou-Legaki *et al*., 1989; Chan and Grosnier, 1991; Koukouras *et al*., 1998; Politou *et al*., 1998, 2000).

Plesionika acanthonotus

Size: Maximum body length: 84 mm. *Habitat*: Deep-water, on muddy bottoms (Pérès and Picard, 1964; Carpine, 1970), between 190 and 1405 m depth, which made the deepest distributed species (Grosnier and Forest, 1973; García Raso, 1996). *Distribution*: This Atlanto-Mediterranean species has been reported from: 1 - Atlantic ocean: Eastern Atlantic from Namibia to the Gulf of Gascon (Maurin, 1963; Zariquiey Alvarez, 1968; Lagardère, 1971;Grosnier and Forest, 1973; Sardà *et al*., 1982; Macpherson, 1983; Fransen, 1991; García Raso, 1996), Western Atlantic, from Brasil to S. Carolina (S.I.Smith, 1882; Grosnier and Forest, 1973); 2 - Mediterranean basin: Western Mediterranean (Zariquiey Alvarez, 1968; García Raso, 1981, 1982, 1996; Holthuis, 1987; Cartes et al., 1993), Central Mediterranean (Arena and Li Greci, 1973; Franceschini *et al*., 1993; Pipitone and Tumbiolo, 1993; Politou *et al*., 2000), Adriatic Sea (Froglia, 1972; Stevcic, 1990), Eastern Mediterranean (Adensamer, 1898; Koukouras, 1973; Katagan *et al*., 1988; Politou *et al*., 1998, 2000).

Plesionika edwardsii

Size: Maximum total length: 166 mm, usually from 80 to 120 mm. *Habitat*: Deep-water species (Pérès and Picard, 1964), on bottoms with very thin mud and with corals (*Dendrophylum*) at depths from 110 to 680 m, mainly between 250 and 380 m (Holthuis, 1987). *Distribution*: This cosmopolitan (Fig. 1), species has been reported from: 1 - Indo-Pacific ocean (Chace, 1985); 2 - Atlantic ocean: Eastern Atlantic, from Sierra Leone to the Noth-West of Spain (Maurin, 1962, 1963, 1968; Lagardère, 1971;Grosnier and Forest, 1973; Sardà *et al*., 1982; Martins and Hargreaves, 1991; Biscoito, 1993), Western Atlantic, from the Gulf of Mexico to S. Carolina (Grosnier and Forest, 1973); 3 - Mediterranean basin: Western Mediterranean (Forest, 1965; Zariquiey Alvarez, 1968; Moncharmont,1979; García Raso, 1981, 1982), Central Mediterranean (Forest, 1967; Franceschini *et al*., 1993; Pipitone and Tumbiolo, 1993; Politou *et al*., 2000), Adriatic (Bombace and Froglia, 1973; Stevcic, 1990), Eastern Mediterranean (Holthuis and Gottlieb, 1958; Koukouras and Kattoulas, 1974; Kaspiris, 1990; Koukouras *et al*., 1992; Politou *et al*., 2000).

Plesionika ensis

Size: Body length: 11-24 mm. *Habitat*: Deep-water, on muddy bottoms (Grosnier and Forest, 1973) at depths between 200 and 732 m (Grosnier and Forest, 1973; Biscoito, 1993). *Distribution*: This Atlanto-Mediterranean (Fig. 1) species is known from: 1 - Atlantic ocean: Eastern Atlantic, from Angola to the North-West coast of Spain (Holthuis, 1952; Holthuis and Maurin, 1952; Maurin, 1968; Grosnier and Forest, 1973; Gonzalez *et al*., 1990; Fransen, 1991; Biscoito, 1993; García Raso, 1996), Western Atlantic (Grosnier and Forest, 1973); 2 - Mediterranean basin: Malaga, Alboran Sea (García Raso, 1981), Crete Island, Aegean Sea (Labropoulou and Kostikas, 1999).

Life History

Plesionika spp life histories are practically unknown, despite the high diversity and high biomass observed for this taxon and their potential as a fishery resource in tropical and subtropical bathyal environments (Zariquiey Alvarez, 1968; Crosnier and Forest, 1973; King, 1981; Thessalou-Legaki, 1992; etc.). However, sparse information is available, mainly for the western Mediterranean and Greek waters (Company 1995; Company and Sardà, 1997; Carbonell and Abelló, 1998; Thessalou-Legaki, 1992).

Growth

The relative and absolute growth parameters are given in Table 1 and 2, respectively. Usually, the available information on growth parameters is taken in a single region, so it is not possible to undertaken intraspecific comparisons of growth performance between the different areas of distribution.

Table 1. Size-weight relationships ($Y = a \cdot X^{b}$, where X = size; Y = weight; a = constant; b = allometric coefficient or slope) for Plesionika species including correlation coefficient (r), significances (S) of slope where this differs from 3 for ln-transformed data (: p<0.05; **: p<0.01; ***: p<0.001), and (n) number of individuals [I: indeterminate individuals ; F:females; M: males;; n.a: not available information]*

Species	Sex	a	b	r	S	n
Plesionika heterocarpus	I+F+M	0.000578	3.1024	0.989	0.0036 **	(188)
	I	0.000135	3.8623	0.948	0.1211	(9)
	F	0.000784	2.9865	0.981	0.7952	(129)
	M	0.000618	3.0883	0.990	0.1701	(50)
Plesionika edwardsii	I+F+M	0.000595	3.0659	0.982	0.0165 *	(453)
	I	0.000063	4.0010	0.923	0.4854	(4)
	F	0.000561	3.0893	0.979	0.0453 *	(209)
	M	0.000929	2.9174	0.976	0.0533	(239)
Plesionika gigliolii	F+M	0.001324	2.8439	0.943	0.0096 **	(285)
	F	0.002457	2.6012	0.888	0.0007 ***	(140)
	M	0.001390	2.9245	0.953	0.0211*	(144)
Plesionika martia	I+F+M	0.000363	3.1968	0.973	0.0000 ***	(370)
	I	0.000056	3.9579	0.938	0.2034	(7)
	F	0.000569	3.0408	0.965	0.4805	(208)
	M	0.000504	3.0806	0.965	0.2452	(149)
Plesionika acanthonotus	I+F+M	0.000575	3.1315	0.961	0.0446 *	(192)
	I	0.000153	3.7074	0.773	0.6253	(7)
	F	0.002604	2.5502	0.928	0.0010 ***	(64)
	M	0.000879	2.9651	0.945	0.7126	(121)
Plesionika antigai	n.a					
Plesionika narval	n.a					
Plesionika ensis	n.a					

Table 2. Von Bertalanffy growth parameters for Plesionika species [CL: carapace length; L_∞: theoretical maximum individual size; k: annual growth rate; WP: winter point; Φ: growth-performance index; I: indeterminate individuals; F: females; M: males]

Species	Sex	CL (mm)		L_∞	*k*	WP	*Φ*	Estimated max.age
		min.	max.					
Plesionika heterocarpus	I+F+M	5.4	20.2	22.7	0.90	0.00	0.603	
	F	7.3	20.2	23.0	0.90	0.90	0.622	1.5
	M	7.2	19.4	22.4	1.00	0.60	0.621	1.5
Plesionika edwardsii	I+F+M	7.4	29.0	31.0	0.70	0.94	0.748	
	F	10.0	29.0	31.0	0.65	0.94	0.697	2.5
	M	10.6	27.2	32.0	0.80	0.40	0.840	2.5
Plesionika gigliolii	I+F+M	5.2	18.6	21.0	0.75	0.48	0.466	
	F	8.0	18.6	20.5	0.75	0.68	0.443	1.5
	M	6.8	16.0	20.0	0.55	0.40	0.259	1.5
Plesionika martia	I+F+M	5.0	26.7	30.1	0.50	0.90	0.561	
	F	9.8	26.7	30.4	0.39	0.86	0.440	2.5
	M	9.3	23.9	27.5	0.54	0.80	0.491	2.5
Plesionika acanthonotus	I+F+M	5.4	17.9	19.0	0.55	0.80	0.252	
	F	8.1	17.9	19.0	0.55	0.83	0.233	1.5
	M	7.8	16.2	18.4	0.50	0.00	0.129	1.5
Plesionika narval	F	7.0	30.0	0.66	31.9			
	M	6.3	28.0	0.54	29.5			
Plesioinka antigai	F	2.5	17.5					
	M	2.4	16.9					
Plesionika ensis	I+F+M	10.2	35.9					

No information of the age, moulting or natural mortality processes are available for any of the species here considered.

Reproduction

Information on reproductive cycles, maturity, fecundity and feeding are available for some of the species in some areas. The information is given by species as follows:

Plesionika antigai

According to Campisi *et al*. (1998), ovigerous females are present all year with the highest percentage between June and November. Calculated size at first maturity in these months is 9.7-10.0 mm CL, respectively. The stage immediately before hatching is most common in June. The smallest ovigerous female are 7.8mm CL in June. The last stage of egg development reaches its maximum in June. The sex ratio (m/f) is 0.6. This value, seems to decrease with increasing depth (Mura and Cau, 1994; Campisi *et al*., 1998).

Plesionika gigliolii

Females with developing gonads are most common during spring and summer months (Mura, 1995; Company, 1995; Company and Sardà, 1997; Company *et al*., submitted). The smallest sizes and a higher proportion of females occur between 350-450 m depth which corresponds to its intermediate depth distribution range. Only large individuals occur in deeper water (Company and Sardà, 1997; Puig *et al*., 2001). At depths where abundance of *P. gigliolii* is restricted, it is substituted by a deeper water species *P. martia* (Company and Sardà, 1997). Its diet is mainly Euphausiacea, Decapoda, and Polychaeta (Mura, 1995).

Plesionika heterocarpus

Reproductive activity throughout the year always with a high percentage of ovigerous females in the population (Company and Sardà, 1997; Company *et al*., submitted). Active predator of benthic organisms, while scavenging activity is more important in the few individuals distributed at depths below 500 m (Labropoulou and Kostikas, 1999). Found in a shallow depth range (<200 m) in the neritic zone, which is more productive throughout a year in relation to phytoplankton and zooplankton biomass. This is one of the main factors that allow the species to have an extended breeding season (Company and Sardà, 1997). The smallest individuals were encountered at the edge of the shelf (area of higher productivity) and were associated with a high female percentage, while a larger proportion of males were present in the deepest range distribution (Company and Sardà, 1997; Puig *et al*., 2001). *P. heterocarpus* is considered to characterize the shelf-slope transition community (146-296 m) in Northwestern Mediterranean (Catalan Sea) (Cartes *et al.*, 1994). It is one of the species which are typical of a zone (NW Spain) characterized by a convergence of water masses bringing about an increase in productivity due to upwelling (Fariña *et al.*, 1997). *P. heterocarpus* has a smaller mean CL than *P. edwardsii* and at depths where its abundance is lower, *P. martia* becomes more abundant (Company and Sardà, 1997). It shows a positive correlation ($p<0,05$) between mean CL and depth (Company and Sardà, 1997; Carbonell and Abelló, 1998).

Plesionika martia martia

Ovigerous females occur in March and November (Spain; Company and Sardà, 1997). This species is an active noctural feeder (Cartes, 1993a). Its diet is based on pelagic prey and it exhibits a distinct feeding pattern conditioned to the availability of this type of prey (Cartes, 1993a). It feeds primary on benthopelagic eucarid crustaceans (Cartes, 1993b). In depths less than 450 m there is a high proportion of females in the population (Company and Sardà, 1997). There is also a positive correlation between body size and depth (Company and Sardà, 1997; Carbonell and Abelló, 1998).

Plesionika narval

According to Gonzalez *et al.* (1997) *P. narval,* in the vicinity of the Canary Islands (Eastern Central Atlantic), performs seasonal migrations. Shrimps concentrate in deep waters in autumn, move to shallower waters during winter and spring, and return to deep waters in summer. Ovigerous females occur all year round but the spawning peak occurs in April to June when the population is found in shallower waters (26-175 m). Ovigerous females decrease in number with increasing depth. Female size at maturity is 11.96 mm CL. The study of the sex ratio by depth and in relation to seasonal migration, as well as the sex differences in growth, confirm that this species conforms to the reproductive pattern of tropical pandalids, in which dioecy occurs. Mean brood size and egg size also increase with depth (Thessalou-Legaki, 1992).

Plesionika acanthonotus

The reproductive period is restricted to late spring-early summer months (Company and Sardà, 1997). The seasonal peak in occurrence of ovigerous females coincides with the maximum annual peak of phytodetritus sedimentation in the Western Mediterranean (Company and Sardà, 1997). The species does not show a clear relationship between size composition and depth or between sex ratio and depth and only in its deepest distribution range (>800 m) a slightly higher proportion of females occur (Company and Sardà, 1997). Pelagic prey contributes a small portion of the diet (Cartes, 1993a). Its diet is based on smaller prey (siphonophores, hyperiids, euphausiids), while benthic prey and Osteichthyes remains are also important (Cartes, 1993b).

Plesionika edwardsii

Ovigerous females occur throughout the year (Spain; Company and Sardà, 1997). The species displays the typical reproductive pattern of tropical pandalids and is dioecious. In the vicinity of Canary Islands (Eastern Central Atlantic) the species performs seasonal migrations. It concentrates in deep water during winter, moves to shallower water in summer and returns to deep water again in autumn (Santana *et al.*, 1997). A spawning peak occurs between April and September (more than one spawning per annum may occur) (Santana *et al.*, 1997; Company and Sardà, 1997). The size at maturity for females is approximately 26 mm CL. Shrimp size generally increases with increasing water depth (Carbonell and Abelló, 1998). The diet is based on pelagic prey (Cartes, 1993a). It consists primarily of benthopelagic eucarid crustaceans, especially *Pasiphaea sivado. P. edwardsii* also feeds on endobenthtic prey, mostly polychaetes (Cartes, 1993b). It is the largest pandalid found in the Western Mediterranean (Company and Sardà, 1997).

Plesionika ensis

This species is an active predator of benthic and hyperbenthic invertebrates, while scavenging activity is more important at depths below 500 m (Labropoulou and Kostikas, 1999). Maximum abundance occurs at 500-700 m (Burukovsky, 1980; Labropoulou and Kostikas, 1999).

Larval ecology

The larval ecology of these species has not been studied. *Plesionika spp* larvae are found throughout the year in the waters of the western Mediterranean (Fuster, 1982). However, the identification of the larvae has only been to genus level. The continuous reproductive activity of the more shallow distributed species, like *P. heterocarpus*, suggests that the larval distribution described by Fuster (1982) could be attributed to this species.

The only available information on larvae settlement is by Puig *et al.* (2001) who suggest that larvae settlement of *P. heterocarpus*, *P. edwardsii*, *P. gigliolii*, *P. martia* and *P.acanthonotus* is linked with oceanographic frontal systems. It seems that the larvae settle at particular times of year on the continental margins in the Mediterranean (Puig *et al.*, 2001).

The Fishery

History

On the fishing grounds of the continental slope of the western and central Mediterranean Sea, *Plesionika* shrimps are mostly caught as by-catch (Carbonell and Abelló, 1998; Marsan *et al*., 2000). In the Spanish Mediterranean trawl fishery these by-catches are associated with the slope shrimp fishery. Landings records per boat and per day are available from the fishermen's associations, and monthly official landings statistics are available, but with the sole exception of the Balearic Sea, the data have not been processed.

The muddy bottoms of the continental shelf and slope off the Spanish coast are exploited by the trawl fleet at depths of 50-800 m. The crustaceans represent an important fraction of the total weight of the slope trawl catches, with a considerable diversity of marketable species. Among the crustaceans, the species of the genus *Plesionika* are regularly present in considerable quantities in the catches. These shrimps are marketed under a common denomination that can be different depending on the fishing area. The composition of the catch is a mixture in which one or other species predominates according to the fishing depth, the area and also the behaviour and characteristics of the gear. For instance, in the shelf upper slope area (between 150-300m depth) the predominant species is *P. heterocarpus* with a proportion greater than 70%, whereas in the middle slope area (at depths over 400 m) the majority of the specimens are of the species

P. martia, which comprise between 30 and 70% of the total catches of the pandalid species. Other species, such as *P. edwardsii*, the only targeted species of the Mediterranean trap fleet, *P. gigliolii*, *P. antigai*, *P. acanthonotus*, and two additional species from the sub order Caridea, *Pasiphaea multidentata* and *P. sivado*, occur in more variable proportions.

In the eastern Mediterranean (Greek waters), trawl fishing occurs is mainly on the shelf and at 400-500 m depth on the slope. The fishery is mostly multispecies and generally targeted to fish. For these reasons, the proportion of *Plesionika* as trawl by-catch is lower than in the western Mediterranean. Furthermore, the species of the genus has no commercial importance in Greece, and it is discarded before reaching the market (Machias *et al*., 2001). Only *P. narval* is known to be caught by traps and consumed locally in the region of Dodecanese.

From 1994 to 2002, an international bottom trawl survey program (MEDITS) was carried out annually by most of the Mediterranean countries. Although *Plesionika* species are not among the target species of the project, abundance data were collected and published for some areas (Carbonell and Abelló, 1998; Politou *et al*., 1998; Ungaro *et al*., 1999; Marsan *et al*., 2000; Politou *et al*., 2000).

A description of the fishing operation, technology and gear used

In the Spanish trawl fleet the gear used is a bottom otter trawl with a codend mesh size ranging from 38-40 mm. The gear can be modified by adding struts, that allow a greater vertical opening of the mouth. Trawlers are equipped with sonar, GPS, radio. On the slope, the duration of the hauls vary between 2-7 hours but are more frequently 5-7 hours in duration in the deepest zone down to 800 m. Each vessel usually has its own fishing grounds, although they can be changed depending on the catch yields and the period of the year. They fish 5 days per week in daily trips of 12 hours.

The gear used by the Greek trawl fleet is a bottom trawl with a 28 mm minimum codend mesh. The trawlers are equipped with GPS, echosounder, plotter and radio. The duration of the hauls on the slope ranges between 2-9 hours. The typical duration of a trip is one day, but it may be longer. A closed season for trawling from 1 June to 30 September is imposed annually in Greek waters.

Profile of the fleet

The Spanish Mediterranean coast has 66 fishning ports. The trawl fleet is composed of 1014 vessels, of which almost 30% trawl on the slope. The fishing power of these trawlers ranges between 400-1200 Hp. Of all the *Plesionika* species, only *P. edwardsii* is targeted by traps. These vessels (2 or 3 boats at the moment) operate at 350-500 metres off Alicante, (Columbretes Islands, Spain) and Balearic coasts (Spanish Mediterranean coast). The traps used differ between zones. For instance, at the Spanish Alicante coast, they are cylindrical with 10 mm plastic mesh. They measure 450 mm in height by 500 mm in diameter and have a frame of steel ribs. They are set in lines of 350 traps, and they are collected every day. They are baited with horse mackerel, scabbardfish, common mackerel, etc. The vessels are 65 grt in capacity and have an average length of 19 m. The landings vary between 60-100 tonnes/year. The daily shrimp yields vary between a maximum total catch of 360 kg and a minimum of 100 g, (Garcia *et al*., 2000).

The Greek trawl fleet is composed of 348 trawlers (census of 2/2001), which are distributed over 41 ports throughout the country. The mean fishing power is 391 Hp and the mean GRT is 62. The mean trawler length is 23.5 m.

Monitoring of the fishery

Information on catch and effort statistics for pandalids is not available for the eastern Mediterranean, due to the very low commercial importance of the group. In the western Mediterranean, although statistical data exist, they are not directly usable, since they are not processed. The only available information concerns the Balearic Island, central Western Spanish Mediterranean Sea, where a monitoring program for the slope fishery provides data on, landings, species composition and yields (g/hour) of pandalid by-catch from 1998 to 2001 (Table 3). The most important species of the group is *P. martia*.

Table 3. Mean yield in g per hour and Standard Deviation (SD) of the Caridea species (Plesionika and Pasiphaea) from the Mallorca Deep-Water Shrimp Trawl fishery (unpublished data).

Year	Mean yield (g/h)	SD
1998	1550.6	690.0
1999	1676.6	1183.4
2000	1563.6	916.6
2001	1274.5	781.8

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The *Plesionika* fishery are not managed *per se* in the European waters (Mediterranean and Atlantic waters), and only global regulations of the trawl fisheries and regional or local regulations are directly applied to this fishery.

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Biology and Fisheries of Pasiphaea sivado (Risso, 1816) and Pasiphaea multidentata Esmark, 1866

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Description and Distribution

Despite high abundance and biomass levels, the species autoecology of caridean decapods dwelling below 200 m is largely unknown. The species making up the genus *Pasiphaea* are distributed worldwide (Silvertsen and Holthuis 1956; Omori 1974; Burukovskij 1993; Hanamura and Evans 1994). New geographical records show how this genus seems to inhabit midwater habitats (epi, meso and bathypelagic) from polar to tropical waters (Clarke and Holmes 1987; Tiefenbacher 1991, 1994; Hanamura and Evans 1994; Burukovskij 1995; Vereshchaka 1995), and several new species have recently been described (Komai and Amaoka 1993; Burukovskij 1995). However, few biological data are available on the species of this genus (Apollonio 1969; Matthews and Pinnoi 1973; Omori 1974; Clarke and Holmes 1987; Gibbons et al. 1994).

The species *Pasiphaea sivado* and *P. multidentata* inhabit Mediterranean and Atlantic waters (Zariquiey Alvarez 1954; Gurriaran 1987). The high biomass and abundance levels of these species and their extensive diel vertical migrations give them an important ecological role, making them key components of the marine food web in the transfer of energy from the pelagic to the benthic habitat. Pasiphaeid species are present in the diets of a wide spectrum of fish and crustacean species inhabiting the Benthic Boundary Layer on the continental slope in the Mediterranean Sea (Relini Orsi and Relini 1990; Golani 1991; Cartes 1993; Pipitone et al. 1994; Bozzano et al. 1997). Both species have been reported to feed on benthic items during daytime, whereas only large specimens that stay close to the bottom at night feed nocturnally (Cartes 1993; Cartes et al. 1993). Most studies on the distribution of these species have only dealt with their distribution in the water column. However, a not inconsiderable portion of the population, particularly large specimens, stays within the Benthic Boundary Layer both by day and by night. Therefore, studies on this part of the population (near-bottom) can also furnish valuable complementary information on the distribution, population structure and biology of these species.

Life History

The few biological data reported on *P. sivado* and *P. multidentata* have focused mainly on descriptions of their larval stages (Williamson 1960; Elofsson 1961). Omori (1974) reported that mesopelagic and bathypelagic species breed throughout most of the year, i.e., species are continuously active reproductively. In contrast, epi and upper mesopelagic species, such as *P. sivado*, spawn at specific times of year, i.e., early summer and early winter (Williamson 1960). The mesopelagic species *P. multidentata* spawns twice yearly in the Gulf of Maine (Apollonio 1960) and throughout most of the year off western Norway (Matthews and Pinnoi 1973).

Growth

Sexual dimorphism is not significant in these pasiphaeid species but males are slighty larger than females in *P. sivado* and slightly smaller in *P. multidentata*. The overall percentage of ovigerous females to total females is higher in *P. sivado* than in *P. multidentata* (46 % vs. 18 %). Depending on the month sampled, two or three well-defined size classes are distinguishable in *P. multidentata*. In the case of *P. sivado*, the undersampling of the smallest individuals makes it difficult to distinguish the first age group. In both species the size of the smallest ovigerous female (14.7 mm CL in *P. sivado* and 29.9 mm CL in *P. multidentata*), which has been assumed to be close to the size at first sexual maturity, was in between two modal size classes (Table 3, Figure 3). *P. sivado* individuals under 10 mm CL and *P. multidentata* individuals under 21 mm CL are classified as being of indeterminate sex due to the absence of external secondary sex characteristics.

For both species the allometric size-weight relationship values (b) is significantly lower than the isometric value of 3, signifying an appreciably larger increase in size as opposed to weight (Table 1). Annual growth rates (k) are higher in *P. multidentata*, and the comparative index used (Φ) also indicated a higher relative growth rate. Maximum age seems to be lower in *P. sivado* (around 2 years) than in *P. multidentata* (between 3 and 4 years). The maximum age attained by each species was estimated from size-frequency histograms.

Reproduction

P. sivado is a more shallow-dwelling species than P. multidentata (Franqueville 1971; Abelló et al. 1988; Cartes and Sardà 1992) (Table 1). There is increasing seasonality in reproductive processes with depth. Both ovigerous females and females with active gonads (maturity stages III, IV, and V) in P. sivado are present year round. In contrast, the deeper-dwelling species, P. multidentata, displays more seasonal spawning pattern. Females with active gonads are found from late summer to late autumn and ovigerous females from September to March-April.

P. sivado females with active gonads in maturity stage V are present year round. Ovigerous females of this species carrying eggs in the most advanced development stage (stage 3; embryos with pigmented eyes) are also present year round. More than one spawning per year may occur. On the other hand, *P. multidentata* females in maturity stages IV and V have only been collected during September, October and November, and ovigerous females are present only during autumn and winter.

Measures of reproductive output per brood were compared on the basis of the gonadosomatic index and the percentage ratio of egg weight to individual weight by species (Table 2). *P. sivado* exhibits a significantly higher gonadosomatic index value at gonad maturity stage V than *P. multidentata* but there are no significant differences in the ratio of egg weight to female body weight. Late developmental stage (stage 3) egg diameter was significantly larger in deeper-dwelling species (Table 3). Absolute brood size is larger in *P. multidentata* than in *P. sivado.* P. multidentata females carries relatively fewer eggs than P. sivado females.

The fishery

These shrimps although they occur in high abundance are not targeted directly. They are captured as by catch and regularly appear on the market.

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Biology and Fisheries for *Squilla mantis* (Linnaeus, 1758)

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Description and Distribution

The systematic position of the spot-tail mantis shrimp *Squilla mantis* is as follows: Class Malacostraca, Subclass Hoplocarida, Order Stomatopoda Latreille 1817 (*ca. 360 sp.*), Family Squillidae (Latreille 1803) Manning 1967, 1968.

Stomatopods have well-developed, compound and stalked eyes. They possess 8 pairs of thoracic appendages (thoracopods) with the first five sub-chelate (McLaughlin, 1980). The most remarkable trait from its physical appearance is the extensively developed second thoracopod, which is subchelate and adapted to their predatory habits (raptorial strike). The last 3 thoracic appendages are bi-ramous, non-chelate, thin, and adapted for walking on the sea floor. Stomatopods have a well-developed abdomen with a large telson. Their pleopods are well-developed, adapted for swimming above the sea-floor. Most species excavate burrows in soft substrates or live in rock crevices. The order is distributed in tropical to subtemperate waters, mainly shallow waters.

S. mantis is found in Mediterranean waters and adjacent Atlantic waters off Portugal, including the Canary islands and Madeira (Manning 1977). Its southernmost distribution is Angola (Manning 1977). Do Chi (1975a) reported that *S. mantis* is distributed from the English Channel to the Gulf of Guinea. It has been recorded as far north as Galway Bay Ireland (O. Tully, pers comm..). It is found from sublittoral depths (> 3 m, Abelló and Sardà 1989) to a maximum depth of 370 m, although it is abundant only down to 120 m. It is found on sandy and muddy bottoms.

The mantis shrimp reaches highest densities in suitable burrowing substrates, specially in areas under the influence of river run-off (e.g., Ebre, Rhone, Po). It is a strongly sedentary species and the rhythmicity apparent in catch data series is not due to temporal changes of distribution of *S. mantis* (e.g., not migrations), but rather to its reproductive and burrowing behaviour (but see *infra*), and temporal recruitment patterns.

In the Mediterranean and adjacent Atlantic waters, 9 species of stomatopods are found. Only *S. mantis* is economically important although a recent Lessepsian migrant, *Oratosquilla massavensis*, has potential economic interest in the Eastern Mediterranean (Holthuis, in *Fiches FAO*).

Life history

Growth and Reproduction

No significant differences in growth, or other population characteristics (eg distribution in space) between males and females have been reported

The mating season occurs from winter to early spring (January to April), when females have active cement glands, although activity of the cement glands may start as early as October (Do Chi 1975b). The activity rate of cement glands is maximum in January (100% of mature-size females) and decreases afterwards (Abelló and Sardà 1989). Eggs are laid from April to June (Do Chi 1975a). In spring and early summer, females incubate their eggs in their burrows, between their walking legs. During incubation, females do not emerge from their burrows, (Piccinetti, Do Chi). Larvae hatch between late spring and late summer (Piccinetti, Do Chi).

According to Abelló and Martín (1993), settlement of post-larvae takes place at the end of summer and beginning of autumn and recruitment to the fishery starts in November-December at *ca.* 6 cm TL for both sexes. Full recruitment to the fishery of individuals larger than 6 mm CL takes place between January and May. The mantis shrimp then grows relatively fast, reaching 13-14 cm TL at the end of the following year (Abelló and Martín, 1993) and growth is specially rapid in summer. Size at maturity (using cement gland activity as the index) for females is 11-13 cm TL (20-24 mm CL) (Piccinetti and Picinetti Manfrin 1970b, Do Chi 1975a, Abelló and Sardà 1989), i.e., female *S. mantis* mature within 1 year of settlement to the bottom.

Abelló and Sardà (1989) found that the population is structured in 3 year classes in the Ebro delta area (Table 1).

Table 1. Population age structure of S. mantis in the Ebro delta.

Age (Cohort)	Modal size, Males (CL mm)	Modal size, Females (CL mm)
I	8	10.5
II	27.5	26
III	36	32.5

The maximum total length reported is 20 cm.

Do Chi (1975b) found a similar population structure in the northern Gulf of Lions:

Do Chi (1975b) suggested a maximum life span of 3.5 years for *S. mantis*, with a maximum exploitation phase of 2 years. Other authors (Abelló and Martín, 1993; Righini and Baino, 1996) have found that the maximum sizes caught (19-20 cm TL) in the fishery would correspond to 3-year old individuals.

Do Chi (1975a) reported that *S. mantis* populations comprise one generation per year and each female spawns a single egg batch.

There is no clear distribution pattern of size by depth, although Abelló and Martín (1993) found that juveniles were more abundant shallower than 30 m depth. Likewise, Piccinetti and Piccinetti-Manfrin (1971) report a certain variability in catches by depth and season and suggest that temperature may play a role in determining local migrations of *S. mantis* in their search for "optimal" temperatures. This phenomenon has been also reported by Do Chi (1975b), but neither its importance to the fishery nor its causal mechanism have been thoroughly investigated.

Reproduction

The male copulatory organs appear in the coxae of the last walking appendices (8th thoracopod). The female's gonopores open in the mid-line of the 6th thoracic sternite, where a bag-like "seminal receptacle" also appears. After coupling, the female may store sperm for *ca.* 2.5 months.

The female possesses cement glands in sternites 6-8 which secrete a sticky substance. Together with the eggs, this sticky substance is "amassed" by the anterior thoracopods. The egg-laying period takes *ca.* 4 hours, producing a capsule containing *ca.* 50,000 eggs. The female incubates the egg mass in her burrow for *ca.* 10 weeks (2.5 months) and does not feed while incubating.

A zoea larva hatches from the egg and follows a planktonic development for *ca.* 2-3 months (Piccinetti Manfrin 1999).

Habitat use and requirements by juveniles and adults

Biasi and Ferrero (1989) note the strong intra-specific spatial competition of mantis shrimp in the pre-exploitation phase, as might be expected in a highly territorial species. Additionally, inter-specific competition (also noted by Biasi and Ferrero, 1989) and availability of suitable substrates for burrowing probably limit the total population number in this species.

Analysis of stomach contents evidenced a significant increase in the percentage of empty stomachs at day time and a diel feeding rhythm, clearly related with *S. mantis* night peaks of activity (see also 4.6, catchability). Piccinetti and Piccinetti-Manfrin (1970a) even indicate that *S. mantis* reared in aquarium refuse to ingest food during the day. The main food items recorded in stomachs analysed by these authors were crustaceans, molluscs and fishes, with a high percentage of empty stomachs and a strong seasonal variability in prey types. On the other hand, Froglia and Giannini (1989) found that the main food items in *S. mantis* stomachs were brachyuran decapods, natantian decapods, polychaetes, benthic fishes and bivalves. As already pointed out by Piccinetti and Piccinetti-Manfrin (1970a), this species may be an opportunistic predator and its diet reflects the local availability of prey. It is also noteworthy that *Liocarcinus depurator* may be an important prey item of *S. mantis* (Froglia and Giannini, 1989). A role as scavenger for the mantis shrimp cannot however be dismissed.

The Fishery

S. mantis is commercially exploited in the Mediterranean coasts of Spain, France and Italy (Abelló and Sardà 1989, Martín 1991, Do Chi 1975b, Piccinetti & Piccinetti Manfrin 1971). The mantis shrimp is mainly caught by bottom trawl, although catches with trammel nets and baited traps also occur. Maximum sizes landed are *ca.* 20 cm TL, but the catches are composed of individuals mainly 12-18 cm total length. It is landed and sold fresh. Although its catches are important only in Spain and Italy, it is present on all Mediterranean markets.

Although *S. mantis* is abundant down to 120 m depth, the highest CPUEs are reported for depths shallower than 50 m in Tuscany (Righini and Baino 1996) and 60 m in the Ebro delta area (Abelló and Martín 1993).

In Italy, the mantis shrimp is the most important crustacean species in the Adriatic fishery by weight, with average annual landings of 2000 mt in the 1980's and 3000 mt in the 1990's. The fishery is located on muddy bottoms at depths ranging from 5 to 60 m in the Northern and Central Adriatic i.e., in shallow waters under the influence of the Po river. In 1995, ISTAT figures show 4433 mt (74% or 3300 mt in Northern and Central Adriatic).

Catches vary by a factor of 10 in different seasons. Abelló and Sardà (1989) reported monthly catches of *ca.* 10 mt from November to March and *ca.* 1 mt from May to July. Trawl surveys (MEDITS project) estimated the density of *S. mantis* populations at 1.94 and 1.70 $kg.km^2$ for 1994 and 1995 respectively, in the northern and central Adriatic sea (Piccinetti Manfrin 1999). These values must be taken as minimum estimates, as they were taken by trawling during daytime and it is known that this species has a nocturnal maximum of activity (Righini and Baino 1996).

Landings from the BCN97.MDB data set (*daily sale bills from the auction at Barcelona port, from 1992 to present)* show that landings of *Squilla mantis* are highly seasonal, with maximum landings in winter. The monthly catch per boat can be as low as 3-4 kg in summer or as high as 10-20 kg (occasionally reaching 100 kg). The catches have been steadily decreasing during the 1990s. Considering that effort has been constant the data suggests a decreasing CPUE for this species in the Catalan area. Parallel to this CPUE decrease, an increase in unit price has occurred.

Catchability

The burrowing behaviour of *S. mantis* makes it vulnerable to the bottom trawl only when individuals are out of their burrows. Catches obtained during a 24-h sampling period by Froglia and Giannini (1989) show that the activity of mantis shrimp peaks at night, between sunset and sunrise. This behaviour makes the species less vulnerable to the fishery in areas where trawling is forbidden by night, e.g. Spain. On the other hand, reduced out-of-burrow activity results from the fact that females rarely exit their burrow when they are incubating the egg masses inside their burrows in spring and early summer. Conversely, catches are much increased in winter, when mating takes place (Piccinetti and Piccinetti-Manfrin 1971). The reproductive behaviour also influences the relative proportion of males and females in the catches by season: females outnumber males only in winter (mating season), while they are outnumbered by males in spring and summer. Do Chi (1975a) reported a seasonally varying sex-ratio for landings at the port of Sète (Gulf of Lions) where males predominate in the catches from April to August, coinciding with the lowest catches and the egg-laying and incubation period of females.

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Biology and Fisheries for Liocarcinus depurator

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Taxonomy

The International Commission on Zoological Nomenclature agreed in 1956 to reclassify the swimming crabs previously considered in the genus *Portunus* Fabricius, 1798, and assigned *P. depurator* to the genus *Macropipus* Prestandrea, 1833. Ingle (1980) and Manning & Holthuis (1981) reduced the genus *Macropipus* to three species and placed the remaining species in the new genus *Liocarcinus* Stimpson, 1971, with *L. holsatus* (Fabricius, 1798) as the type species. Later on, Holthuis (1987) created a new monotype genus, *Necora,* to separate *N. puber* (Linnaeus, 1767) from the genus *Liocarcinus*. Nowadays the genus *Liocarcinus* includes 10 species all distributed in the Eastern Atlantic and Mediterranean Sea, except *L. corrugatus* (Pennant, 1777) which is also reported in the West Pacific shores (Manning & Holthuis 1981, García-Raso 1984, Passamonti *et al.* 1996/97).

Nonetheless, morphologic and karyological data still perceived the genus *Liocarcinus* to be an unnatural group and it has been suggested that it should be further splitted into different genera (Froglia & Manning 1996). According to these data, *L. depurator* would belong to a new genus together with *L. bolivari* characterised by long and thin walking legs and dorsally granulated carapace.

Through allozymic analysis, Mantovani *et al.* (1992) reclassified the groups and considered that *L. depurator* and *L. corrugatus* should be included in one group, *L. arcuatus* and *L. maculatus* in another group and *L. holsatus* with *L. vernalis* in a third group. In a subsequent study Passamonti *et al.* (1996/97) suggested that the genus *Liocarcinus* stays with the same three species, a second group would be composed by *L. depurator* and the morphologically similar *L. bolivari* and a third group with *L. maculatus* and *L. arcuatus.* However, neither study included all the species of the genus and the intraspecific geographical variability observed does not suggest conclusive results.

Description

Liocarcinus depurator is a typical portunid crab with a carapace broader than long, with small tubercles dorsally positioned and transversal carinas. Its colouration is reddish-brown to light cream. The frontal carapace is provided with a median lobe slightly more prominent than two similar flanking lobes. The tip of the last pereiopod is paddle-shaped and violet in colour. (Zariquiey-Álvarez 1968). It has narrow elongated heterochaelic claws. The crusher claw is usually located on the right handside of the body (Abelló *et al.* 1990), and it is bigger and armed with broad molariform teeth, which can deliver a substantial compressive force for crushing resistant prey (Seed & Hughes 1995).

Distribution

Liocarcinus depurator is distributed along the eastern Atlantic coast from Mauritania and the Canary Islands (NW Africa) to the Norwegian coasts up to 68º N and throughout the Mediterranean Sea (d'Udekem d'Acoz, 1999). *L. depurator* is an eurythermic, euribathyic temperate species (Pérès & Picard 1965, Christiansen 1982) with a wide bathymetric range (continental shelf and upper slope) and habitat. It is found among several types of substrates, especially on muddy and sandy-muddy bottoms (Table 1). Almaça (1985) stated that depth and/or substrate act as the major factors limiting distribution of Mediterranean Brachyura. Acording to this author, *L. depurator* avoids competition with other *Liocarcinus* by preferentially occupying deeper habitats with muddy bottoms.

Stevcic and Galil (1994) divided the Mediterranean in several subregions (Western, Eastern, Central, Adriatic Sea and Black Sea) and verified the presence of *L. depurator* within all sectors. In the Mediterranean Sea, *L. depurator* has been recorded from the sublittoral down to over 800 m depth, and exceptionally deeper than 1000 m (Cartes *et al.* 1993), but with highest densities usually at depths shallower than 100-200 m (Sardá & Palomera 1981, Mori & Zunino 1987, Abelló *et al.* 1988, Abelló 1993, González-Gurriarán *et al.* 1993). No major evidences for seasonal changes in the depth distribution are found, although Mura (1987) observed that *L. depurator* in Sardinia was found deeper in winter than in summer. Scuba dive observations in shallow waters in Scotland indicated that this species performs depth migrations (Glass 1985).

In the Cantabrian Sea and Galicia, it is one of the most abundant species both in the continental shelf and within the Rías, particulary on the raft culture areas (Iglesias & González-Gurriarán 1984, González-Gurriarán 1986, González-Gurriarán & Olaso 1987, Olaso 1990, González-Gurriarán *et al.* 1993, García-Castrillo & Olaso 1995, Fariña *et al.* 1997). Raft areas have a large amount of objects and organisms deposited on the bottom, giving shelter to the epibenthic animals and possibly form a good place for the development of oportunistic feeders like *L. depurator*. In the British Isles, *L. depurator* has been mainly reported as a subtidal species (Glass 1985, Clark 1986, Glass & Huntingford 1988, Hall *et al.* 1990, Nickell & Moore 1992), but it appears sporadically during low tide in estuaries, tolerating salinities of 29-33 during the summer season (Mathieson & Berry 1997). In a study of a Scottish estuary it was verified that this species is not very tolerant to low salinity. Densities in this area were very low and restricted to summer months (Mathieson & Berry 1997), which correspond to the periods of warmer water (Glass 1985). Salinity variations have also been presumed to affect the distribution of *L. depurator* in the Rías.

L. depurator has been reported aggregate (Freire *et al.* 1991b, González-Gurriarán *et al.* 1993) on the Galician continental shelf. These geostatistical studies perceived depth as a limiting factor restricting distribution of *L. depurator* on a large scale, while upwelling, outwelling (nutrient rich waters from the Rías) processes and sediment type affected the spatial structure on a small scale. The distribution of *L. depurator* in the Rías is determined by the oceanic-estuarine gradient at a large scale and by environmental fluctuations at a small scale (Freire *et al.* 1993).

Concerning the spatial organization of the populations, Abelló (1993) showed a tendency for sizes to increase with depth in both sexes in a *L. depurator* population off the Catalan coast, with recruitment taking place mainly on the shallow continental shelf (25-50 m), although the bathymetric range where recruitment takes place can be wider.

Densities

L. depurator is the dominant brachyuran by-catch in Mediterranean demersal fisheries down to 200 m depth (Sardá & Palomera 1981, Abelló *et al.* 1988). Its highest densities are found at depths between 50-100 m in the Catalan Sea (Table 3) (Abelló *et al.* 1988, Abelló 1993), especially in the vicinity of deltas (Ebro, Llobregat). In the Ligurian Sea, overall densities are lower and maximum densities are located around 90 m depth (Table 2)(Mori & Zunino 1987). In the South coast of Spain maximum densities are located from 36 to 90 m deep (García-Raso 1984).

In the Atlantic, higher densities of *L. depurator* occurs during the summer months in the Gulf of Cadiz (Manjón-Cabeza & García Raso 1998). In the Galician coast, the highest values of abundance and biomass are in depths less than 125 m depth (Table 2) (González-Gurriarán & Olaso 1987, González-Gurriarán *et al.* 1993). Northern areas have higher densities than southern, with maximum values observed around Fisterra (Table 1) (González-Gurriarán *et al.* 1993, Fariña & Pereiro 1995). Maximum abundances in mussel raft areas are found at night, often during winter (Fernández *et al.* 1991, González-Gurriarán *et al.* 1995). Lagardere (1973) observed a peak of *L. depurator* distribution around 150 m depth in the Gulf of Gascogne (Atlantic coast of France), although its overall densities in this area were very low (Lagardere

1973). In the Clyde Sea (Scotland), *L. depurator* is one of the numerically more important brachyuran species (Nickell & Moore 1992). In Scottish lochs (Glass 1985, Glass & Huntingford 1988, Hall *et al.* 1990) densities are very low (Table 1) and restricted to summer months (Mathieson & Berry 1997).

Growth

Size-weight relationships are shown in Table 3. Significant differences have been found between the allometric curves for sexes and for moult stages and reproductive stages (Abelló 1986, Mori & Zunino 1987, Fernández *et al.* 1991).

A significant difference between males and females has been found in the relative growth of the crusher chela propodus (Mori & Zunino 1987, Abelló *et al.* 1990). Males have longer chelae for a given size. Adult males and females show positive allometric growth in this relationship, while juveniles show isometric growth (Mori & Zunino 1987, Abelló *et al.* 1990, Muiño *et al.* 1992). No differences between juveniles and adults occurs in the size – chela propodus length relationship in the Ligurian Sea (Mori & Zunino 1987). However, Muiño *et al.* (1999) and Abelló *et al.* (1990) observed two clear different phases of growth separated by the pubertal moult. Highly positive allometries in chela growth would be adaptive due to the use of chelae in male agonistic displays and other mating-related behaviours (Glass & Huntingford 1988). On the other hand, large chelae may be disadvantageous for swimming ability, widespread in portunid crabs, and so limiting the value of a possible highly positive allometry as in other crabs (Abelló *et al.* 1990).

Female abdominal segments also show a two-phase pattern of growth (Mori & Zunino 1987, Muiño *et al.* 1992). The first phase is characterised by a highly positive allometry followed by a sudden decrease and a second phase where the growth level is still positive but much lower (Muiño *et al.* 1992). This has been attributed to the existence of an optimal abdomen width to carry eggs.

Only two studies have estimated Von Bertalanffy growth parameters in *L. depurator*, one in the Mediterranean (Abelló, 1986) and the other in the Atlantic, in Galicia (Fernández *et al.* 1991) (Table 3). Immature individuals do not exhibit growth or size differences between sexes (Abelló, 1986); differences arise later, with maturity. Males have higher growth rates than females (Table 3).

Reproduction

Different methods have been applied to determine the size at sexual maturity, either directly related to reproductive criteria or based on morphometric analyses. The size of functional maturity is greater in males than in females (Table 4). Females reach maturity within their first year of life, both in Galicia and in the Mediterranean (Abelló 1986, Fernández *et al.* 1991).

Global sex-ratios have been found to be slightly biased toward females in the Catalan coast and in the Ligurian Sea (Mori & Zunino 1987, Abelló 1993). Significant variations with depth have also been recorded. Thus, the proportion of females increased with depth in the Catalan Sea: males tend to be more abundant on the continental shelf, while females predominate between 200-350 m (Abelló 1986, 1993). Differences in size and growth rates produces biased sex ratio for some size classes after the maturity moult (Mori & Zunino 1987, Fernández *et al.* 1991, Abelló 1993). Between 19-27 mm CL, females are significantly more abundant than males, while from 33 mm on, males are more abundant (Abelló *et al.* 1990). On the other hand, males have faster growth rates (Fernández *et al.* 1991). According to Abelló *et al.* (1990), females invest more energy in reproduction after maturity, while males can continue to invest that energy in growth. This differential investment may explain different sex ratio by size class and growth rates.

Reproduction and moulting are two strongly interrelated processes. No evidence for a marked male reproductive cycle has been found, since males are sexually mature throughout the year (Mori & Zunino 1987, Abelló 1993) (Table 3). Also, no evidence of a clear moulting cycle is present in males. The female reproductive cycle is more marked. In northern latitudes, ovigerous females are more common in spring and summer (Glass 1985, Allen 1967). In the Mediterranean ovigerous females are recorded throughout the year with a marked autumn-winter peak (Abelló 1989). Moulting crabs occur throughout the year in the Mediterranean and in Galicia (Mori & Zunino 1987, Abelló 1989, Fernández *et al.* 1991). Wear (1974) reported that *L. depurator* could incubate three or more batches of eggs without an intervening moult. Evidence for a second batch of eggs in the Mediterranean has been based on gonad examination (Mori & Zunino 1987, Abelló 1993). The monthly evolution of the gonosomatic index clearly shows the existence of a marked maturity cycle in the Mediterranean (Abelló 1989). Active vitellogenesis begins in July with peak values in November-December when spawning begins.

Fernández *et al.* (1991) found that the reproductive output of *L. depurator* is higher in Galicia than in the Mediterranean, due to greater growth rates, larger sizes and two annual spawnings. Still, in the Mediterranean, Abelló (1989) and Mori & Zunino (1987) suggested that a small percentage of females may spawn twice a year and females appear to reach maturity in their first year of life.

Direct measurements of reproductive output of *L. depurator* only exist for Mediterranean and Galician populations (Mori & Zunino 1987, Abelló 1989, Muiño 2002) (Table 3). Fecundity is significantly related to size. In the Mediterranean Sea, the number of eggs carried by females ranged from 25,000 to 230,000 eggs, whereas in the Galician populations it ranged between 12,000 and 203,000 eggs. Under laboratory conditions, the incubation time in *L. depurator* is 31.5 days, at 13.1^{o}C and 25.5 days at 15^{o}C (Wear 1974). Based on this information, Mori & Zunino (1987) estimated an incubation period of around 30 days for crabs living on the continental shelf in the Ligurian Sea.

Activity patterns

L. depurator is mainly active at night. Thus, Patterson (1984), using underwater video recordings in the Irish Sea, observed that there was an increased emergence of the species from the substratum during the night. González-Gurriarán *et al.* (1995) compared diel variations in the total catches of *L. depurator* within three areas in Ría de Arousa, observing also that densities were significantly higher during the night in the outer and the central channel. However the opposite pattern was observed in the inner channel. This may be related to the lower depth of the inner channel area coupled to a tidal effect on the activity patterns. Glass (1985) also identified depth as a factor affecting the diel pattern of activity, since, from scuba dive observations in a Scottish loch, he noticed that individuals from shallow water showed tidal rhythms of activity. Abelló *et al.* (1991) showed the occurrence of endogenous rhythmic circadian patterns of activity in subtidal populations of the Irish Sea, with peak values located around midnight. The occurrence of different activity patterns between *L. depurator* and its congeneric *L. holsatus* in subtidal waters was attributed to a behavioural mechanism to avoid direct competition or niche overlap. Freire et al. (1991a) observed that night samples presented higher stomach repletion values than day samples.

Behaviour

L. depurator is a highly aggressive species. Intraspecific fights between males take mainly place during the pre-mating processes (Glass 1985, Glass & Huntingford 1988, Huntingford *et al.* 1995). Size difference among opponents appears to be the major factor explaining fight success (Parker & Rubenstein 1981, Maynard Smith 1982, Enquist & Leimar 1983).

Discards and Mortality

Mortality due to fishing pressure of a non-target species such as *L. depurator* occurs both by direct discard of non commercial species/sizes from the fishing boats and through damaging by fishing gears (non-catch mortality). In this last case, damaged animals remain in the seabed and constitute an easy target to opportunistic feeders like *L. depurator* itself (Demestre & Sánchez 2000). The effect of non-catch mortality in *L. depurator* was tested in three different areas within the Irish Sea (Ramsay *et al.* 1998). In Dulas Bay-Anglesey (40 m depth, coarse sand with gravel and shell debris substrate, samples from April and October in a low commercial fishing activity zone) and in Red Wharf Bay-Anglesey (12 m depth, sandy substrate, samples from April in an occasionally visited commercial trawls area) there was no significant effect on *L. depurator* density after trawling, while in Walney Island (36 m depth, muddy substrate, sampled in October in an area heavily fished by commercial beam trawls) there was a significant decrease in density after two days of fishing (Ramsay *et al.* 1998). This last area was the one presenting highest densities from the three experimental sites (>40 ind.1000 m^2) and factors such as sampling month and different depths within the sampled areas may have interfered with these results.

Feeding

Like other crabs, *L. depurator* does not feed during premoult and immediate postmoult, and the maximum observed stomach fullness takes place during late postmoult (Abelló & Cartes 1987, Freire 1996). Gut contents analysis indicate that *L. depurator* has a generalist diet, preying mainly on sessile and macroinvertebrates with low mobility (Freire *et al.* 1996), but also on fast swimming prey such as crustaceans (*Alpheus glaber*, *Processa caniculata*, *Pasiphea sivado*, etc.) and small fish (Abelló & Cartes 1987). In the Galician Rías, *L. depurator* diet was significantly influenced by mussel culture (González-Gurriarán *et al.* 1995). In the raft areas, the mussel *Mytilus edulis* constituted 22.1% of crab diet and the crustacean *Pisidia longicornis* 14.3% (González-Gurriarán *et al.* 1989). A slight degree of cannibalism, with large individuals preying upon juveniles, has been reported in Scotland and in the Catalan Sea (Abelló & Cartes 1987, Hall *et al.* 1990). In general, the diet of males and females does not differ significantly, either qualitatively or quantitatively (Abelló & Cartes 1987, Mori & Manconi 1989, Freire 1996). However, ovigerous females have a less diverse diet than males and non-ovigerous females and there were significant differences between sexes in five dietary components in the Ría de Arousa (Freire 1996).

Seasonal variations of the diet were observed in the Catalan coast (Abelló & Cartes 1987). During summer and autumn an increase in fish consumption was detected, attributed to a peak in settlement to the bottom of fish juveniles. The abundance of each prey in relation to the season emphasised a generalist and opportunist feeding behaviour of this species.
Size-related differences in diet composition have also been reported in the Galician Rías (González-Gurriarán *et al.* 1989, Freire 1996).

Fast moving portunids, like *L. depurator* are adapted to catch relatively rapid prey, and so have fast claws with a low mechanical advantage (Seed & Hughes 1995). The functional structure of *L. depurator* chelipeds appears to be very versatile in order to consume a large range of different preys.

Larval ecology

The larval development of *L. depurator* consists of five zoeal stages and one megalopa (Ingle 1992). Given the high number of larval stages, larval dispersion can be assumed to be high in this species. Not many papers have dealt with the larval ecology of this species in particular, because the morphological differences between zoeae of the different species of the genus present in European waters are practically non-existent in the early stages. It is a common practice to identify zoeae of *Liocarcinus* only to genus level.

The size of the larvae ranges from 1.5 mm in the zoea I to 2.8 mm in the zoea V (tip to tip of the rostral and dorsal spines). The megalopae measure about 2.0 mm CL. Higher densities of *L. depurator* megalopae are detected in night samples, both in the neuston and in the water column down to 50 m depth over the continental shelf in the eastern Mediterranean (Abelló & Guerao 1999), suggesting that megalopae may spend day-time hours resting on the bottom or in the suprabenthic layers.

The Fishery

Portunid crabs are regularly caught in the Mediterranean and European Atlantic by bottom trawls, static nets and pots (Holthuis 1987). In many cases, they are discarded at sea, or in part used as bait. The landings for human consumption are restricted to some Mediterranean areas. They are also sometimes processed in Ireland. They are often sold in mixed crates as "crabs" or "other crustaceans" and it is therefore very difficult to estimate their actual catches and landings. In some Mediterranean areas, such as Catalonia, Liguria and Greece, *L. depurator* is included in the bulk of the catch sold under the category "crabs". Other crabs may be important in specific regions: brachyuran species, such as *Maja squinado* (Liguria and Adriatic coasts), *Calappa granulata* (Spain); or Portunids, such as *Macropipus tuberculatus* (Spain, Liguria), *Liocarcinus arcuatus* (Liguria), *Liocarcinus corrugatus* (Spain, Liguria) or *Liocarcinus vernalis* (Liguria and Adriatic coasts).

Lloret *et al.* (2000, 2001) detected a marked seasonality in catches of *L. depurator* off the Catalan coast in the western Mediterranean, with peaks of catches in June-October, due to recruitment to trawl nets taking place in August-October. A significant relationship between CPUE and Rhone river runoff was found, with a time lag of 6-10 months (Lloret, 2001).

Catalonia:

Catches of crabs (mainly *L. depurator*) constitute 0.2% of the total crustacean catch. 90% of the crabs are caught in the ports south of Barcelona, in areas with a large continental shelf. Total catches vary between 300 and 450 tons (1988-1999). A slight seasonality is apparent, with higher catches in summer.

Greece:

Catches of crabs (mainly *L. depurator*) constitute 2% of the total crustacean catch (1990-1998) (Politou, pers. comm.). Most of the catch originates in the Northern and Central Aegean sea. Total catches were *ca.* 100 tons in 1999. *L. depurator* is caught as by-catch of multi-species continental shelf fisheries and, to a lesser degree, as by-catch of the *Nephrops norvegicus* and hake fisheries in the Mediterranean. As it is a by-catch species, no specific information can be given on fleets and gears. Refer to Caddy (1993) or Farrugio *et al.* (1993) for a general introduction to multi-species fisheries in the Mediterranean.

Discarding

L. depurator is almost always discarded at sea in the Atlantic and in many Mediterranean ports. In a study of discarding of the hake fishery in four ports of the Mediterranean (Spain and Italy), Martín (2001) reported that this species is entirely discarded in the North Tyrrhenian sea and the Balearic islands (where catches are <1 kg/day/vessel), while discards represent between 20 and 30% of the catch in two ports of the Catalan sea (from 1 to 15 kg/day/vessel). Groenewold & Fonds (2000) report between 50 and 60% of mortality rates in discards of *Liocarcinus* sp. in discarding experiments of beam-trawl catches in the North sea.

Table 1: Liocarcinus depurator depth range, substrate, geographical area reported and respective reference (d'Udekem d'Acoz 1999).

Depth (m)	Substrate	Area	Reference
5-256	Sand mud and detritus	Adriatic Sea	Stevcic (1979) Stevcic (1990)
80	Sand	Malta and Fifla Islands	Schembri & Lanfranco (1984)
10-300	-	Ligurian Sea	Tunesi (1986)
5-871	Detritous	Helenic Islands	d'Udekem d'Acoz (1992)
3-871	Muddy	Catalan Coast	Abelló (1993)
1-450	Sandy- muddy	Malaga (South Spain), Huelva, Cadiz	González-Gordillo et al. (1990) García-Raso (1984).
10-750	Muddy	Ligurian Sea	Relini et al. (1986)
90-135 350-650	Muddy; with Funiculina quadrangularis	Southern Sardinia	Manning & Froglia (1982) Mura (1987) Mura & Cau (1994) Mura & Cau (1992)
167-205	Shell remains	Marroco	García-Raso (1996)
0-465	Shell remains, rock and muddy	Gulf of Viscaya (Bilbao)	Gutierrez et al. (1989) Díez et al. (1994)
5-30	Coarse (high hydrodynamism)	Strait of Messina	Spanò (1998)
7	-	Piran Golf (Adriattic)	Manning & Stevcic (1982)
40-550	-	Balearic Islands	Garcia Socias & Gracia (1988) Forest (1965)
36-146	-	Israel	Holthuis & Gottlieb (1958)
80	Mud-sand	Portugal	Nunes-Ruivo (1961)
0-450	Soft, sandy and mixed bottoms, gravel	British coast	Ingle (1980) Hayward et al. (1993)
12-40	Mud, sand, gravel and shell debris	Irish Sea (Anglesey)	Ramsay et al. (1998)
65	Muddy	Sicilian channel (Tunisian coast)	Falciai (1997)
5-10	-	Turkish Black Sea	Holthuis (1961) Ates (1999)

Table 2. L. depurator abundance and biomass values observed in different geographical areas, time period (years, hours or seasons), depth ranges and respective reference.

Depth (m)	**Abundance/tow (60 min)**	**Biomass (g/tow)**	**Local**	**Yr/Month/ Hour**	**Reference**
15 (?)	13-14 juvenile.m^{-2} 0.25 adults.m^{-2}	7.5 g.m^{-2}	Loch Gairloch, (Scotland)	1987 (?)	Preliminary estimates in Hall, et al. (1990)
-	0.14 ind.m^{-2} 0.04 ind.m^{-2}	-	Loch Sween (Scotland)	Sep-Nov Others	Glass (1988) (1985)
50 100-200 100-200	1 1-4 1		Coast of Scotland West Shetland Fladdeen	1977-81	Dyer et al. (1983)
0-200	0.005-0.01 ind.m^{-2} (max. 0.14 ind.m^{-2})		Moray Firth (East coast of Scotland)	1980-84	Basford et al. (1989)
15 15-40	0.014 ind.m^{-2} 0.141 ind.m^{-2}	0.170 g.m^{-2} 1.550 g.m^{-2}	Ría de Muros e Noia. Raft area Middle channel	1978/79	González-Gurriarán (1986)
1-32	1.87 ind.10 min tow^{-1} (max. 6-10 ind.)	32.49 g.10 min tow^{-1}	Ría de Ferrol	October 1990	Freire et al. (1993) González-Gurriarán et al. (1991)
10	63 45 80.3 171.0		Ría de Arousa-raft area (mussel culture, mud bottom)	14:40 (April 1989) 19:28 01:00 12:04	González-Gurriarán (1995) (Figure2)
20	104.0 162.0 350.0 7.3		Ría de Arousa-raft area (mussel culture, mud bottom)	17:29 (April 1989) 22:15 03:26 10:02	González-Gurriarán (1995) (Figure2)
40	5.7 8.3 13.0 4.7		Ría de Arousa-central channel (muddy)	15:56 (April 1989) 20:58 02:39 08:26	González-Gurriarán (1995) (Figure2)
<200 200-500	10 5	143 29	Miño-Fisterra (Galicia)	1979-84	González-Gurriarán (1987)
<200 200-500	19 2	277 16	Fisterra-E Bares (Galicia)	1979-84	González-Gurriarán (1987)
<200	5	59	E. Bares-Ribadeo (Galicia)	1979-84	González-Gurriarán (1987)
100-500	30.94 48.88	408.96 471.50	Galicia coast	Autumn (1980-86) Spring (1984, 86, 87)	Fariña et al. (1997)
99-425 80-436 88-422	2.58 2.79 33.36		Galician Coast (Miño-Ribadeo)	Sept 1983 May 1984 Aug-Sept 1984	González-Gurriarán et al. (1993)

8-30		0.2 (WW.m^{-2})[1] 0.56	Outer Ría de Arousa (raft culture)	Sept 78-Oct 79	Fernández et al. (1991)
8-30		0.06 (WW.m^{-2})[1] 0.004	Inner Ría de Arousa (raft culture)	Sept 78-Oct 79	Fernández et al. (1991)
40		0.004 (WW.m^{-2})[1]	Central channel (Ría de Arousa)	Sept 78-Oct 79	Fernández et al. (1991)
10 12 36	0-40 0-10 20-70		Anglesey Anglesey Walney	1995	Ramsay et al. (1998)
10 20 30 50 90 300	3 3.5 8.7 39.3 157.3 7.0	15 23.5 117.3 148.3 675.0 65.6	Ligurian Sea	Jan 82-Apr 83	Mori & Zunino (1987)
0-25 25-50 50-100 100-150 150-200 200-300 300-400 400-500 500-600 600-700 700-800	876 684 1131 113 40 26 8 1 4 4 1		Catalan coast (from Sant Caarles to Roses)	June 1981-May 1983	Abelló (1989)

Table 3: Biological characteristics of Liocarcinus depurator by region.

Parameter*	**Region**		**Source**
	Galicia (Atlantic)	**Mediterranean**	
Size-weight relationship	Male 0.00042 x $CW^{2.836}$ Female 0.00057 x $CW^{2.745}$		Fernández et al. (1991)
		Male 0.00028 x $CW^{2.928}$ Female 0.00003 x $CW^{2.910}$	Mori & Zunino (1987)
		Male 0.605 x $CL^{2.9956}$ Female immature 4.45 x $10^{-4}CL^{3.072}$ Female mature 6.71 x $10^{-4}CL^{2.959}$ Female ovigerous 6.34 x $10^{-4}CL^{3.011}$	Abelló (1986)
von Bertalanffy growth parameters	CW male L_{inf} 51.4-56.6 male k 2.72-3.09 male t_o 0.26-0.31 female L_{inf} 39.0-43.1 female k 2.71-4.79 female t_o 0.22-0.29		Fernández et al. (1991)
Moult frequency		males: irregular females: April-October	Mori & Zunino (1987)
		males: irregular females: May-July	Abelló (1989)
	late summer - early autumn males: throughout the year females:		Fernández et al. (1991)
Size-fecundity		range: 25000-140000 N=3912.9CW-65821 egg diameter 280-382 µm	Mori & Zunino (1987)
		range: 30000-230000 log(n)=-0.705+3.75log(CL)	Abelló (1989)
	range: 12000-203000 log(n)=-1.2737+3.8373log(CW)		Muiño (2002)
Egg incubation period		around one month	Abelló (1989)
		around one month	Mori & Zunino (1987)
Size-maturity		males: 27-30 mm CW females: 22-24 mm CW	Mori & Zunino (1987)
		males: 20 mm CL (CW=25.4 mm)	Abelló et al. (1990)
		females: 18-20 mm CL (CW=22.8-25.4 mm)	Abelló (1989)
	males: 31.4-35.7 mm CW females: 25.5-31.5 mm CW		Muiño et al. (1999)
Age at maturity		within first year of life	Mori & Zunino (1987) Abelló (1989)
	within first year of life		Fernández et al. (1991)
Spawning frequency		1-2 per year	Mori & Zunino (1987) Abelló (1989)

	2 per year		Fernández et al. (1991)
Ovigerous season		All year: November-March	Abelló (1989) Mori & Zunino (1987)
		All year	García-Raso (1984)
	All year: January-May		Fernández et al. (1991)
Longevity		1-2 years; max: 3-4 years	Abelló (1986)

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Biology and Fisheries for Munida spp.

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Taxonomy

The Galatheid 'crabs' are a cosmopolitan group of marine decapods commonly known as squat lobsters. They are members of the infraorder Anomura, Class Crustacea and most are benthic in lifestyle but some species may swarm in pelagic waters eg. *Munida gregaria*. The benthic forms occur on a variety of substrates from rocks to soft mud depending on the species in question (Zainal 1990). The family contains 7 genera of which *Munida* and *Galathea* are the most widely studied. In general species of *Munida* live at greater depths than species of *Galathea* and have a wide distribution both deep off the continental shelf and inshore around the British Isles. These species include *Galathea dispersa, G. intermedia, Munida microphthalma, M. rugosa, M. sarsi, M.tenuimana, Munidopsis antoni, M. aries, M.bermudezi, M.sarsi, M.curviostra, M. parfaiti, M. rosorata, M..serricornis* and *M. tridentate*. The common inshore species are the *Galathea* and *Munida* species (Zainal 1990).

Biology

Fisheries for these species are pporly developed. A short account of each species is presented below

Genus *Munida* Leach.

The galatheid genus *Munida* has a worldwide distribution and includes about 100 species ranging in depth distribution from the sublittoral to depths of more than 2000m. Some species of *Munida* have considerable potential economic importance, however information on certain species is still sparse in areas around Europe (Hartnoll *et al*., 1992).

Munida rugosa Fabricus 1775.

Munida rugosa is a shallow dwelling species of increasing economic importance. The exact distribution and bathymetric range of *Munida rugosa* has in the past been difficult to determine because of nomenclature confusion (Rice & Saint Laurent 1986). In general however *Munida rugosa* is found in the Eastern Atlantic from Shetland and Sognefjord (Norway) in the north to Madeira in the south, and in the Mediterranean at least as far east as the Adriatic. It is restricted to waters not deeper than 300m having mainly a distribution along the continental shelf (Rice & Saint Laurent 1986). This species has been recovered from depths as shallow as 8m in the Firth of Clyde, Scotland and no deeper than 280m in the Porcupine Seabight where it overlapped with *Munida sarsi* but was relatively low in abundance compared to other species of *Munida* (Attrill 1988). It is commonly found on soft mud and bedrock (Zainal 1990), sandy gravel or sheltering in depressions under stones or in crevices. *Munida Rugosa* has been known to occupy burrows of other animals e.g. Red-band fish *Cepola rubescens* and the Norway Lobster *Nephrops norvegicus* (Atkinson 1988).

Ovary development in *Munida rugosa* was observed between Spring and Autumn and eggs hatch from March. The mean egg diameter recorded by Zainal (1990) from samples taken in Scotland was 0.89 ± 0.88mm and in general eggs are incubated on the pleopods for at least five months with hatching occurring in the spring. Larger females usually carried more eggs (Zainal 1990) and sexual maturity is reached at a carapace length of 17mm. The diet of *Munida rugosa* is varied made up of polychaetes and crustaceans, bivalves, algae etc and in some specimens sediment was found indicating deposit feeding. Feeding in the Porcupine seabight was observed to peak at night (Attrill 1988). Zainal (1990) also reported munida rugosa to have low gill area values compared to other Decapod crustaceans, which reflects its relative inactive lifestyle.

The average size of adult *Munida rugosa* is 80 mm. The cephalothorax is red-brown and much duller than *Munida sarsi*. *M.rugosa* has no spines on the fourth abdominal tergite which distinguishes *M. rugosa* from *M. sarsi* and *M. tenuimana* in which spines are always present (Rice & Saint Laurent 1986). The median rostral spine is usually uniformly coloured (Zainal 1990). There are also distinct geographical variations in *M. rugosa* within the Atlantic populations, with the number of spines increasing further south. In general eyes are quite small on adults and there is no significant difference in weight/length relationships between male and female but there is a difference in the relative growth of body parts. The abdomen width in females was always greater than in males of the same carapace length with females showing positive allometry and males exhibiting negative allometry (Zainal 1990). Cheliped length showed positive allometry in males and negative allometry in females.
As yet the fishery for *Munida rugosa* is not developed in Europe and at present it is mainly caught as a by-catch of the creel fishery for crab in Scotland.

Munida sarsi *Huus 1935*

Munida sarsi is a deepwater, bottom dwelling animal (Berrill 1970). This species is primarily a species of the upper continental slope and is the most northerly distributed species of *munida* extending as far north as Iceland and south to the Bay of Biscay (Zariquiey Alvarez 1952) and the northern coast of Spain (Rice & Saint Laurent 1986). This species has not been recorded in the Mediterranean or from the coast of Portugal (Hartnoll *et al*., 1992). *Munida sarsi* has a depth range of 100-1000m but is most commonly found between 250-400m. In a study conducted over the Porcupine bank *Munida sarsi* was the most abundant of the *Munida* species reaching its maximum abundance at depths between 400 and 500m (Attrill 1988). Attrill found that *M.sarsi* overlapped the distribution of *M.tenuimana* in the Porcupine Seabight.

Adult *Munida sarsi* has a mainly orange colouration with a very obvious white band across the anterior part of the carapace at the level of the bases of the rostral spines and including the orbital grooves. Adults have relatively large eyes and two spines on the fourth abdominal tergite and the median rostral spine is orange with a white patch near the tip (Zainal 1990). The average length of male carapaces sampled in the Porcupine Seabight was between 8- 20mm and the females average length was between 8-17mm (Hartnoll *et al*., 1992). In the same study male chelae were found to grow isometrically before maturity and positively allometrically after maturity. Female chelar growth was found to be close to isometric throughout their growth. There is an annual reproductive cycle in *Munida sarsi* with females laying eggs in November to December and incubating them until April, May of the following year when they hatch and the females usually moth thereafter. Males molt in February.

Munida intermedia A.Milne Edwards and Bouvier 1899.

Munida intermedia is found in the Eastern Atlantic from the Goban Spur at about 50°N to the Azores and in the Mediterranean as far east as the Adriatic from 120 to 800m depth (Rice & Saint Laurent 1986). Adults have a red brown or orange cephalothorax similar to rugosa but the orbital region in front of and beneath the frontal border is marked with bright red patches. Adults also have large dilated eyes.

Munida tenuimana *G.O Sars 1872.*

Munida tenuimana is distributed in the eastern Atlantic from Iceland down to the Iberian peninsula and in the Mediterranean as far as the Adriatic sea (Hartnoll *et al*., 1992). The bathymetric range of the species varies geographically with the species found deeper in the southern warmer waters120-280m in Iceland, 250-300m in Norwegian waters, 400m in the Mediterranean. It is typical of the bathyal mud assemblages in the Western Mediterranean. Attrill (1988) recorded this species from 700-1410 in the porcupine bight with most animals occurring at 1296m. Adults have a pale upper surface with red tipped spines and generally orange under the surface with brilliant red tips to the legs. Male and female specimens have a similar length distribution with an average carapace length of 14mm (Hartnoll *et al*., 1992).

The diet of Munida tenuimana is made up of various polychaetes, crustaceans and fish (Cartes 1993).

Munida microphthalma A.Milne Edwards 1880.

Munida micorpthalama is widespread in the North Atlantic from Iceland to the Cape Verde Islands (Hartnoll *et al*., 1992). Attrill (1988) found this species at 1630-1640m in the porcupine sea bight.

Galthea dispersa Bate 1859.

Galathea dispersa is a sublittoral species found in depths between 10-500m. It is common along all British coasts and very common elsewhere as north as Norway and south Iceland and south to Madeira and the Mediterranean and the Canary Islands. Adults are commonly found from shallow/sublittoral and offshore to the edge of the continental shelf. Adults have a carapace length of approximately 25mm with its colour varying from yellowish to red and may have white spots. Chelipeds generally have no spines and the rostrum have a single-spined tip densely covered in setae. Eggs are carried by the females during the spring and the larvae of *Galathea dispersa* are the only species of Galathea to have five zoel stages.

Galathea intermedia Lilljeborg 1851.

Galathea intermedia is a sublittoral species found along the British coasts and very common elsewhere in Norway down to Daker in the Mediterranean (Hayward and Ryland 1990). This species is found on coarse substrate consisting of empty shells and pebbles. Allen(1967) recorded this species to be commonly found on rock, stones, gravel and hard mud and sand. The adults are relatively small squat lobsters with a narrow finely toothed rostrum, the carapace averages 9mm with a total length of 18mm. Ovigerous females are found from the middle of March to the beginning of October with the first juveniles being observed in August. The growth of *Galathea intermedia* is rapid and they are reported to have a life span of about one year, some specimens might survive into a second year and reproduce once more (Hayward & Ryland 1990).

Galathea nexa Embleton 1834.

Galathea nexa is a sublittoral species found between 25-270m. It is not common around the south and west coasts of Britain but common further south as far as Tenerife and in the Mediterranean (Hayward& Ryland 1990). Adults have a carapace length of up to 20mm and a short broad rostrum with a sharp point and long spines on each side. The chelipeds are hairy with long spines on the carpus and merus but not on the propodus. Each abdominal segment has a single transverse groove.

Galathea squamifera Leach 1814.

Galathea squamifera is the most common species around the British isles extending north to Norway and south to the Mediterranean. Juveniles are usually found deeper than the adults which are found in greatest abundance between 30 and 70m. Adults have a carapace length of up to 35mm and a brown carapace with a green tint and red tipped spines. The rostrum is short and broad with a long apical spine and shorter lateral spines. The chelae are covered with tubercles but lack spines. Adults are found beneath rocks on sheltered to moderately exposed shores, feeding on suspended detritus. Females carry eggs in late winter and spring.

Galathea Strigosa Linnaeus 1767.

Galathea strigosa is a relatively large squat lobster with a carapace length of 50mm. Adults have a reddish brown carapace with bright blue striae and are normally found on rock strewn slopes or gravel bottoms. The bathymetric range of *G.strigosa* ranges from the shallow, sublittoral to 600m and is very common around the British Isles. It’s geographical distribution extends north to the north cape of Scandinavia and south to Spain, the Canaries along the Mediterranean and in the Red Sea. Morphological studies of the adults indicate that they are restricted to rocky areas where their food is obtained by detrital deposit feeding and scavenging and they exhibit nocturnal peaks in activity. Female *G. strigosa* carry eggs throughout the winter.

Larval development

All larvae of the galatheids have 4-5 zoel stages and two main modes of reproduction have been postulated (Wenner 1982). In *Munida* animals produce many small eggs from which pelagic larvae emerge. In *Munidopsis* a few large eggs are produced that develop into advanced larvae and remain in the bathymetric realm of the parent.

The Fishery

Galatheid fishery is still relatively underdeveloped in Europe but there is a large fishery worldwide. In New Zealand, *Munida gregaria* is being commercially fished for use as a food stock for cultured salmon (Zeldis 1985) and in Chile there is a large galatheid fishery of *Cervimunida johni* and *Pleuroncodes monodon* (Bahamonde *et al.*, 1986). In Europe however the Galatheid fisheries are very underdeveloped with a small fishery in Scotland for *Munida rugosa* (Howard 1981) where they are mainly caught by creel or as a trawl by-catch. Shellfish processing companies now handle the species (Anon 1999) but this fishery is still opportunistic and underdeveloped. Because the galatheid are not commercially exploited in Europe there is a lack of biological and biometric information available.

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Biology and Fisheries for Cancer pagurus in northern Europe

Description and distribution

Physical appearance

Cancer pagurus L. is a brachyuran cancrid crab found on the continental shelf mainly in northern Europe. Taxonomically it is in the sub-order brachyura and family Cancridae. The adults are brown in colour dorsally and pale yellow ventrally. The ventral colour is yellowish white after moulting. There is black colouration on the tips of the dactylus and propodus. The carapace is broad and oval with no protruding rostrum. The margins of the carapace have rounded lobes and indentations. The chelipeds are large and almost equal in size. Mature males have relatively larger claws than females. The fifth pereiopods are relatively short and deflected backwards, used for digging in soft sediment and gripping solid substrates. The abdomen of the female is broad with a setose margin. The male abdomen is narrow and recessed. Adult size can reach 260 mm carapace width.

Distribution

Cancer pagurus occurs from Norway in the north to Gibralter in the south as depths from low water mark to 330 m. It's habitat ranges from solid bedrock to sand substrates. Relatively sedentary mature males tend to inhabit hard substrates that provide shelter, although they do occur on softer sediment. Females occur on mud-sand-gravel substrates and brooding females dig pits in the sediment. Juveniles are abundant in shallow hard substrates close to the low water mark and in shallow coastal waters. Spatial segregation by size occurs and size increases with depth LeFoll (1982). Nursery areas therefore tend to be in coastal waters.

Migration

Extensive migration of adults females has been demonstrated in northern Europe. Crabs may range over 100s of kms and also make return migrations. These migrations may be linked to seasonal reproductive activity. Rates of movement average 0.14 km.day^{-1}. Larvae are also widely distributed on the coastal areas of the continental shelf. The population structure is therefore open over scales of 100s of kms although several discrete populations may exist in northern Europe. Males are more sedentary.

Life History

Moulting and Growth

Data on growth are derived from tag-recapture experiments, radiometry, evolution in mean size (juveniles) and laboratory cultivation. The increment in mean size is more easily determined than moult frequency which varies spatially and temporally (Table 1).

The majority of mature adult female crabs moult between July and October in the major fishing areas in northern Europe (Edwards 1972). As hard-shelled males copulate with females in the soft-shelled condition, males moult slightly later than females. Adult crabs moult a maximum of once annually and may skip moult in some years. Moult frequency decreases in frequency with increasing size at least in females.

Juvenile crabs moult a number of times annually. Newly settled first crab stage juveniles ranging between 2.2-2.7mm carapace width attain a size between 5-8mm in the first summer of growth, depending on the timing of settlement, by undergoing 4-5 moults. Moult increment is 26-29% of pre-moult carapace width. This may be as high as 32% for crab of pre-moult widths of 6-10 mm (Robinson, 1998).

Size at maturity

Morphometric and physiological maturity occurs between 104-120 mm and 105-115 mm respectively off the north west coast of Ireland (McInerney 1997) On the basis of ovary maturation Le Foll (1986) estimated the minimum and mean size at maturity to be 104mm and 117mm respectively in south Brittany. Based on observation of berried females kept in tanks, Latrouite & Noël (1993) estimated the mean size at functional maturity to be 137 mm for females in Biscay bay and western Channel. Using a different method of assessment Edwards (1971) estimated that 50% of females were mature between 127-139mm. Cosgrove (1998) using the methodology of Le Foll, determined that 50% of females in the north-western Irish offshore fishery were mature at 121mm. Morphometric maturity of females in this fishery occurred at 126mm.

Mating

Male crabs attend to females in the period prior to moulting. In laboratory based studies males have been observed guarding females for up to 1 month before the females moult. When moulting occurs the male often helps to remove the shed exoskeleton from the soft female prior to mating. Males will often stay in attendance for some time after the female has moulted and remains in a soft-shelled condition. After sperm impregnation, the female secretes a substance that hardens on contact with seawater forming a solid 'sperm plug' preventing sperm loss. One sperm delivery may be sufficient to fertilise eggs in the following year. Male crabs held in captivity where able to attend and mate a number of times in one season.

Spawning

The majority of females spawn in late autumn and winter. Females spawn on soft ground to aid attachment of the eggs to the pleopods. Eggs do not attach to the pleopods if crabs spawn in featureless artificial containers. The eggs are carried until hatching between May and July. Maximum spawning frequency for mature females is once a year. In Biscay bay and the Western Channel 85% of females larger than 170mm (CW) are berried annually. Radiometric carapace ageing indicates that molting and spawning in the same year is the general rule. A delay between the two events may be as short as 3 months (Latrouite & Noël, 1993). In Biscay bay and Western Channel spawning starts in mid November and finishes in January (Latrouite & Noël, 1993).

Fecundity

The development of eggs is punctuated by a diapause or resting phase approximately 3 to 4 days after spawning. The eggs cease to develop for 8 weeks, after which normal development is resumed. Eggs increase by approximately 50% in size during development. Egg size is variable ranging between 0.32mm diameter at spawning and 0.5mm at hatching. Orange coloration at hatching reddens and then darkens with development, with eyespots evident at later stages.

The largest sample of gravid females examined was by Cosgrove (1998) for the Irish offshore fishery. Le Foll (1986), using a derived fecundity relationship from French caught crab, estimated that individuals of 116-178 mm CW would carry between 0.2-2.0 million eggs respectively. Cosgrove's data indicated a range of 0.8-1.9 million eggs for the crab of the same size range. The largest female recorded during any study (Cosgrove 1998), measuring 225mm CW carried 3.4 million eggs. Edwards (1971) and Hines (1991) also presented fecundity data based on smaller sample sizes from U.K. populations.

Sex ratio

Recent studies of juveniles in shallow sub-tidal habitats showed that the sex ratio was 1:1 (Robinson, 1998). This is also true for undersized discards in the Irish offshore fishery (Cosgrove, 1998). Female however constitute 87% of the commercial catch. This would suggest size specific changes in catchability, distribution or mortality for males. Sex ratio and size composition also vary seasonally and especially geographically. (Latrouite & Morizur 1988).

<u>Diet</u>

Cancer is often perceived to be a scavenging species. Predatory, cannibalistic and suspension feeding behaviours have also been documented.

<u>Predators</u>

Octopii (*Eledone cirrhosa* & *Octopus vulgaris*), European lobster (*Homarus gammarus*), conger eels (*Conger conger*) and several seal species probably represent the only predators of large mature crab with hardened shells. These species also prey on crabs in the soft-shelled condition. Larger crabs in the soft-shelled condition are cannibalised by conspecifics and octopus when held in the laboratory or trapped in fishing pots. Juveniles are predated by a variety of fish, decapod and bird species. Cannibalism is also evident, both by juvenile and larger individuals.

Comment [DL9]: which ones ? Octopus vulgaris ?

<u>Disease</u>

Necrotic 'black spot' shell disease is common in both sexes. The disease causes a black discoloration of the exoskeleton, and is particularly evident on the carapace. In some fisheries most mature crabs are infected to some extent. It is believed that the causative bacteria are retained within the host even after moulting. The appearance of crabs with a noticeable level of discoloration is unappealing to the consumer and therefore they are discarded from the catch. Sampling of discards in the Irish offshore fishery during 1996-1997 revealed that of the 28% of the catch discarded, 14% of these were due to shell necrosis.

Hematodinium sp, a parasitic dinoflagellate which can develop in the blood of crabs has been found in *Cancer pagurus* (Latrouite et al. 1988) from Scotland to Biscay Bay. Prevalence was found to be independant of size, sex and intermolt stage, and lower in deep than in shallow waters. The resulting pathogeny known as "bitter crab desease" causes mortalities in winter and spring.

Larval ecology

Larvae of *Cancer* develop through five zoeal stages and one megalopal stage before metamorphosing to the first benthic crab stage. The duration of the first zoea stage is approximately 5 days at 20°C (Nichols *et al*., 1982). The duration of larval development from stage I to settlement lasts approximately 30 days at 17°C. Megalopae measure approximately 2mm carapace width at settlement. Larvae display diel vertical migration and are found at various depths in coastal and shelf areas. An instantaneous daily rate of mortality between stages I and IV of 0.028 (2.8% daily) was quoted by Nichols *et al*. (1982). The linkage between sites of larval release and nursery habitats is poorly understood in most stocks.

A number of studies have examined the seasonal occurrence of larvae. In Ireland they are found between March and September (O'Ceidigh, 1962), in the North Sea from May to December (Rees, 1952), off Plymouth from April to November (Lebour, 1947), in the Irish Sea from May to October (Williamson, 1956), in Denmark from April to October (Thorsen, 1950), off the English East Coast from July to November (Nichols *et al*., 1982), off the French coast of the Western Channel from April to October (Martin., 1985), off south Britany in Biscay Bay from January to (Martin, 1989).

Off the north west coast of Ireland larvae of all stages are more common in coastal waters than in offshore waters of the continental shelf (unpublished data).

Settlement and early life history

Settlement of *Cancer pagurus* has been detected in a number of distinct shallow water habitats (Robinson & Tully 2000). Physically complex habitats with interstitial spaces afford shelter to newly settled individuals. Juveniles were absent from sand and small stone habitats. Physically complex habitats with no algal canopy supported limited settlement but did not contain individuals from previously settled cohorts. Physically complex habitats with an algal canopy supported both settlement and juveniles from previously settled cohorts. Overall abundance of

Cancer was significantly correlated with the extent of algal coverage. Settlement was detected in these habitats, located on the southern coast of Ireland, between July and September.

The bathymetric depth distribution of settlement is unknown. The abundance of newly settled and juvenile crab in shallow water less than 20m may indicate that these areas represent the main settlement habitats.

Robinson and Tully (2000) recorded an average density of 25 individuals m^{-2} in shallow cobble habitat (<12m depth) with algal canopy during late August, 16 of which were newly settled. The maximum density of juveniles in any one sample within this habitat, 44 individuals m^{-2}, was recorded in early August. Of this number, 28 individuals could be identified as young of the year. Individuals >40mm CW never constituted more than 19% of the crabs observed in this habitat during the year, with the largest measuring 80mm CW.

Juvenile *Cancer* are known to predate conspecifics when held in captivity. Laboratory studies of crabs of various sizes <50mm carapace width, held together at a density approximating to that observed in the wild, showed a 76% survival after 1 month. This may indicate that intra-specific interaction may play an important role within high-density nursery grounds.

Suction sampling of juvenile habitat was conducted off the south coast of Ireland during 1997. Assuming constant inter-annual recruitment, the overall length-frequency histogram from the sampling period indicated a significant reduction in numbers after settlement. The exponential decline in numbers with size of crabs less than 50mm carapace width (y=59.33+exp-0.17x), would suggest that mortality or emigration play an important role in early life history. It seems unlikely that such small individuals would undertake significant ontogenetic migrations at such a small size. These estimates are for one location and there are no comparative data from other regions.

Table 1 Biological characteristics of Cancer pagurus by region. CL = carapace length, CW = carapace width.

Parameter		**Region**	
Country		**Ireland**	**France**
ICES Area		**VIa, VIIb**	**VIId,e,f,g,h, VIIIa,b**
Locality		To 12 miles	More than 30 ICES statistic rectangles
Size-weight relationship	Male Female	$Wt=3E-05x^{3.3}$ $Wt=3E-04x^{3.0}$	$W = 72*10^{-6}CL^{3.518}$ or $24*10^{-6}CW^{3.388}$ $W = 907*10^{-6}CL^{2.919}$ or $324*10^{-6}CW^{2.848}$
vonB Growth parameters		Unknown	M : $CL = 140[1-e^{-0.39(t-0.83)}]$ F : $CL = 130[1-e^{-0.25(t+0.82)}]$
Other growth models		Unknown	-
Moult increment		26%	Imm M+F : $CL_1=1.2CL_0+2$ Ad M : $CL_1=1.15CL_0+8$ Ad F : $CL_1=1.03CL_0+15$
Moult frequency		Annual	Ad M : more or less annual Ad F : F% = $-2.034CL_0+234$
Natural mortality		Unknown	Unknown
Size-fecundity		$Fecundity=82.6CW^{1.93}$	$0.0038CL^{4.174}$ $0.00061CW^{4.145}$
Size-maturity (males)		126mm	-
Size at maturity (female)		121mm (50%)	CL 85mm or CW 137 mm (50%)
Spawning frequency		Annual	Annual for 85% of females
Egg incubation period		5-8 months	5-7 months
Hatching season		May-Aug	April-June

Longevity	Unknown	Unknown (15 years ?)

The Fishery

Cancer is the subject of a target mono-specific pot fishery especially in offshore waters. It is also targeted in multi-species fixed net fisheries in the English Channel and in France. It is caught as a by-catch in trawl fisheries.

Modern crab fishing boats mainly fish with creel, parlour, inkwell or barrel pots, or a combination of these. Generally, all types are covered with a mesh netting of 50-60mm. The use of parlour pots in France is strictly regulated.

In France where a specific licence is required to fish for crabs and lobsters licencees also fish with nets although the nets are targeted at *Maja squinado*. Nevertheless by-catches of *C. pagurus* are important in large mesh nets used for monkfish/rays. Crabs of high commercial value are dis-enantangled properly for sale while others are generally killed and discarded. By-catches of *C. pagurus* in (smaller mesh) nets used for catching sole are also important especially in Biscay bay. Almost all of these crabs are killed and discarded. Undersized or poorly conditioned crabs are used as bait in whelk fisheries particularly where whelk and crab co-occur on the same fishing grounds.

In Ireland crab is the 3rd most important species nationally and the second (after Nephrops) most important crustacean fishery. Approximately 50% of the national landings of 10000 mt come from the north west offshore vivier fleet (6 vessels). An important inshore fleet also fishes in the northwest. Crab fishing is also important on the west, southwest and south coasts. Fishing effort is increasing. Most of the crab are exported live to France although late in the year much of the catch is processed locally. Landings in France are approximately 6000 mt per annum having declined from over 11000 tonnes in the mid 1970s. This is not due to reduction in catch rate but to lower effort.

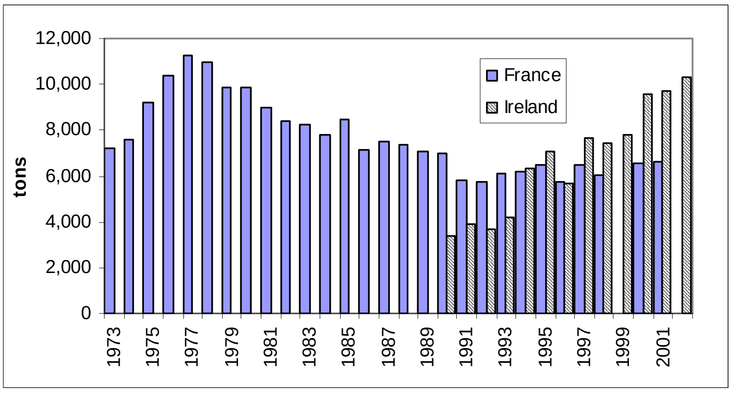

Fig. 1. Annual andings of Cancer in France and Ireland since 1990.

Fishing method

The following description of fishing methods is generally applicable to both inshore and offshore potting vessels. A varying number of pots is attached to a main rope, the number depending on the size of boat and fishing location. Pots are positioned at variable intervals, again depending on the vessel. The main leader rope is weighted with heavy anchors at each end, and is often mark by buoyed surface ropes. The duration of time that each string is left baited on the seabed fishing, the soak time, is dependant on the number of strings a vessel works and conditions at sea. Soak times of one or two days are normally preferred as bait freshness, and hence its ability to attract crabs deteriorates after this time.

Crabs are discarded from the catch during grading when they are undersized, lacking either claw, in soft-shelled condition, suffering from obvious shell necrosis, carrying eggs, or when dead, dying, weak or damaged.

The minimum size limit of discards is determined both by legislation and by market requirements. The minimum legal landing size dictated by EU legislation varies by sub-area.

Crabs that have recently moulted are discarded. These crabs yield very low quantities and poor quality meats (muscle and hepatopancreas).

To prevent crabs damaging each other after capture and during storage the claws can be disabled by a process in which the muscle between the propodus and dactylus is cut to render the claw unusable. When done properly blood loss is very slight. This process is more commonly prior to overland in water transport or during long term storage.

De-clawing of crabs is a practice where the chelipeds are pulled from body of the crab which is then discarded at sea. Crab claws contain higher value white crab meat. This practice can occur when there is no market for the lower value brown meat, when crabs are weak, or when shell necrosis of the carapace is evident. The de-clawing of crabs, especially when in a weak condition, probably causes mortality European legislation limits the landing of claws to 1% of the total weight of the catch.

Smaller inshore boats store their catch in on-deck containers. To prevent the catch from drying out containers are covered by wet cloth sacks. The catch must be landed each day, as the condition of crabs deteriorates rapidly when out of water.

Offshore 'vivier' boats are equipped with large hull tanks filled with seawater. The tanks have varying holding capacity depending on the size of the vessel. The modern offshore vessels can hold between 8-12 tonnes of crabs. The tanks can be opened to allow fresh seawater to enter and circulate when at sea, and closed when in shallows where ingress of sediment and lower salinity water can occur. Under-floor aeration provides additional oxygenation. Crabs can survive in the tank for over a week, but mortality increases with each day spent at sea. Weakened, bleeding and damaged crabs often die in the densely packed tank.

The total number of days that a vessel can fish each year is dependent on a number of factors, but is mainly dictated by the size of the vessel. The number of days varies between boats within an area, between regions and between countries. Strong tidal currents can cause damage or loss of fishing gear. In areas where tidal currents are particularly strong fishermen must bring all of their gear to shore intermittently. Rough seas often restrict smaller boats from putting to sea, but larger tank boats continue to operate in winds of up to force 9. For these reasons, smaller inshore vessels fish during a distinct season the duration of which varies with region, while larger tank boats have the ability to fish year round. Vessels in some fisheries stop fishing for several weeks when the majority of crabs are soft-shelled after moulting, and may target other species during this time (e.g. salmon). The development of steel pots allows some offshore fishermen in areas with lower tidal regimes to leave their pots at sea all year round.

Catchability

Environmental, physiological and behavioural factors can influence catchability. Increase in seawater temperature is normally associated with increases in feeding activity and bait scent diffusion. Changes in temperature also effect physiological processes such as growth and reproduction, both of which have an effect on catchability. Water movements effect both bait scent diffusion and locomotion of crabs to bait. High velocities disperse bait scent rapidly, but make upstream movements difficult. Diurnal rhythms effect the feeding activity of *Cancer*, with increased foraging activity at night. Wind stress effects water movements across the seabed. This can lead to tangling of fishing gear on the seabed and reduced catchability. Strong tides may also have an effect on the general activity of crabs.

There are marked spatial differences in the size composition and sex ratio of crabs, which also vary with season. Under-representation of crabs between 90-140mm, which should be retained by pot mesh, may be an indication of size specific catchability. The catchability of female crabs changes with reproductive condition. Cessation of feeding occurs over the winter and spring while eggs are brooded, with a voracious return to feeding after hatching occurs.

Comment [DL10]: Also recently molted crabs are voracious.
Swell is known to favour high cpue whilst it's the contrary when wind are coming from land (according to fishermen swell affects the fishery even on grounds deeper than 100 m)

It is thought that crabs will not enter traps that already contain octopii, lobster or conger eels.

Fishing trap considerations: As a number of bait types are used by the crab fishing industry, bait efficiency must be considered when making comparisons within and between fleets. The different pots used by fishing fleets within and between countries should be considered. Both Inkwell and barrel pots have hard openings which can allow escape. The soft mesh openings of creel and parlour pots offer no such escape route however the pot is orientated. As some vessels fish more than one type of pot on different strings, pot type should be noted. Trap saturation can occur in areas where catches are particularly high.

Due to interaction between a number of the factors listed above, the period that a pot is immersed for is key in the calculation of catchability. The relationship between trap immersion time and catch effects the calculation of catch per unit effort for this species.

Significant interactions occur with other fisheries. Crab are caught in gill nets and tangle nets and can be killed or de-clawed. Beam trawlers also catch or damage/kill crab on the seabed.

Monitoring of the fishery

Table 2 summarises the method and extent of monitoring of Cancer fisheries in Europe. The main fisheries are all monitored although the method and quality of the data may vary between regions.

France

In the first part of the 20th century pot fisheries targeted clawed and spiny lobster. Crabs were an undesirable by-catch and were generally discarded. The decline of lobster stocks in the '60 resulted in increased interest in crabs. In France after a phase of expansion until 1977, the fleet faced difficulties due to a reduction in catch rates specially in coastal waters and a reduction in prices due to growing imports from the UK. Part of the fleet shifted to fish netting in the '80.

At a national level the number of French potters and/or netters targeting crab and lobster fishing in 2000, was between 900 and 1000. Most of these also engage in other fishing activities such as dredging, netting and lining and not all may target crab all the time. Within this fleet, 20 are 17-25 m long, 50 are 13 to 17 meters and 830-930 less than 13 meters. The corresponding number of crew is around 2000, gross tonnage around 10 000 tx, power around 90 000 KW and number of pots around 200 000. An estimation of the length of nets is much more uncertain. Their distribution along the French coast is :

Eastern Channel (Dunkerque à Cherbourg)	: 170 boats
Western Channel (Cherbourg à Camaret)	: 470 boats
South brittany (Douarnenez à La Vilaine)	: 170 boats
Biscay Bay (south of "Vilaine"	: 150 boats

The geographic distribution of their activity is shown in Table 3.

Table 3. Annual percentage of fishing days by ICES division for French offshore potters for periods 1986-1995 and 1996-1999.

	IVc	VIIa	VIId	VIIe	VIIf	VIIg	VIIh	VIII a	VIII b	VIIId
Average 1986-1995	<1	<1	1%	62%	7%	4%	10%	13%	<1	1%
Average 1996-1999	0	0	3%	48%	6%	5%	14%	20%	<1	4%

Annual catches increased from 1973 – 1977 in France due to development of the targeted crab fishery. They peaked at 11000 mt per year and declined to 8000 mt during the 1980s and to 6000 t per year after 1990.

Evolution of fishing effort for a fleet of potters can be assessed by a series of more or less precise indicators like the number of boats in the fleet, the number of pots per boat, the number of days hauling pots, the number of pots hauled annualy by the fleet. Table 4 summarizes theses indicators for offshore potters from Morlaix district (main offshore fleet) for the period 1985 to 1999. Pots and fishing strategy have not changed during the period, although GPS positioning has facilitated the fishing operation in recent years.

Table 3 Catch and effort monitoring of Cancer fisheries in Europe. Data are acquired over different spatial resolutions mainly by fishermen carrying compulsory or more commonly voluntary logbooks. Most of the important fisheries have catch and effort monitoring programs.

Sea area	**Institute**	**Spatial resolution**	**Amount per year**			**Who collects ?**			**Method**							
			Pot hauls (m)	**Boat days**	**No. boats**	**Fishers**	**Observers**	**Index vessels**	**Diary**	**EU Log**	**National log**	**Voluntary log**	**Processor data**	**Discard data**	**Length of series (yrs)**	**Data quality**
Irish offshore	TCD	GPS	1.8	1500	6	X	X	X	X	X					1990-2003	XXX
Irish inshore	BIM	Port	1.6	1400	40	X	X					X	X	X	9 yrs processor, 1 yr logbook	XX
	MI	ICES Div	1	5500	60	X							X			
East Channel	CEFAS	Location				X						X				
West Channel	CEFAS	Location				X						X				
West Channel (7E)	IFREMER	ICES Rec	0.76	760	10	X				X					1986-2002	XXX
Biscay Bay (8A,B,D)	IFREMER	ICES Rec	0.91	980	12	X				X					1986-2002	XXX
Celtic Sea (7F,G, H)	IFREMER	ICES Rec	0.2	210	10										1988-2002	XXX
Celtic Sea	BIM/TCD	Location	?			X	X	X				X		X	2	XX
England,Wales Inshore	SFCs	Location	?			X					X	X				
Scottish east	FRS MLA	Port	0.1	540	2	X		X	X			X			up to 7	XXX
Scottish west	FRS MLA	Port			2	X		X	X			X			up to 6 months	
Wnorth Sea	CEFAS															
Enorth Sea																
Norway <63N	IMR,MF	ICES & Location	0.014	200	5	X	X	X				X		X	2	xxx
Norway >63N	IMR,MF	ICES & Location	0.138	800	20	X	X	X				X		X	2	xxx
Sweden	TMBL, IMR	ICES Rec	0.012	300		X	X	X		X	X	X		X	9	XX

Table 4. Activity of offshore French potters 1985-1999.

	1985	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Number of boats at least 1 trip in year at least 10 trips in year	 18 17	 16 12	 16 14	 14 13	 18 16	 17 15	 16 13	 15 15
No. of trips for the fleet	*390*	254	277	275	292	323	271	301
No. of hauling days for the fleet	*2400*	1659	1992	2020	2207	2402	2051	2267
Hauling days / trip / boat		*6.53*	*7.19*	*7.35*	*7.56*	*7.44*	*7.57*	*7.53*
No. of pots hauled by the fleet (x1000)	*1820*	1266	1552	1598	1737	1954	1707	1937
Nb pots hauled / boat / day	*745*	*763*	*779*	*791*	*787*	*813*	*832*	*854*
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	
Number of boats at least 1 trip in year at least 10 trips in year	 15 14	 15 14	 15 14	 13 13	 14 13	 13 11	 13 12	
No. of trips for the fleet	283	287	271	243	263	214	234	
No. of hauling days for the fleet	2142	2226	2161	1953	2088	1752	1858	
Hauling days / trip / boat	*7.57*	*7.76*	*7.97*	*8.04*	*7.94*	*8.19*	*7.94*	
No. of pots hauled by the fleet (x1000)	1873	1932	1893	1771	1980	1655	1744	
No. pots hauled / boat / day	*874*	*868*	*876*	*907*	*948*	*945*	*939*	

During the period 1993-1999 the number of boats, trips and days fishing has decreased but fishing effort of each potter has increased. Potting inshore has decreased.

Ireland

The offshore fishery in Ireland has been closely monitored since its inception in 1991. High quality GPS referenced data on catch is sourced from private diaries held by the skippers. Automated electronic logbooks are currently being developed for these vessels. Catch rates in the inshore and offshore fishery are similar (Fig. 1, Table 5). Catch rates in both sectors have been stable since 1995.

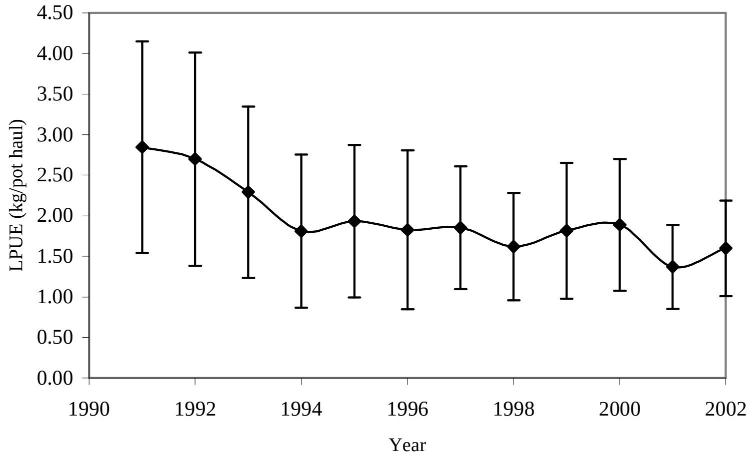

Fig. 1. Landing per pot hauled in the Irish offshore crab fishery 1991-2002.

Table 5. Landing and discards per pot haul by county in Ireland in 2002.

	LPUE			DPUE			By_catch		
County	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Clare	*56*	2.10	0.81	*56*	2.01	1.07	*71*	0.01	0.013
Cork	*92*	2.31	0.85	*91*	0.59	0.59	*103*	0.01	0.01
Donegal	*0*	•	•	*0*	•	•	*19*	0.03	0.007
Galway	*72*	1.19	0.42	*72*	2.00	1.22	*60*	0.04	0.022
Kerry	*181*	2.96	1.16	*162*	1.21	0.65	*283*	0.02	0.011
Mayo	*114*	3.01	2.42	*81*	1.22	3.76	*63*	0.01	0.008
Waterford	*358*	1.48	0.80	*347*	0.58	0.70	*474*	0.01	0.013
Wexford	*223*	2.28	2.23	*214*	0.82	0.59	*425*	0.03	0.019
	1096			*1023*			*1498*		

Landings Statistics

The official Food and Agriculture Organisation (FAO) figures for *Cancer pagurus* landings (metric tonnes) by country in 1998.

Table 6. Landing statistics by country

Country	**Landings (tonnes)**	**Country**	**Landings (tonnes)**
Belgium	180	Norway	2944
Channel Islands	2214	Portugal	13
Denmark	21	Spain	50
France	5598	Sweden	93
Germany	44	United Kingdom	21799
Ireland	7392		
Isle of Man	274	European total	**40622**

Targeted fisheries exist in all of the countries listed in Table 6 The UK, Ireland and France have the highest landings. Sweden and Norway have significant recreational fisheries that are not included in the figures.

Management of the fishery

France : A combination of the measures listed below are used by each country within Europe to regulate their crab fishing fleets. Minimum size regulations apply in all areas. In France MLS is 130 mm CW south of 48° N and 149 mm north of 48°. This MLS difference reflects much more market preferences than biological differences. In France there is protection but no enforcement for soft shell crab. It is forbidden to land claws only although claws can be sold separately from the body.

A specific licence is compulsory for professionnal fishing of crabs and lobsters. Only potters and netters may have it. The licence is given to a boat owner for a given boat. The licence is renewed annually by Industry at a Regional level. It's cost is currently around €50 . The number of pots per boat is limited on the basis of crew onboard. In most areas, a maximum of 200 pots per crew and a limit at 1000 pots per boat applies. Each pot must been tagged. Tags are distributed by the Industry Regional Authority. The tag indicates the name of the boat and a series number for the pot. The owner/skipper must declare landings.

Trawlers may not have a specific "crabs and lobsters" fishing license but they may land up to 10% crabs and lobsters (by weight) each trip. This derogation has been obtained by some inshore trawlers who used to target spider crabs at some period of the year. It does not concern very much edible crab.

Ireland: The only current legislation in Ireland is a MLS of 130 mm south of 56^{o}N and 140 mm north of 56^{o}N. In effect the market dictates the actual minimum landing size.

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The Biology and Fisheries for Homarus gammarus L.

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Description and distribution

The European lobster, *Homarus gammarus* (Linnaeus, 1758) is a large clawed lobster of the Infraorder Astacidea, Family Nephropidae, Subfamily Nephropinae, and is thus in the same subfamily as *Nephrops norvegicus*. The spiny lobster or crawfish species caught in Europe, *Palinurus spp.*, are however in a separate Infraorder, Palinuridea.

Homarus gammarus is found from northern Norway to the coast of Morocco, and throughout the western and central Mediterranean as far as Crete although it is less abundant in there. Lobsters are generally found in coastal waters out to about 50 m depth, but can occasionally be found up to 150 m.   The fisheries are primarily coastal in nature, but fishing has been known to occur in deeper offshore areas in the English Channel and in the north of Biscay Bay for example. Distribution is generally patchy with concentrations on hard ground which provides good shelter. Larger, older individuals can often be found in isolated wrecks or reefs away from any population concentrations.   Juvenile lobsters up to around 40 mm carapace length are cryptic in their habitat, but beyond this size, juveniles and adults are found on the same grounds. Tagging studies of wild lobsters suggest that there are no major directed movements of pre-recruit and mature adults, and most recaptures have occurred within 10 km of their release.

Life history

Moulting occurs more than once a year in pre-recruit adults, but for the size range of lobsters found in the commercial fishery, it is assumed there is an annual moult, with mating, spawning and hatching of eggs by females in alternate years. However this bi-annual spawning pattern is based on that observed in the American lobster, *H. americanus*, and there is some evidence in some areas for annual spawning. For example in the western Channel about 80% of females larger than 100 mm are found berried in winter/spring which tend to indicate that this proportion spawns every year. Tag returns in Ireland have shown annual spawning in some cases and spawning and moulting in the same year.

Both juvenile and adult lobsters have specific habitat requirements. Unfortunately the juveniles are cryptic up to about 40 mm carapace length and thus very little is known about their habitat and distribution. Indeed recent research studies in Ireland, United Kingdom, Norway and Italy have failed to find any very small early benthic stage lobsters and thus it is hard to determine whether there is any habitat limitation occurring in these early stages. Habitat could be limiting for juveniles or adults, but even for the related species *H. americanus*, which occurs at very much higher densities, the evidence for any density dependent habitat limitation is equivocal.

An example from the UK fishery of parameters describing population characteristics or rate processes for juveniles and adults is presented in Table 1. Data from all other countries will be included in the final version of this review. Data is now becoming available on likely variations in fecundity and maturity across Europe and this will also be included in the final version. There is currently insufficient data available to determine the relationship between stock and recruitment.

Growth rate is known to be highly variable and cohorts may recruit to the fishery over a number of years. Growth may also be habitat limited and regional variation in size structure may result from a combination of fishery and environmental effects.

Size at maturity has been studied in most countries albiet by different methods. Most of the estimates are based on the occurrence of ovigerous females. Tully et al (2001) studied a range of

parameters	k=0.0965, L_{inf} =175			=126, t_o = 0.3 M : k= 0.08, =162, t_o = 0.3
Other growth models	Logistic models			
Moult increment	10% by length	Male : $CL_1 = 1.09CL_0 + 2.44$ Female : $CL_1 = 0.99CL_0 + 9.50$	9 mm for commercial size	F : CL1=8.32+0 *CLo
Moult frequency	Variable	% : Male : F = -3.53CL_0 +422Female : F = -2.35CL_0 +316	A proportion of commercial size moult annually	Annual
Natural mortality	Unknown			
Size-fecundity	F=376*CL-27110	F=466*CL-37020	y = 4E-03$x^{3.1554}$	y = 0.0102*X
Size-maturity	90mm CL (50%)	97mm CL (50%)	P(m)=1/(1+exp(14.96-0.16*CL)	
Age at maturity	Unknown	Unknown	Unknown(>7 yrs)	
Spawning frequency	Bi-annual, annual?	Annual for 80% of females CL > 100 mm	Some proportion spawn annually	
Egg incubation period	8-10 months	7-8 months	8-10 months	
Hatching season	May-September	May-July	May-August	
Longevity	Up to 75 years		Unknown	

Larval ecology and settlement

Information on larval ecology and settlement for *Homarus gammarus* is sparse primarily due t the very low density of larvae in the open sea which makes quantitative sampling difficult. Th are four pelagic larval stages, and the fifth stage settles out on the sea bed. The duration of the larval stage is approximately 4-6 weeks, and information from *H. americanus* suggests that the larvae of *H. gammarus* may be capable of directed swimming in their later stages, and quite sophisticated behaviour in relation to settlement site choice. Only two studies (Nichols and Lovewell, 1987 and Tully and O'Ceidigh, 1987) provide any real quantitative data on larval distribution and abundance. In Ireland larvae occur between May and October but primarily in July and August. Larvae are distributed in surface waters and undertake diel vertical migration between the top 5 m of waters and the neuston (Tully and O'Ceidigh 1987). Larval swimming capacity is strong and stage IV larvae have the ability to dive in search of suitable substrate. Th do not tend to swim through thermoclines. Larvae have been recorded only in inshore water of pots. Landings were high in the early part of the 20th century until the 1960s, but have been relatively stable in the last 20 years. Fishing is primarily by pot or trap, although there are som areas in England where there are significant landings of lobsters from trawling. In western Channel generally lobsters are captured in tangle nets targeting monk, skates and rays. An example of the fleet profiles is given in Table 2a,b.

Table 2a.. Profile of fishing fleet for Homarus gammarus by region in the UK.

Parameter	Region		
England & Wales	**East coast**	**English Channel**	**Wales**
Locality	Inshore/offshore	Inshore/offshore	Inshore/o
Number of vessels	c. 500	c. 950	c. 180
Average GRT	Unknown	Unknown	Unknown
Average length of vessel	Unknown	Unknown	Unknown
Average number of crew	1-5	1-5	1-4?
Gear used	Creels, parlours	Inkwells/parlours	Creels/pa
Gear units per boat (traps, length of gill nets)	Up to 1200 (crab fishing also)	Up to 2000 (crab fishing also)	Up to 300
Multispecies fishery	Yes	Yes	Yes
Targeted or by-catch	Both	Both	Both
Other species captured	Cancer, Necora	Cancer, Necora, Maja, Palinurus	Cancer, N Maja, Pal
Technical fishing aids (GPS, plotters etc.)	Various	Various	Various
Dependency on this species (on a scale ?)	High	More on crabs	High

Table 2b.. Profile of fishing fleet for Homarus gammarus by region in France

FRANCE	Region		
Parameter	**7d**	**7e**	**8a,b**
Locality	Inshore (mainly)/offshore		
Number of vessels	170	470	300
Average GRT	8 T (min 0.7 - max 162)		
Average length of vessel	9 m (min 4 m - Max 25 m)		
Average horse power KW	90 kw(min 4 kw – Max 552 kw)		
Average number of crew	2 (min 1 – Max 7)		
Gear used	Pots (creels or inkwells) – by catches in tangle n		
Gear units per boat (traps, length of gill nets)	Limited at 200 pots per crew with a maximum of 10 boat		
Multispecies fishery	Yes	Yes	Yes
Targeted or by-catch	Both	Both	Both
Other species captured	Cancer, Necora, Maja	Cancer, Necora, Maja	Cancer, N Maja
Technical fishing aids (GPS, plotters)	Various	Various	Various

Gear units per boat (traps)	30-1000
Multispecies fishery	To some degree but mainly taget and mono specific
Targeted or by-catch	Both
Other species captured	Cancer, Necora
Technical fishing aids (GPS, plotters)	GPS, plotters, haulers
Dependency on this species	High for the majority of vessels

Catch rates of *Homarus gammarus* are influenced by catchability due to diel, tidal and seasona effects, and intra- and interspecific behavioural effects around the trap which may be size- or s specific. Size distributions are also strongly influenced by the selectivity of the traps, but in general lobster traps have little impact on the habitat and other non-target species.

Monitoring of the fishery

There are both regional and national monitoring programmes for lobster in most countries (Tal 3,a,b) although the qualtity and quality of data from these sources are often poor. The fishery i difficult to monitor as there are 100s of small vessels operating in it and they land their catch daily at a multitude of landing places. A significant recreational fishery exists in Norway and locally and seasonally in France, UK and Ireland.

Table 3a. Landings and effort statistics for Homarus gammarus by region in UK and Ireland

Statistic	**Region**			
England and Wales	**North Sea**	**Channel**	**Wales**	**Ireland**
Annual landings	508	249	90	900
Annual effort	Unknown			Unknown
Standardised LPUE	Variable			7-12 per 100 pot hauls
Annual discards	Unknown	Unknown	Unknown	
Mortality of discards	Very low	Very low	Very low	Very low
Sex ratio of the catch	30-70% female	30-70% female	30-70% female	1 : 1
Spatial resolution in catch and effort data	Individual string data	Local fishing area	Local fishing area	Local fishing area
Length of time series	15 years	13 years	20 years	Locally 10 yrs
Quality of data	Very good	Poor	Very good	Locally good

Quality of data	Landing : very poor No data on effort	Good but restricted to a few logbooks	Landing : very data on effort

Assessment and management of the fishery

Assessment of lobster stocks is currently carried out using standard length-based assessment techniques such as length cohort analysis, although age-based techniques are being developed based on new information available on the length-age relationship. Egg per recruit analysis in Irish fishery suggests that egg production is approximately 7% of unfished levels. Given the lo egg per recruit, very low larval densities and apparent absence of juveniles in many benthic habitats presumably suitable for settlement recruitment may currently be limited by larval supp and egg production. Nevertheless recruitment has been increasing in recent years and catch rat are stable or increasing in some areas .

The lobster fishery is subject to an EU minimum landing size of 87 mm mm carapace length (CL), with each individual country able to introduce it's own national legislation. National legislation in the UK, France and Ireland is shown in Table 4. Table 5 describes regional management measures currently enforced by some of the 12 regional management bodies, the Fisheries Committees in the UK. France has recently introduced restrictive licencing for crab a lobster fisheries and the UK will do so from 2004. Ireland has been discussing the introduction lobster specific licences locally and nationally since 1995. No catch restrictions apply in any a

Table 4. Management measures and structures for Homarus gammarus

	Region		
Management measures	UK	France	Ireland
Technical measures *:*			
Minimum landing size	87 mm CL	87 mm CL	87 mm CL
Sex restrictions	Berried females in some areas	no	
Other technical restrictions	See Table 5		V-notched lobster
Effort control *:*			
Quota	None	None	None
Seasonal or other closures	None	None	None
No take zones	None	Several sanctuaries	None
Licencing sheme	From 2004	Yes, national	None
Gear limitations	None	Parlour pot forbidden. pots max by crew mem 1000 pots max per boa	None
Management structures :			
Centralised, local, co-management, TURFs, ITQs	EU, national and local	EU, national and local	EU and national

Northumberland, North Western & North Wales, South Wales

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Assessment of crustacean fisheries in Europe

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Introduction

Crustacean stock assessments are driven primarily by the requirements for management advice and the type of management system in place. In addition they are constrained by the biological and life history characteristics of the stocks concerned and the quality and availability of data to service the stock assessment. For many crustacean stocks, assessments can be undertaken on a local basis, but for international stocks exploited by more than one country, it is often necessary for an international agency to act as an umbrella organisation for a formal stock assessment process.

In Europe the major finfish stocks are subject to a plethora of management measures which may restrict capacity, effort and total allowable catches (TACs), or impose gear specification and technical conservation measures such as minimum landing size (MLS). For finfish the most important management measure has been TAC controls and to furnish the requirement for annual quota management, regular assessments under the auspices of the International Council for the Exploitation of the Sea (ICES) are required to provide absolute estimates of stock status and catching opportunity. Additional assessments may be carried out more occasionally in order to address particular management aspects, such as the imposition of a new mesh size or MLS.

The situation for shellfish stocks is rather different in Europe. Only *Nephrops* and *Pandalus* are subject to annual TAC control and for these species ICES Working Groups meet annually to update the international database, carry out assessments and provide advice on future TACs. For other species, assessments may be no more complex than collating trends in catch or landings per unit effort (CPUE/LPUE), and without rigorous management measures in place, formal analytical assessments may not be required.

Crustacean fisheries are of undoubted economic value in Europe, but the wide range of species exploited from northern Norway to the Mediterranean means that methodological approaches have often been applied and developed in isolation. A key goal of this Concerted Action project is to synthesise the approaches to stock assessment, and to point the way forward. Thus in this Work Package we summarise the state of play of crustacean stock assessments in Europe and provide three major reviews on the subject. By synthesising a number of studies we hope that some common approaches and practices will evolve in the future even if there are no formal structures for assessment of some crustacean species.

Stock assessment methods used currently in Europe

Stock assessments are with exception generally not undertaken routinely for crustacean fisheries in Europe (Table 1). Annual assessments are completed for *Nephrops* (in the ICES area) using VPA methods and for *Pandalus* using direct survey of biomass. In the Mediterranean there is more emphasis on direct survey than in the Atlantic area. Direct survey has in some cases been used in the Atlantic area for *Nephrops* (Ireland, UK) using trawls or more recently using underwater TV surveys, whereas research surveys are much more commonly used in the Mediterranean (*Aristeus, Parapenaeus, Nephrops*) usually as part of the International Bottom Trawl Survey Programs.

Research surveys do not usually estimate absolute biomass but indicate relative changes in population size and structure, distribution and seasonal migrations. They provide more information on the biology and distribution of the species than stock assessment advice on levels of production, biomass and sustainable yields. There are important trap fisheries in the Atlantic area and North Sea for *Cancer pagurus* and *Homarus gammarus* and because of difficulties in quantifying catchability, trap fishery surveys provide at best relative abundance estimates, and the catch rate data are not standardised for changes in catchability.

Commercial catch per unit effort data is the most common type of information available for many stocks. The quality, spatial and temporal resolution and time series for these data vary between locations and across species. Data may be spatially referenced by GPS, by ICES statistical rectangle or by general sea location name. Generally the commercial CPUE data, either from trawl or trap fisheries, is not developed to a standardised model and there is a high level of uncertainty as to how these data reflect actual changes in stock abundance. Commercial catch rate data may reflect changes in stock abundance, but for crabs and lobsters the lag between recruitment to the benthic habitat and recruitment to the fishery along with inherent high natural variability in growth rate ensures that recruitment overfishing may not be detected with these data at a sufficiently early stage. No recruitment indices have been developed for any of the European crustacean species that could forewarn of declining recruitment a number of years prior to commercial exploitation.

Analytical models such as VPA and Y/R analyses have been used in management advice in some cases. Pseudo age based VPA is used by the ICES *Nephrops* Working Group to assess *Nephrops* in the Atlantic area. Local examples of the application of VPA, Y/R or egg per recruit are also apparent but there seems to be little attempt to systematically integrate the outputs from these models into management of the fisheries or indeed to assess how reliable these methods are for crustacean fisheries. Application of age based methods in particular is prone to bias because of the difficulty in obtaining age data. In the long lived species such as *Cancer* and *Homarus* it has not been possible until recently to derive age data, but the development of the lipofuscin technique to age lobsters and crabs promises to contribute to more accurate stock assessments for crustaceans. In the best case age structure can be derived from size distribution data in short lived species such as *Parapenaeus* and *Palaemon* but there is a deal of uncertainty in deriving age structure data in many species.

A number of crustacean fisheries are assessed under the auspices of ICES, and in section 3 these approaches are summarised. In section 4, Mike Smith and Julian Addison provide a detailed review of stock assessment methods applied to crustacean fisheries both in Europe and around the world. The review ranges from surplus production models to dynamic age, size or stage structured models, and considers the assumptions underlying the models, the benefits and disadvantages and examples of their application. The review then provides a detailed synthesis of methods for dealing with uncertainty in crustacean stock assessment.

However the main emphasis of most of the ICES Working Groups is on northern European stocks, and many of the studies reviewed by Smith and Addison are assessments of major crustacean fisheries for which detailed time series of data are available. In comparison there are a wide variety of crustacean species exploited in southern European and Mediterranean waters and the species, their fisheries and the nature of assessments are reviewed in section 5 by Lleonart and Maynou.

Lleonart and Maynou provide summaries of the different methods of stock assessment and provide details of their suitability and application to Mediterranean crustacean fisheries. Their review covers a wider range of assessment methodology than that by Smith and Addison, including trawl surveys and standard assessment techniques, but also ecological approaches and bio-economic models. Finally, in section 6 Alexis Conides provides a technical description of stock assessment methods including the various parameter inputs such as growth, maturity and fecundity, and encompassing both metapopulation and bio-economic models.

Table 1. Stock assessments for crustacean fisheries by country. VPA=virtual population analysis, LCA=length cohort analysis, Y/R = yield per recruit, CPUE=catch per unit effort, EPR=egg per recruit

Species	**Norway**	**Scotland**	**England & Wales**	**Ireland**	**France (Atlantic)**	**France (Med)**	**Portugal**	**Spain (Atlantic)**	**Spain (Med)**	**Italy**	**Greece**
Nephrops norvegicus		Survey, Trawl and TV,LCA Y/R	VPA, Survey CPUE	VPA, Survey, CPUE	VPA CPUE	Survey	VPA, Survey, CPUE	VPA CPUE	LCA, Y/R, CPUE, Survey	Survey, LCA, Y/R, CPUE	Survey
Pandalus borealis	Survey										
Homarus gammarus	EPR	CPUE, Y/R LCA	Y/R, LCA	LCA, EPR, CPUE	CPUE,						
Palinurus elephas			CPUE	CPUE			?		CPUE, Survey	CPUE	
Cancer pagurus		CPUE, Y/R LCA	Y/R, CPUE LCA	CPUE	CPUE						
Maja squinado				CPUE	Survey						
Necora puber		CPUE, Y/R		CPUE							
Liocarcinus depurator											Survey
Crangon crangon			CPUE, Survey								
Palaemon spp.				CPUE, Y/R							
Parapenaeus longirostris						Survey	CPUE, Y/R, Survey	LCA, Y/R	Survey	Survey, LCA, Y/R, CPUE	Survey
Aristeus antennatus						Survey	CPUE, Y/R, Survey		VPA, LCA, Y/R,CPUE, Survey	Survey, LCA, Y/R, CPUE	Survey
Aristeomorpha foliacea						Survey	Survey			Survey, LCA, Y/R, CPUE	Survey
Penaeus kerathurus										Survey, Y/R, VPA, GLM	Survey, Y/R, VPA, GLM
Squilla mantis										CPUE	
Plesionika spp.											Survey

Crustacean assessments undertaken by ICES

(i) *Nephrops* assessment in Europe

Of the European decapods, *Nephrops* stocks are the most widely monitored and are subject to regular assessment under ICES auspices. The work undertaken by the ICES *Nephrops* Working Group demonstrates many of the benefits of a formal framework under which to carry out assessments. In particular, it demonstrates the utility of standardisation of techniques across stocks, and the peer review of the adequacy of the various stock assessments shown in Table 2 allows an evaluation of the quality of the output from the assessment. Three methods of assessment are applied routinely by the ICES *Nephrops* Working Group:

1) Virtual population analysis (VPA). Extended survivors analysis (XSA), a tuned VPA method is used most often. Length structured data are 'sliced' to provide catch at age data prior to the VPA. Assessments are generally carried out separately for males and females.
2) Length cohort analysis (LCA). The exact (as opposed to Pope's approximation) algorithm for this equilibrium method is used with length structured data averaged over a number of years. Assessments are generally carried out separately for males and females.
3) Burrow count TV surveys. These provide a fishery-independent index of abundance which is useful for identifying stock trends, but at the present time no formal analytical assessment method for estimation of stock abundance or fishing mortality is used. The surveys provide a combined sex index.

Table 2 gives details of ICES stock assessments for *Nephrops* and a nominal quality grade provided by the Working Group (ICES, 2003a). A number of factors influence the quality of the assessments including; the assessment method, sex, and location of the fishery. The relative importance of the fishery is important in determining sampling levels and hence quality, while depth and location have a bearing on the feasibility of routinely applying TV surveys. This approach of grading the quality of assessments could be applied usefully for other species and stocks.

The ICES *Nephrops* WG considers that the XSA assessment carried out provide an acceptable description of stock status where data are adequate, but recognises that there are a number of problems with this approach and has investigated alternative assessment methods when possible. Among these are a length structured analysis based on the approach of Sullivan (1992) and implemented by Dobby (2003) and the catch survey analysis method (CSA) based on Collie & Sissenwine (1983) and recently implemented by Mesnil (ICES, 2002; 2003a; Mesnil, 2003). The latter method has been widely used for assessment of crustacean stocks in North America (e.g. Collie & Kruse, 1998; Cadrin, 2000).

Although there are concerns regarding the XSA assessments in particular regarding age/length slicing and constant catchability assumptions, the method does provide the basis for advice and since this is the standard age-structured method used by ICES the range of outputs are relatively familiar to scientists and managers.

Table 2. ICES Nephrops assessments for 2003 and nominal quality

Management area		**Fishery unit**		**Gear**	**Sex**	**Method**	**Quality**
A	Va	1	Iceland			National	
B	Vb (nonEC)	2	Faroe			None	
C	VIa	11	North Minch	trawl	M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
					C	TV Survey	acceptable
				creel	M	LCA	acceptable
					F	LCA	just adequate
		12	South Minch	trawl	M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
					C	TV Survey	acceptable
				creel	M	LCA	acceptable
					F	LCA	just adequate
		13	Clyde		M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
					C	TV Survey	acceptable
E	IIIa	3 & 4	Skagerrak & Kattegat		C	VPA &YPR	acceptable
F	IVa (Rects. 44-48,E6-E7 & 44E8)	9	Moray Firth		M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
					C	TV Survey	acceptable
		10	Noup			None	
G	IVa (W of 2°E excl. Moray Firth)	7	Fladen		M	LCA	questionable
					F	LCA	questionable
					M	VPA (trial)	just adequate
					F	VPA (trial)	just adequate
					C	TV Survey	acceptable
H	IVb,c E of 1°E excl. 43F5-F7	5	Botney Gut		M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
		33	Off Horn Reef			None	
I	IVb,c W of 1°E	6	Farn Deeps		M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
					C	TV Survey	acceptable
		8	Firth of Forth		M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
					C	TV Survey	acceptable
J	VIIa N of 53°N	14	Irish Sea East		M	VPA &YPR	just adequate
					F	VPA &YPR	questionable
					F	LCA	just adequate
		15	Irish Sea West		M	VPA &YPR	acceptable
					F	VPA &YPR	acceptable
L	VIIb,c,j,k	16	Porcupine Bank		M	VPA (trial)	questionable
					F	VPA (trial)	questionable
					M	LCA	just adequate
					F	LCA	just adequate
		17	Aran Grounds		M	LCA	just adequate
					F	LCA	just adequate
					M	VPA &YPR	acceptable
					C	TV Survey	acceptable
		18 & 19	Ireland NW & SW & SE		M	LCA (trial)	
					F	LCA (trial)	

Table 2 continued ICES Nephrops assessments for 2003 and nominal quality

Management area		Fishery unit		Gear	Sex	Method	Quality
M	VIIa S of 53^{o}N & VIIf,g,h excl. 31E1, 32E1-E2	20 to 22	Celtic Sea		M	VPA &YPR	acceptable
N	VIIIa,b	23 & 24	Bay of Biscay		C	VPA &YPR	acceptable
O	VIIIc	25	North Galicia		M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
		31	Cantabrian Sea			None	
Q	IXa	26 & 27	W Galicia & N Potugal		M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
		28 & 29	SW & S Portugal		M	VPA &YPR	acceptable
					F	VPA &YPR	just adequate
		30	Gulf of Cadiz			None	
S	IVa E of 2^{o}E & 43F5-F7	32	Norwegian Deep			None	

Two other species regularly assessed under ICES auspices include two species of shrimp *Pandalus borealis* and *Crangon crangon*.

(ii) *Pandalus* assessment in Europe

The ICES *Pandalus* Assessment Working Group considers that *Pandalus* in the North Sea consist of two closely linked stock units, the Norwegian Deeps and Skagerrak (IVa east & IIIa) and the Fladen Ground (IVa). A further fishery used to be prosecuted on the Farn Deeps, but is now considered to be negligible. Data are compiled for the Fladen Ground, but a formal analytical assessment has not been carried out by the WG since 1992. The Norwegian Deeps and Skagerrak stock of *Pandalus* has been assessed using two assessment methods; the age structured tuned VPA method (XSA) and since 2000 a production model modified to include predator and recruitment indices (Stefánsson et al., 1994). In 2002 the WG decided that length slicing (Bhattacharya's method, FISAT software) and XSA were no longer appropriate assessment methods for this species because there are few ages in the stock, large uncertainties in ageing particularly for older ages and M is greater than F and varies with predator abundance (ICES, 2003b). It was also noted that the production model biomass trends were in better agreement with landings per unit effort (LPUE) trends than those from XSA.

(iii) *Crangon* assessment in Europe

In the 1970’s the ICES *Crangon* Working Group used a variety of methods to assess the state of the *Crangon crangon* stocks in the North Sea, including a modified Leslie method, Jones’ length cohort analysis and swept area methods (ICES, 1979; Tiews, K. & Schumacher 1982). Assessments have also been carried out by other authors, for example using swept area to estimate stock size and length structured equilibrium methods (e.g. ELEFAN) to estimate von Bertalanffy growth parameters and total mortality (Oh et al., 1999).

More recently the ICES *Crangon* study group has presented biomass estimates by swept area from the demersal young fish surveys carried out in the Netherlands (ICES, 2000). Due to the short life span of *Crangon,* formal length or age based methods have been avoided. In 2003, a stage structured yield per recruit model incorporating seasonal patterns of natural and fishing mortality and temperature dependent growth (Temming & Damm, 2002) was introduced to the WG and used to investigate some alternative scenarios of exploitation.

(iv) Crab species

The ICES Study Group on the Biology and Life History of Crabs meets every two to three years and has collated available biological and fishery information on various crab species including *Cancer pagurus, Maja brachydactyla* and *Paralithodes camtschaticus.* To date these meetings have concentrated on biological information on these species and the collation of catch or landings per unit effort (CPUE/LPUE) data and in general have not yet undertaken conventional routine analytical stock assessments using standardised methodology as practised by the *Nephrops* and *Pandalus* Working Groups.

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Review of Stock Assessment Methods for Crustacean Fisheries

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Abstract

Crustacean fisheries account for nearly 30% of all fish and shellfish landings by value world-wide. A range of stocks assessment methods are available and this paper reviews and evaluates their use in crustacean stock assessment. Methods covered include surplus production models, delay-difference models, depletion methods, equilibrium yield- and egg-per-recruit models and dynamic size-structured models. The development, underlying assumptions, data requirements, benefits and disadvantages of each model are briefly considered. The implication of uncertainty in data, parameter estimates and model structure and how it can be treated, is also considered. Finally we speculate on ways in which crustacean stock assessment methodology may evolve in the future.

Keywords: stock assessment; crustacean fisheries; uncertainty

Introduction

Fisheries for crustacean species are globally important, primarily due to their high-unit value. Recent FAO statistics (1999) show that landings from wild marine crustacean fisheries totalled almost 6000 million tonnes with a value of just under $20 billion (FAO, 2001). With fin fish stocks declining world-wide, crustacean fisheries are becoming increasingly important and now account for 7 % of all fish and shellfish landings by weight and 28 % by value. Many crustacean fisheries are artisanal, prosecuted by many small boats using static gears and their socio-economic importance may therefore be even greater. This increasing importance requires therefore that effective stock assessment and management programmes for crustacean fisheries are put in place.

Crustacean stock assessment can be addressed using models based on commercial fisheries data or by fishery independent methods. The latter are considered to provide snapshot estimates of standing stock or other parameters, which are derived completely independently of fishery data and are not considered here. This paper considers methods which model stock and/or fishery dynamics and utilise primarily commercial fisheries data (catch), although fishery independent information may also be incorporated in the models.

The models available to the stock assessment scientist range from relatively simple surplus production models to more complex age- or size- structured analyses. In this paper we review the available methods, describe their underlying assumptions and data requirements, consider the advantages and disadvantages of the methods and give examples of their application to crustacean fisheries. We do not consider spatial models for crustacean stock assessment in the form of either metapopulation modelling approaches which describe a series of sub-populations linked by larval recruitment, or models which consider the spatial distribution of individuals within a sub-population. Appendix 1 provides a summary of methods, with reference to their sources, and Appendix 2 provides examples of the application of these methods to crustacean fisheries. The categorisation of methods is not wholly discrete, with overlap from one category to another occurring as methods are developed and extended to account for features specific to particular fisheries, or are generalised for wider application. The lack of clear divisions between methods prompted Xiao (2000) to suggest that each model be called after its originator, e.g. Schaefer (1954) production model. Throughout we take into account specific biological aspects of crustacea, such as growth by moult and our inability to age individuals effectively, which may render standard fin fish assessment methods unsuitable for the stock assessment of crustacean fisheries.

Following the description of stock assessment methods applied to crustacean fisheries, we consider the problem of uncertainty in stock assessment which applies to all assessment methods, and describe ways in which uncertainty can be addressed by stock assessment biologists and managers. Finally we suggest ways in which crustacean stock assessment methodology may advance in the future.

Surplus production models

Surplus production, or biomass dynamics, models have a long tradition in both finfish and shellfish stock assessment (e.g. Pereiro & Fernandez, 1974; Maigret, 1977; Polovina, 1989) and are still extensively used (e.g. Yoshimoto & Clarke, 1993; Stefansson et al. 1994; Breen & Kendrick, 1998; Cadrin, 2000). Biomass is modelled simplistically as a function, which combines life processes (recruitment, growth and natural mortality) and takes no account of population age or size structure. The biomass model is linked to the exploitation history of the fishery by an abundance index, often catch per unit effort (CPUE), assumed proportional to biomass, although fishery independent indices may be used. Historically the models were often fitted assuming equilibrium, but this method often performs poorly and time series fitting using maximum likelihood or non-linear least squares minimisation is now the generally accepted approach. There may be confounding between parameters unless the stock has an exploitation history covering a wide range of biomass and fishing effort levels (Hilborn and Walters, 1992) as was noted during a preliminary assessment of the edible crab, *Cancer pagurus* in the English Channel (ICES, 1998). If non-linear least squares minimisation is used for fitting the objective function can be modified to take account of additional data using a weighting parameter as developed originally for catch at age analysis (Fournier & Archibald, 1982; Deriso et al. 1985), which can be useful in overcoming problems of parameter confounding.

Simplicity is both a strength and weakness of surplus production models. They require few data (time series of catch and abundance index), are straightforward to implement and extend and few assumptions render them relatively transparent. They provide a useful tool for evaluation of management actions (Hilborn, 1997). However their simplicity precludes insight to the dynamic processes (growth, stock recruitment relationship) and inability to address age or size specific issues (e.g. changes to selection pattern, minimum landing size (MLS), discarding practise) limits their utility for evaluating technical measures.

Three classical models are the widely used Graham-Schaefer model (Graham, 1935; Schaefer, 1954; 1957; Ricker, 1975; Fletcher, 1978; Gulland, 1983), the Fox (1970) model and the Pella and Tomlinson (1969) model. The Schaefer model is based on the logistic equation and biomass declines linearly with fishing mortality, while in the Fox model biomass declines exponentially with fishing mortality. Pella and Tomlinson (1969) introduced a third parameter to modify the shape of the function, thus providing more flexibility, but at a cost as the model may be volatile and lead to estimates with high variances and parameter confounding. Butterworth and Punt (1992) advise that the sensitivity to the shape parameter should be tested. Other models have been proposed (Ludwig & Hilborn, 1983; Shepherd, 1982a) using the Ricker (1954) and Shepherd (1982b) functions originally developed for stock recruitment relationships.

The constant catchability assumption (i.e. that biomass is proportional to abundance index) may be modified using relationships such as a power model with catchability dependent on population size (Cooke, 1985), or stochastically modelling catchability as a random walk to account for random variability or technical creep. However, Punt and Hilborn (1996) warn of caution in shaping the relationship between catch rate and biomass. Nonetheless the constant catchability assumption may be violated over time, a problem common to much fisheries assessment, as well as due to spatial and behavioural (Frusher et al. in press) characteristics commonly exhibited by crustacea.

The methods of using equilibrium assumptions or average effort (Fox, 1970) for fitting, have been shown to perform poorly and are not generally recommended. Transformations into dynamic, or analogous difference, equations solved by multiple linear regression have been carried out (Schnute 1977; Hilborn, 1976; 1979), but most recent application has used time series fitting using maximum likelihood or nonlinear least squares minimisation. Error can be considered as either process, occurring as a result of stochasticity in the processes of the model while observations are made without error, or observation where error occurs in the observations and the model is considered to be deterministic (Punt & Hilborn, 1996). The latter is the more commonly used and generally recommended approach.

Prager (1994) reviewed estimation techniques and developed the ASPIC computer program (Prager, 1995) which includes extensions for handling missing and extra data, bootstrapping to obtain confidence estimates, bias and forecasting. Monte Carlo simulations have been used extensively to assess and address bias in surplus production model parameters (Uhler, 1979; Hilborn, 1979; Mohn, 1980; Roff & Fairbairn, 1980; Roff, 1983; Breen & Kendrick, 1998; Cadrin, 2000) and are considered essential by Hilborn & Walters (1992), although Punt & Butterworth, (1993) showed bootstrapped confidence intervals may be optimistic. A comparison of methods and measuring uncertainty is provided by Polacheck et al. (1993) for finfish species and slipper lobster.

Extended or modified surplus production models

Explanatory data may be used to extend surplus production models to model the effects of external factors on stock dynamics. Freon (1988) considered pristine biomass and catchability coefficient parameters, for the Schaefer, Fox and Pella-Tomlinson models as functions of an environmental variable and produced software for such analysis (Freon et al. 1990).

Stefansson et al. (1994) carried out an assessment of *Pandalus borealis* in Icelandic waters using a production model extended to include a recruitment index and juvenile cod biomass estimates as a predation index. The model has subsequently been used by the ICES *Pandalus* Assessment Working Group (ICES, 2001b) to take account of the high levels of shrimp predation by cod and compared with the standard age-based assessment.

Polovina (1989) linked stock production models for 3 isolated stocks of Hawaiian slipper lobster and assumed the intrinsic rate of population growth (i.e. biological parameters) was the same, thus enabling a reduction in the numbers of parameters requiring estimation from very sparse data.

Production models can also be extended to include age structure (e.g. Punt, 1994; Restrepo & Legault, 1997), but ageing problems currently limit application in crustacean stock assessment.

Delay difference models

Delay-difference models extend surplus production models by including biologically meaningful and measurable parameters and considering time delays in the biological processes (Hilborn & Walters, 1992). They differ fundamentally from the aggregate biomass function of surplus production models by explicitly modelling age-structured dynamics and the lag between spawning and recruitment, but by making simplifying assumptions regarding growth, survival, fecundity and selectivity they avoid the complexity of formal age, size or stage structured models. Key assumptions are that all exploited fish are fully vulnerable to fishing and fish have the same natural mortality rate.

Minimum data requirements for estimating delay difference model parameters include time series of catch and relative or absolute abundance. Other additional biological information, exploitation rates or recruitment indices may be included as data or modelled. Parameter confounding is common and successful estimation requires auxiliary information on growth, natural mortality and/or the form of the stock recruitment relationship. It is then possible to obtain estimates for the remaining parameters with reasonably small standard errors and correlations (Quinn & Collie, 1990).

The models were developed initially by Deriso (1980), and elaborated by Schnute (1985, 1987), Kimura et al (1984), Kimura (1985), Fogarty & Murawski (1986) and Fournier and Doonan (1987), the latter adopting a Bayesian approach to allow the inclusion of prior knowledge. Early derivations assumed growth was linear and dependent on the mean weight of the previous age but Horbowy (1992) presented three models which, depending on the growth functions used, corresponded to von Bertalanffy, Brody or logistic growth models (Quinn & Deriso, 1999). Schnute (1985) and Fournier & Doonan (1987) recommend using a 3 parameter stock recruit relationship (SRR) with a shape parameter (Deriso, 1980), but Hilborn and Walters (1992) suggest there is little gain from this and recommend using Ricker or Beverton & Holt SRR models.

Various fitting methods have been suggested (Deriso, 1980; Schnute, 1985; Walters, 1987; Fournier & Doonan, 1987; Jacobsen et al. 1987; Kimura et al. 1996; Meyer & Millar, 1999a; 1999b); including non-linear least squares minimisation, Kalman filtering and Bayesian approaches. Quinn and Deriso (1999) note that simple estimation procedures are often unsuccessful and describe Monte Carlo Markov Chain (MCMC) and Kalman filter methods for combined error model fitting. Mogul & Lara (1997) used a Bayesian framework to compare a range of models including a delay difference model for *Panulirus argus* stock assessment.

Simulation studies based on delay difference models enable a structured insight into the responses to perturbation or the effects of particular biological processes. They are relatively easy to implement and provide a good framework for dynamic analysis of management measures and an aide to understanding of age structure and temporal effects under non-equilibrium conditions (e.g. Tyler et al. 1985; Hall, 1997; Fogarty, 1998; Walters et al. 2000).

However, where data are relatively scarce delay difference models offer little or no advantage over surplus production models for parameter estimation because of their demands for extra information and may result in multiple solutions, or spuriously good fits. Punt & Hilborn, (1996) suggest that age structured dynamic models are less restrictive and preferable to delay difference models if more complex models than surplus production models are required.

Depletion methods

Closed system depletion models

Depletion methods provide a useful means of stock assessment when data are scarce. They examine how measured removals of fish (catch) influence the relative abundance of remaining fish, the latter being estimated by an abundance index, often catch rate (CPUE) normally considered proportional to population size. With a closed population, no recruitment or natural mortality, the problem equates to predicting how large a cumulative removal is required for abundance index to reduce to zero. Closed system depletion methods provide a snapshot of population abundance or other stock parameters, without insight into the stock dynamics over time.

The classical depletion methods are attributed to Leslie & Davis (1939), DeLury (1947), other works include Moran (1951) and Zippin (1956; 1958) and earlier works by Helland (1913-1914) and Hjort et al. (1933), cited by Ricker (1975). The simplest depletion estimator consists of dividing the fishing period into 2 halves, assuming the population is closed and catch rate in each period is proportional to abundance (Seber & Le Cren, 1967). Catch (rate) in the second fishing period is expected to be lower since abundance was reduced by the catch already taken. The Leslie & Davis estimate uses cumulative catch and an abundance index, which may be independent of the fishing process. The DeLury method assumes all fish are equally vulnerable and that fish and fishing effort are randomly distributed. The abundance index is CPUE measured over short time periods such that population size is proportional to CPUE. Both the Leslie & Davis and DeLury models have a linear form and can be fitted graphically or by linear regression.

Where fishing is intense over a short period of time depletion methods are powerful tools for estimating initial abundance, although caution regarding catchability assumptions may be appropriate and simulations to estimate reliability are recommended (Hilborn & Walters, 1992). Measurement error in the independent variable (cumulative catch or effort) may cause catchability (q) to be negatively biased and initial stock size overestimated especially for the DeLury model. The Leslie & Davis model is more flexible and robust to this. Ricker (1975) suggests variability in q is probably the greatest source of error, with q a function of population size, declining as the population is depleted. The possibility of some animals not available to the fishery (q=0) for technical, spatial or behavioural reasons may also cause problems and variability in q is of particular concern when the methods are applied to crustacea (Miller, 1990). Variability in q biases q upward because catch is dominated by more catchable animals and hence population size is biased downward. The presence of large numbers of animals with low catchability may be detected by curvature of the depletion regression if at least 10 time periods are used (Hilborn & Walters, 1992). Bias may also occur with depletion models because the same fishing episode is often used to provide cumulative catch and CPUE estimates which are not independent, although maximum likelihood estimation has been used to overcome the problem (Schnute, 1985; Zippin, 1956). Morgan (1974) found DeLury estimates of *Palinurus cygnus* density to be underestimated by 75% when compared with tag-recapture estimates, while Morrissy (1975) found Leslie estimates of freshwater crayfish were underestimated by between 47% and 61% when compared with counts taken after the pond was drained. Simulation studies have shown large biases in DeLury and Leslie estimates if q was over-estimated and moderate biases if q was underestimated (Bratten, 1969; Miller & Mohn, 1989).

The terms removal and index removal (IR) may be used to distinguish fishery derived or independent catch rates. IR (and CIR, see below) methods (e.g. Petrides, 1949; Seber, 1982; Routledge, 1989; Pollock & Hoenig, 1998) are common in wildlife literature but have received less attention in fish stock assessment. Chen et al. (1998) developed formulae for estimating variance and bias in population estimates and related parameters. Simulation studies showed paired sample design i.e. using the same sample stations for each survey performed better than random samples and always produced feasible estimates with minimal bias and small standard error. Chen et al. applied the methods to snow crab in Newfoundland but estimates of population size were rather variable, because catch was a small fraction of the stock and resulted in small changes in catch rate. Frusher et al. (1998) applied IR (and CIR) methods to Tasmanian rock lobster and estimated exploitation rates, consistent with the distribution and effort of the fishing fleet. Bootstrapping sample data showed wide variation around the estimated exploitation rates, attributed to the non-random distribution of lobsters. They recommended the methods should be restricted to fisheries with high exploitation rate and relatively uniform size composition over the survey area.

Change in ratio (CIR)

The change in ratio rationale (Kelker, 1940; Paulik & Robson, 1969) has been applied primarily in mark recapture analyses, but the method is included here since CIR and IR are often used together (e.g. Dawe et al, 1993; Chen et al. 1998; Frusher et al. 1998) and CIR has similarities with depletion methods. The method works by dividing the population into 2 distinct components and observing the change in their ratio following a known removal of animals. Eberhardt (1982) and Dawe et al. (1993) recognised the importance of replicate CPUE samples for estimation of empirical variances of the component proportions. The population is assumed closed, or factors affecting the population (migration, natural mortality, etc.) are assumed to apply equally to the 2 components. Relative catchability of the 2 components is assumed constant, although actual catchability can change between episodes. The method has recently been applied to a range of crustacean stocks including *Homarus americanus* (Comeau & Mallet, 2001), *Pandalus platyceros* (Bishop et al. 2000) and *Chionoecetes opilio* (Dawe et al, 1993; Chen et al. 1998).

Open system depletion models

As depletion models have been generalised to open systems by making assumptions regarding stock dynamics (Allen, 1966; Chapman, 1974; Sainsbury, 1982) they become similar to production models. The models have been further developed to include stage- and age-structure (Collie and Sissenwine, 1983). The 2 stage model of Collie & Sissenwine, often referred to as catch survey analysis (CSA or C-S analysis) has been widely used for crustacean assessment (e.g. Conser, 1991; Kruse & Collie, 1991; Conser & Idoine, 1992; Collie & Kruse, 1998; Cadrin, 2000) often using indices for undersized and legal sized animals. Data needs for CSA are catch data, survey abundance indices, covering both pre-recruits and exploited ages, and an estimate or assumption of natural mortality.

The model of Collie & Sissenwine smoothed the abundance index and used a Kalman filter (Kalman, 1960) to partition error into observation error and process error. Catchability was overestimated if catch was assumed taken instantaneously at the start of the year, but a model analogous to Pope's cohort analysis approximation (Pope, 1972) was considered adequate if catch occurred evenly though the year. Catchability was also sensitive to natural mortality, underestimating natural mortality caused overestimates of catchability and vice versa. Collie & Kruse (1998) tested a modified version of CSA using simulated data and for realistic levels of measurement and process error, bias in abundance estimates was less than 5%. Recent applications have used non-linear minimisation assuming observation error rather than the Kalman filter approach advocated by Collie & Sissenwine.

Cadrin (2000) carried out a comparative study on Gulf of Maine shrimp, *Pandalus borealis* using stage based CSA and the ASPIC surplus production model by simulating catch and survey data with a range of coefficients of variation (CVs). CSA performed well when CVs were low (<10%) but broke down as CVs increased and was unreliable when CVs exceeded 40%. ASPIC performed less well with frequent convergence problems even for moderate CVs (>20%) on input data. Performance was best if the input data had a wide range of contrast. The CSA process equation may be robust to different population dynamics, but CSA has been found to be sensitive to incorrect model assumptions (e.g. natural mortality, length selectivity of the fishery, relative survey catchability of pre- and post- recruits) when applied to American lobster (Conser & Idoine, 1992) and king crab (Collie & Kruse, 1998) fisheries. Correct definition of the pre-recruit and fully recruited size classes is very important.

Age-structured depletion analysis is essentially a series of depletion experiments, each on an individual cohort and providing information on catchability which can be compared across cohorts present at the same time and should therefore enable better estimation than aggregate models. However ageing problems in crustacea limit its application at present.

Equilibrium length based methods

Jones length cohort analysis (LCA)

Length based cohort analysis (Jones, 1981; 1984) produces estimates of abundance and fishing mortality at length given growth parameters, assumptions regarding natural mortality and a catch length frequency distribution from a population assumed to be at equilibrium. The duration of time spent in each length class is calculated using the growth parameters. Estimates of the population number entering each length class are made either by Pope's cohort analysis approximation or by numerically solving the catch equation (Sparre et al. 1989). The process continues recursively estimating fishing mortality and numbers backwards along the 'pseudo-cohort'.

Hilborn and Walters (1992) note the equilibrium assumption is critical and results can be misleading unless the stock is in equilibrium, or at least recruitment and exploitation rates have been stable without trend. They suggest the method is a poor alternative to age structured virtual population analysis (VPA), a view shared by Lai & Gallucci (1988). Nevertheless LCA has been and still is quite widely used (e.g. Bannister & Addison, 1986; Addison. & Bennett, 1992; Cadrin & Estrella, 1996; Garcia-Rodriguez & Esteban, 1999; ICES, 2001a), since in conjunction with Thompson & Bell (1934), or length based yield per recruit, analyses, it provides a framework for management evaluation in species where age based data are unavailable.

Yield, spawner and egg per recruit models

Yield, spawning stock biomass, and egg per recruit models are not strictly assessment models but provide a framework for evaluation of management measures. They were developed as an age based method but have been generalised to use size structured data and are commonly used following LCA. Data requirements for yield per recruit analysis are size specific: weight, natural mortality and exploitation pattern, whilst maturity and fecundity by size, are additionally required for spawning stock biomass (SSB) and egg per recruit analyses. The yield per recruit model (Beverton and Holt, 1957) works by assuming 1 recruit and projecting it forward based on fishing and natural mortality to estimate numbers in each size class during the lifetime of the cohort. Weight, proportion mature and fecundity by size are applied to estimate yield, SSB or number of eggs by size class, which are summed over all classes. Per recruit models are extensively used in crustacean fisheries (Bannister & Addison, 1986; Ebert & Ford, 1986; Fogarty & Idoine, 1988; Pitcher et al. 1997; Hobday & Ryan, 1997; Mohan, 1997).

Fogarty & Murawski (1986) listed 4 central assumptions; growth and natural mortality rates are unrelated to stock density; constant recruitment; fishing mortality is distributed over the entire exploitable stock; population dynamic processes can be integrated over a series of annual cycles to provide a cumulative evaluation of the yield potential of cohorts. They noted that these assumptions are clearly deficient for a variety of invertebrate stocks and that, accounting for probabilistic annual moulting frequency and discontinuous growth of crustacea in the growth function is a major requirement for more realistic yield models. They extended yield per recruit models, incorporating density dependent growth, or moult probability and increment, for surf clam and American lobster, respectively.

Per recruit models assume equilibrium, indicating long term changes in yield, SSB or egg production, while short to medium term consequences are not explained. They are straight-forward computationally and useful in judging the impacts of changes in size limits and fishing mortalities on yield and egg production (Hilborn, 1997). Since recruitment is assumed constant only information regarding growth over-fishing is provided, the effects of stock density on recruitment are not taken into account. Combining per recruit analysis with a versatile stock recruitment function allows comparison under different characteristic stock recruitment assumptions (Shepherd, 1982b; Bannister & Addison, 1986; Addison. & Bennett, 1992).

Dynamic length-, stage- based methods – Leslie matrix models

Dynamic length and stage structured models were developed from the age structured matrix representation of Leslie (1945) and statistical catch at age analyses (Doubleday, 1976; Fournier & Archibald, 1982; Deriso et al. 1985; Gudmundsson, 1986; 1994; Kimura, 1989). These were generalised allowing the model to be framed in classes representing size, developmental stage, sex or area (Usher, 1966; 1971; Sainsbury, 1982; Caswell, 1989; Sullivan et al. 1990; Sullivan, 1992). Dynamic size-structured models provide a means of explicitly modelling moult-increment growth processes and have been widely applied recently to assessment of crustacea and other invertebrates (Bergh & Johnston, 1992; Walters et al., 1993; Punt & Kennedy, 1997; Zheng et al., 1995; 1998; Lai & Bradbury, 1998).

The models have a high degree of biological realism and can be applied to policy and risk evaluation, but are computationally complex and need a high level of technical expertise to develop. Their technical complexity may also result in a lack of transparency to biologists and managers (Hilborn, 1997). They require considerably more data and biological assumptions than most other methods; size frequency data are the basic input, but assumptions regarding biological processes (growth, maturity, natural mortality) require extensive supporting data and additional assumptions regarding catchability or selection pattern may be required. Population dynamics may be linked to the observed system by minimising differences between modelled and observed abundance indices or size frequency distributions, the latter an alternative to the assumption of constant catchability which is inherent in most assessment methods.

Dynamic length based models require many assumptions and are specifically tailored to particular species and/or stocks. We provide two examples of such models.

Zheng et al. (1998) estimated abundance of Tanner crab using a probabilistic moult frequency and increment model for growth in separate sex length based models incorporating shell hardness. Parameters were estimated assuming log-normal observation error and minimising least squares differences between observed and modelled length frequency distributions. The length based approach incorporated survey, fisheries and tagging data, linking abundance estimates from multiple years through a population dynamics model. Modelling population dynamics filtered survey measurement error resulting in year to year abundance estimates that were less variable than independently considered swept area estimates.

Punt et al. (1997) used tagging experiments and maximum likelihood to estimate a transition matrix for monthly growth of size disaggregated populations of *Jasus edwardsii*. The matrix represented probabilities that an animal in a particular size class would grow into another size class in the model time step. These data were used in a dynamic length structured model, within a Bayesian framework utilising the Metropolis algorithm (Hastings, 1970; Gelman et al. 1995), to estimate recruitment and fishing mortality parameters and for risk analysis of potential management measures (Punt & Kennedy, 1997).

Age structured methods

The use of statistical catch at age and VPA based methods for crustacean assessment is limited by problems with ageing. Discussion here is confined to examples of application of age structured methods to *Nephrops* (ICES, 2001a) and *Pandalus* (ICES, 2001b) stocks.

Catch-at-length data can be converted to catch-at-age data using knife edged length slicing (ICES, 2001a) prior to assessment. Age structured methods can then be applied including virtual population analysis (VPA) (Gulland, 1965; Pope, 1972; Hilborn & Walters, 1992; Darby & Flatman, 1994), separable VPA (Pope, 1977; 1979; Pope & Shepherd, 1982; Shepherd & Stevens, 1983; Darby & Flatman, 1994) and extended survivors' analysis (XSA) (Shepherd, 1992; Darby & Flatman, 1994.) Length slicing may introduce error and/or reduce contrast and age-structured methods are not widely applied to longer lived crustacean species.

Numerous statistical catch at age and VPA based methods are described in the literature. Hilborn & Walters (1992) and Quinn & Deriso (1999) provide many relevant references.

Consideration of uncertainty

Uncertainty is inherent in all forms of stock assessment and has a variety of causes and effects. Uncertainty may be due to measurement (observation) error or process error caused by random effects around the deterministic value. It may consist of random noise or it may have systematic pattern. Further error, often bias, may be introduced into the assessment process by model mis-specification. Uncertainty in results (estimated parameters and summary statistics) may be considered in terms of the distributions of the results, which encompasses the expected value, dispersion and bias, or in terms of the sensitivity of results to the input data, models and assumptions. It is important to consider not only the confidence intervals for the statistic of interest, but also the drivers for the result. A further consideration is interaction between parameters formally expressed in terms of covariance. Fortunately many methods estimating dispersion metrics of parameters will also provide information regarding covariance.

Patterson et al. (2001) considered 3 approaches for considering uncertainty; frequentist, Bayesian and likelihood.

Frequentist approaches assume parameters are exact and confidence intervals are derived from multiple analyses of the distribution of the data. Frequentist approaches do not offer a cohesive approach to the incorporation of prior information, but do offer non-parametric techniques and thus relaxation of assumptions regarding error distributions. Bias resulting from estimation is admitted and techniques to adjust for it have been developed.

Bayesian methods on the other hand consider parameters to have a (posterior) probability distribution, dependent on the prior probability distribution and the likelihood of the parameter given the data. The posterior distribution of a parameter in a Bayesian analysis is integrated over all possible values of the other parameters. Prior probability distributions provide a formal method for inclusion of knowledge from other sources and are formally distinguished from data, but specification of prior distributions is not trivial and the methods are computationally intense. Non-parametric analogues of Bayesian techniques are not available and methods to deal with bias have not been investigated.

Likelihood methods formally describe the probability of alternative model parameters given the data and are conceptually attractive. The probability distribution of the parameter of interest is conditioned on the maximum likelihood values of the other parameters. Likelihood methods become complex if interest parameters are not formal model parameters (e.g.

variances or transformations) and as the number of parameters increases. This tends to restrict the approach to simpler fisheries models. Non-parametric approaches are not available.

Figure 1 presents a variety of methods for evaluating uncertainty in stock assessment and projection. The text below elucidates, numbers in parentheses refer to Figure 1.

Bayesian (1) or likelihood (2) frameworks formally express parameters in terms of their probability distribution given the data and uncertainty in the data is not acknowledged. Punt & Kennedy (1997) provide an example of a length structured assessment for rock lobster utilising a Bayesian framework.

What follows is primarily a frequentist approach in which the methods are grouped into four broad categories of uncertainty: sampling variability, differences between modelled and observed data; model performance and sensitivity analyses.

Sampling variability

If data consist of multiple samples (or can provide replicate estimates by assuming a parameter is constant over time) then by making assumptions regarding error distributions, analytical estimates of uncertainty (3) can be produced (e.g. population estimates of snow crab from change in ratio methods (Chen et al. 1998) or standard error of survivors estimates from XSA (Darby & Flatman, 1994)). Alternatively, random draws (with replacement) and recombination of the samples can be used to generate multiple datasets and subsequently an empirical estimate of parameter distribution (4). We refer to this method as a non-parametric bootstrap of the data. It has the advantage that no assumptions need to be made regarding the distribution of the data, which are considered to be representative of the population. Frusher et al. (1998) used this technique to evaluate CIR and IR assessment of lobsters in Tasmania. For a parametric bootstrap of the data the input data are modelled parametrically using the mean and variance of the samples and an assumption regarding the distribution of the data. Random deviates drawn from this distribution provide the multiple datasets required for estimation of a distribution for the parameter of interest (5).

Even if data are not available (or not directly used) it may still be possible to make some informed decision about the level and distribution of an input parameter and by generating random deviates of the input parameter estimate a distribution for statistic of interest (6). This type of approach might be used to investigate the effects of variability in natural mortality. When the deviate is based on assumption we refer to the method as a Monte Carlo simulation, however if the deviate were based on modelled data it would be termed a parametric bootstrap of the data (5).

Differences between the modelled and observed data

An alternative method is to generate an expectation of data from the fitted assessment model and bootstrap (Efron, 1981; 1982; 1985; 1987) differences between the observations and this to provide multiple datasets. As when bootstrapping the data, the residual bootstrap could be non-parametric (7) where random redrawing of residuals between observed and expected data were reapplied to the expected value. Alternatively the expected data could be modelled parametrically with an assumed error distribution and random deviates sampled from this distribution to provide the multiple datasets, a parametric bootstrap of the model (8). Methods (4) and (5) were dependent only on the data or assumptions regarding them, but methods (7) and (8) incorporate assumptions regarding the stock or fishery dynamics to model the expectation of the data. Methods (7) and (8) can be used assuming either process error where the modelled data are considered to be stochastic and the observed data measured without error, or assuming observation error in which case the modelled data are considered deterministic and the observed data stochastic.

Model performance

Simulating the biological system allows the performance of different assessment methods to be evaluated dependent upon the assumptions of the simulation model (9). Chen et al. (1998) evaluated CIR and IR estimators using paired and random sampling designs to sample from a simulated system, while Cadrin (2000) generated replicate sets of abundance and biomass indices, based on a recent shrimp assessment with differing levels of log normally distributed measurement error, to compare the performance of CSA and surplus production models. Building on this technique leads to scenario models (10), which combine stochastic system models (stock dynamics, fishery) and models of the management process (sampling, assessment, regulation) which feed back into the system model with explicit time structure. Scenario models allow comparative evaluation of management strategies within an experimental framework, which also allows alternative model choices for robustness testing and may also provide valuable insight into assessment performance and bias.

The methods above have generally produced results that can be expressed in distributional terms. However for sensitivity or robustness analyses a series of experiments which evaluate effects of discrete parameter settings (11), or different models, or sub-components of the overall assessment model (9), may be used. Comparison of results over different options might suggest results are robust to various plausible models, or parameter values, in which case management can be applied, or sensitive to model/parameter choice in which case the need for more research in this area is high-lighted. Since all models are by definition a simplification of the real system, this approach provides comparative information on the effects of model mis-specification. This type of approach has been used to explore the effects of different hypothetical stock recruitment relationships using a yield per recruit framework (Addison & Bannister, 1998). Stochastic modelling of trends (12), for example by using random walks, may be useful for modelling parameters that are thought to be 'more or less' constant, perhaps changing gradually in response to environmental conditions or gradually increasing due to technical improvements.

Sensitivity analyses

Sensitivity of results may be formally stated in terms of derivatives with respect to a particular variable, or a matrix of partial derivatives with respect to input variables, the Jacobian matrix. This gives information on the rate of change of the statistic of interest relative to change in the input variable. Derivatives may be analytically calculated(13), or numerically estimated by perturbation analysis (14) where each data point is sequentially varied and the change in results used to estimate partial derivatives. Barbeau & Caswell (1999) used perturbation analysis to evaluate management scenarios for survival of seeded populations of scallops. Jack-knifing (15) (Efron, 1981; 1982) involves sequentially excluding each data point and re-estimating the results providing estimates of dispersion and the relative influence of each data point.

In conclusion, existing methods provide a flexible array of tools to investigate the sources and outcomes of uncertainty. However their use and statements regarding uncertainty must be considered carefully. Simulation envelopes derived by bootstrap or Monte Carlo simulation depend on assumptions and may not represent the true confidence intervals. Stochastic processes may have been omitted and the simulation envelope under-estimates of true variability, or conversely co-varying variables may have been modelled independently resulting in over-estimation of variability. No method can make up for poor data, the adage ‘garbage in, garbage out’ is particularly relevant as better sampling is likely to both reduce uncertainty and provide better quantification of it. Similarly no method can overcome the issue of conflicting sources of data. The best approach may be to conduct separate analyses and present the alternatives to decision makers (Richards, 1991; Schnute & Hilborn, 1993).

Patterson et al. (1999) concluded that stock assessments and management forecasts depend on the principal assumptions underlying the structural model (e.g. whether or not catch is assumed to be exact), time-dependence in catchability, modelling of natural mortality, recruitment, and growth, and the basis for probability inference (Bayesian, bootstrap, etc.). Choice of assumptions depended on a variety of factors including the purpose of the analysis, the institutional framework for method development and usage, and availability and customary usage of software tools. No particular consensus appeared to exist among fisheries scientists as to the most appropriate choices and implications of different approaches were rarely examined. Despite much recent progress in method development, the extent to which probability distributions, estimated for management purposes, adequately represent the probabilities of eventual real outcomes is largely unknown and therefore statements regarding the probability of outcomes should be couched in relative rather than absolute terms.

Concluding remarks

In this paper we have summarised a range of stock assessment methods that are available to the crustacean fisheries biologist, and reviewed techniques that are currently available to evaluate uncertainty in the whole assessment process. We conclude by suggesting a number of ways in which crustacean stock assessment methodology may develop in the future.

Dealing with uncertainty

Perhaps most importantly, rapid development of computer technology means previously computationally prohibitive methods are becoming commonplace. This trend seems set to continue and will promote routine use of complex and stochastic models such as Bayesian analyses or spatially structured models. However, current practises still have room for improvement. Elements of the assessment process are often fragmented, outputs from one analysis providing input to the next, and while variance may sometimes be accounted for, covariance is usually ignored. There is therefore scope for development of integrated packages encompassing the complete assessment and projection process and retaining relationships between variables within each stochastic realisation. Evaluation of management strategies for actual stocks, or based on archetypal stock dynamics, may identify robust management regimes and provides useful insight into bias induced by assessment and management process, and application of simulation models to investigate the full management process seems set to expand. Managers are now accustomed to probability statements attached to metrics of interest in the decision making process and development and refinement of methodologies to produce these is set to continue.

Model choice and comparison of performance

Any assessment or management evaluation must make assumptions and use simplified models of the true system. There is a trade off between the number of parameters to be estimated and assumptions made for simple and complex models. Comparative studies have demonstrated that simpler methods may sometimes perform as well as, or better than complex models (Richards & Schnute, 1998). Simple models which retain biological realism should not be overlooked because they are generally more transparent than complex methods and likely to produce robust conclusions. Punt & Hilborn (1997) recommended Bayesian methods for decision analysis, but also emphasised the need to apply a number of alternative methods noting that results which are robust to model choice will carry more weight.

More biologically realistic models

Most of the models described in this paper were developed as tools for assessing fin fish stocks, and may not be entirely appropriate for use in crustacean stock assessment. We foresee future developments in crustacean-specific models which more explicitly incorporate aspects of crustacean biology such as stepwise growth, or which allow variable or explicitly modelled trends in catchability. A major problem with most stock assessment methods is that they are age- rather than size-based, and the current inability to routinely age crustacean species limits the range of assessment models that can be used for crustaceans. However recent advances have been made in techniques for ageing crustaceans (Sheehy et al., 1995, 1998,1999; Ju et al., 2001) which, provided they can be developed sufficiently to allow routine ageing, promise to open up a wide range of assessment models.

The second major area of development in crustacean stock assessment models which is likely to occur in the near future is the explicit modelling of spatial structure of crustacean populations. Spatial structure can be incorporated at two scales. In crustacean species, larvae dispersal between geographically defined stocks may suggest a metapopulation modelling approach where several sub-populations are linked by dispersal (Hanski, 1999), an approach applied for example by Fogarty (1998) for *Homarus americanus*, and by Botsford et al. (1998) for *Cancer magister*. Spatial structure may also be incorporated by considering the spatial distribution of individuals within a sub-population and the consequent spatial distribution of the fishing effort that targets those individuals (Caddy & Seijo, 1998; Orensanz et al., 1998).

Independent parameter estimation

Finally, no amount of bootstrapping will get round the “garbage in, garbage out” problem. Ultimately the quality of advice must depend on the quality of the underlying data. Sensitivity analyses can show where results are robust to model or data deficiencies and direct resources towards improving those areas lacking in knowledge. Fishery-independent methods have an important role in stock assessment for the provision of management advice and also by providing independent estimates for some parameters in stock assessment models and 'ground truthing' dynamic models. The development of fishery-independent methods seems set to continue particularly incorporating technological developments such as remote sensing (e.g. telemetry, thermal/sonic imaging, underwater TV), automated data capture and transmission systems (e.g. satellite imaging and data transmission), and computer aided analysis tools (e.g. image analysis).

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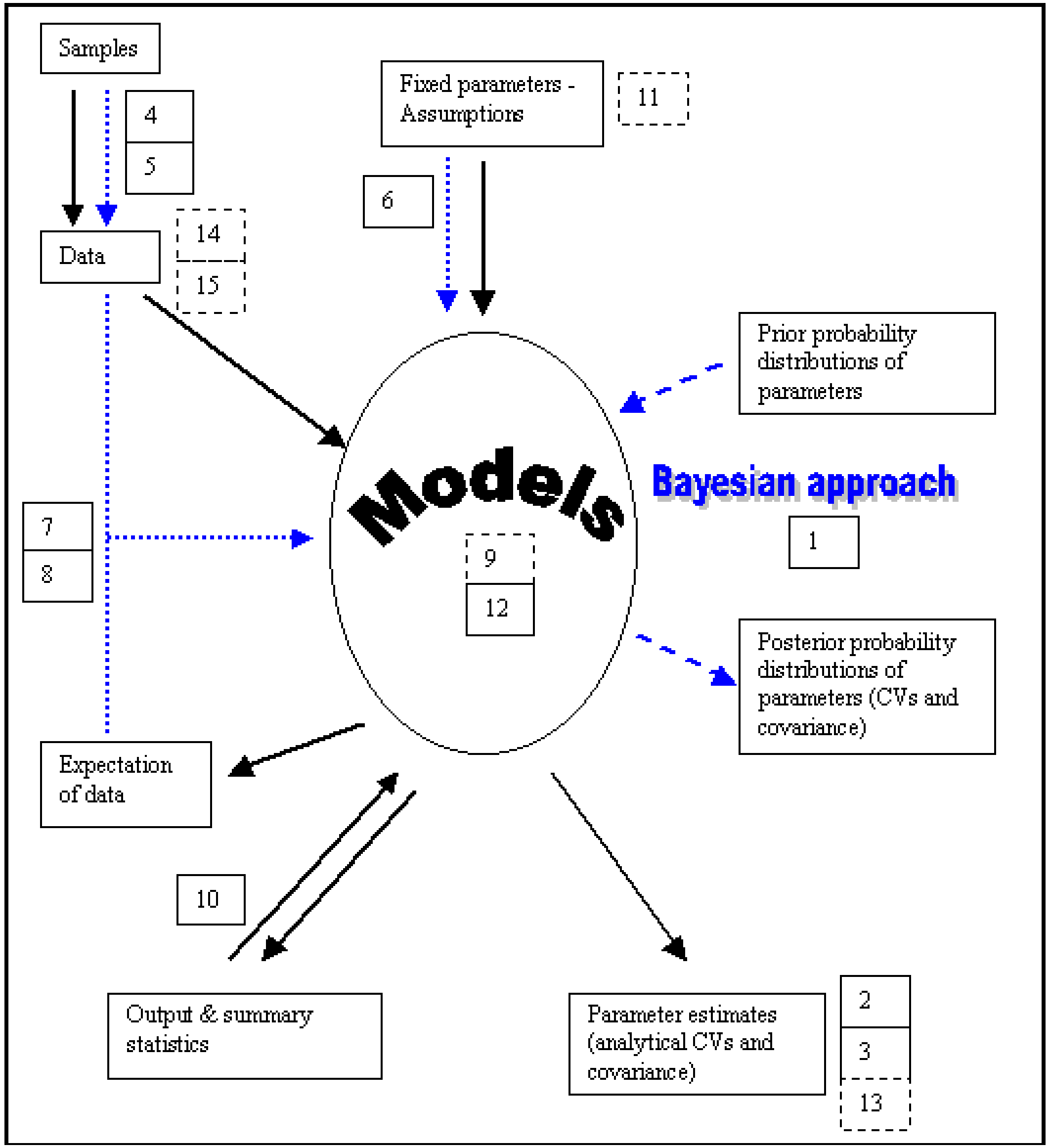
Figure 1. Schematic representation of methods for evaluation of uncertainty in stock assessment and projection



1) Bayesian estimation of posterior probability distributions.
2) Likelihood profiling.
3) Analytical variance and covariance estimates.
4) Non-parametric bootstrap of the data.
5) Parametric bootstrap of the data.
6) Monte Carlo simulation of assumed input parameters.
7) Non-parametric bootstrap of the model fit.
8) Parametric bootstrap of model fit.
9) Model testing on simulated systems.
10) Scenario modelling with feedback.
11) Sensitivity to range of discrete input parameters.
12) Stochastic modelling of trends in parameters (e.g. random walks).
13) Analytical calculation of derivatives.
14) Numerical estimation of derivatives (perturbation analysis).
15) Jack-knife of data points.

Appendix 1. Methods, data requirements, advantages and disadvantages

Method	Data requirement	Advantages	Disadvantages	References
Surplus production models				
Surplus production models (SPM)	Time series of catch and abundance index.	Minimal data requirements and assumptions. Framework for management evaluation. Easily extended.	Earlier fitting methods made equilibrium assumptions. Need contrast in the data to get meaningful fit. Aggregate dynamics don't provide insight. Unable to address age/size based issues.	Graham, 1935; Schaefer, 1954; 1957; Pella and Tomlinson, 1969; Fox, 1970; Ricker, 1975; Fletcher, 1978; Shepherd, 1982; Gulland, 1983; Hilborn & Walters, 1992; Prager, 1994; 1995; Punt & Hilborn, 1996; Quinn & Deriso, 1999; Cadrin, 2000.
Extended modified surplus production models	Time series of catch, abundance index plus auxiliary data e.g. recruitment index, predator index, environmental signal, trend in q, etc.	Relatively low data requirements and assumptions. Able to address specific issues.	Greater data requirement and more assumptions than above.	Freon, 1988; Hilborn & Walters, 1992; Steffanson et al. 1994; Punt & Hilborn, 1996; Quinn & Deriso, 1999.
Age/stage structured surplus production models	Aggregate time series of catch and abundance index. Age structured data or assumptions for biological parameters (growth, maturity natural mortality) and selection pattern.	Age structure taken into account. Flexible framework for evaluation of management and technical measures, without the complexity of fully age structured methods.	More complexity, data requirements and assumptions. Problems with ageing crustacea.	Hilborn, 1990; Punt, 1994; Punt & Japp, 1994; Punt & Hilborn, 1996; Restrepo & Legault, 1997.
Delay difference models				
Delay difference models	Time series of catch and abundance index. Growth and stock recruitment models. External information on growth, natural mortality and form of SRR may be required to avoid parameter confounding.	Explicit consideration of age structure in models. More biological realism and temporal structure in the model.	Parameter confounding common, unless some parameters fixed or estimated externally. More data requirements and assumptions than SPM.	Deriso, 1980; Schnute, 1985; Fogarty & Murawski, 1986; Fournier & Doonan, 1987; Hilborn & Walters, 1992; Quinn and Deriso, 1999.

Method	Data requirement	Advantages	Disadvantages	References
Depletion methods				
Closed system depletion methods - Leslie & Davis, DeLury	Time series of catch and catch rate (catch/effort) usually taken in a short period of time.	Computationally straightforward and with minimal data requirements and simple assumptions.	Provides snapshot estimates without account of dynamics. Assumption of closed system limits applicability. Requires frequent surveys in relation to fishing. Fishing intensity must be high.	Leslie & Davis, 1939; DeLury, 1947; Zippin, 1956; Seber & Le Cren, 1967; Ricker, 1975; Hilborn & Walters, 1992.
Closed system depletion methods - Index removal (IR)	Sampled catch rates before and after significant catch.	Computationally straightforward with minimal data requirements and assumptions. Dispersion statistics available.	As above.	Petrides, 1949; Eberhardt, 1982; Seber, 1982; Routledge, 1989; Roseberry & Woolfe, 1991; Dawe et al., 1993; Chen et al., 1998; Frusher et al., 1998.
Change in ratio (CIR)	Catch rates by component before and after significant catch by component.	Computationally straightforward with minimal data requirements and assumptions. Dispersion statistics available.	As above.	Kelker, 1940; Paulik & Robson, 1969; Seber, 1982; Pollock, 1991; Dawe et al., 1993; Chen, 1995; Chen et al, 1998; Frusher et al., 1998; Pollock & Hoenig, 1998.
Open system depletion methods Catch survey (C-S) analysis (CSA)	Time series of catch, abundance index, recruitment index, or age structured data.	Useful for crustaceans as discontinuous growth stages can be accommodated. Error can be partitioned into observation and process by using Kalman filter for fitting.	More data and assumptions required for open or age/size based systems. Sensitive to assumptions of natural mortality, relative catchability and size/age of recruits.	Allen, 1966; Ricker, 1975; Hilborn & Walters, 1992. Collie & Sissenwine, 1983; Conser, 1991; Kruse & Collie, 1991; Conser & Idoine, 1992; Collie & Kruse, 1998; Cadrin, 2000.

Method	Data requirement	Advantages	Disadvantages	References
Equilibrium length based methods				
Length Cohort Analysis/VPA (LCA)	Length composition, growth model and parameters. Assumed of natural mortality rate (M).	Relatively low data requirements. Provides length based exploitation pattern and basis for evaluation of technical measures. Convergence of results if F is high relative to M.	Equilibrium assumption may often be violated, which can produce misleading results.	Jones, 1981; 1984; Lai & Gallucci, 1988; Sparre et al. 1989; Hilborn & Walters, 1992; Quinn & Deriso, 1999.
Yield spawner and egg per recruit models(YPR)	Selection pattern, natural mortality and weight by age/length. Maturity/fecundity by age/length for spawning biomass/egg per recruit.	Computationally straightforward and can be extended to model stock recruitment relationship and density dependent growth under equilibrium assumptions. Provides a framework for evaluation of management measures.	Not an assessment method. Cannot account for variability in recruitment and growth. Stock recruitment relation and density dependent growth effects not modelled in basic model. Provides information only on equilibrium conditions, not short term effects.	Beverton & Holt, 1957; Gulland, 1983; Quinn & Deriso, 1999.
Stage based YPR	Size/stage based moulting probability and increment – growth rate. Fishing mortality rates.	Relatively straightforward computationally. Provides a framework for evaluation of management measures.	As above and difficult to get crustacean growth rates.	Fogarty & Murawski, 1986.
Dynamic size structured methods				
Dynamic size-, stage-structured models (Leslie matrix models)	Size/stage disaggregated time series of catch. Abundance indices or selection pattern. Natural mortality and growth rates from external sources or assumed. Stock recruitment relationship or time series of recruitment.	Explicit consideration of stage, size and temporal structure, provides framework for technical measures evaluation. Can model discontinuous growth processes. Good biological and selection pattern data provide an alternative to fitting using catchability model.	Many assumptions, high data and technical knowledge requirement. Computationally complex and may lack transparency.	Leslie, 1945; Usher, 1966; 1971; Sainsbury, 1982; Rosenberg & Beddington, 1988; Getz & Haight, 1989; Caswell, 1989; Methot, 1990; Sullivan et al. 1990; Sullivan, 1992; Bergh & Johnston, 1992; Walters et al., 1993; Punt & Kennedy, 1997; Zheng et al., 1995; 1998; Lai & Bradbury, 1998.

Method	Data requirement	Advantages	Disadvantages	References
Age structured methods				
VPA/cohort analysis/ separable VPA	Time series of catch at age data. Assumed M at age. Terminal population (or F) estimates for VPA/cohort analysis. Selection pattern assumed fixed in separable VPA.	Age and time structured estimates of numbers and fishing mortality. Convergence of results if F is high relative to M. Provides the basis for evaluation of management and technical measures.	High data requirement. Catch at age data assumed exact. Assumptions regarding M and terminal numbers may not apply.	Gulland, 1965; Pope, 1972; 1977; 1979; Pope & Shepherd, 1982; 1985; Shepherd & Stevens, 1983; Hilborn & Walters, 1992; Darby & Flatman, 1994; Quinn and Deriso, 1999.
Tuned VPA (ADAPT, ICA, XSA)	Age structured time series of catch and abundance indices (aggregated abundance index may be used by ICA). Assumed values for M at age.	Advantages of VPA plus able to include extra data. Explicit age structured models for many variables. Able to weight and smooth variables.	Many assumptions, high data and technical knowledge requirement. Complexity may mask the assessment drivers.	Parrick, 1985; Gudmundsson, 1986; Gavaris, 1988; Conser & Powers, 1989; Shepherd, 1992; Conser, 1993; Darby & Flatman, 1994; Patterson & Melvin, 1996; Patterson, 1999.
Statistical catch at age analysis	Age structured time series of catch and abundance indices. Assumed M at age.	Age structured models and able to include extra data. Statistical consideration of error on variables.	Many assumptions, high data and technical knowledge requirement. Parameter confounding may occur if the data do not have contrast.	Doubleday, 1976; Paloheimo 1980; Fournier & Archibald, 1982; Deriso et al. 1985; Gudmundsson, 1986; 1994; Kimura, 1989; Methot, 1990; Hilborn & Walters, 1992; Quinn & Deriso, 1999.

Appendix 2. Some examples of the application of stock assessment methods to crustacean (or other shellfish) stocks

Type	Method	Authors	Genus
Surplus production models	Surplus production	Morgan, 1979; Saila et al., 1979;Yoshimoto & Clarke, 1993; ICES, 1998; Breen & Kendrick, 1998; Cadrin, 2000.	Panulirus, Cancer, Homarus, Jasus, Pandalus
Surplus production models	Extended surplus production	Steffanson et al. 1994.	Pandalus
Delay difference models	Delay difference models	Fogarty & Murawski, 1986; Hall, 1997, Mogul & Lara, 1997; Fogarty, 1998	Jasus, Homarus, Panulirus
Open system depletion models	Catch survey (C-S) analysis (CSA)	Conser, 1991; Kruse & Collie, 1991; Collie & Kruse, 1998; Conser & Idoine, 1992. Moriyasu et al. 1998. Cadrin, 2000	Homarus, Paralithodes, Chionoecetes, Pandalus
Closed depletion models	Leslie & Davis, DeLury, Index removal (IR)	Morgan, 1974; Morrissy, 1975; Dawe et al. 1993; Chen et al. 1998; Frusher et al. 1998.	Palinurus, Cherax, Chionoecetes, Jasus
Closed depletion models	Change in ratio (CIR)	Dawe et al. 1993; Chen et al. 1998; Frusher et al. 1998; Bishop et al. 2000; Comeau & Mallet, 2001	Chionoecetes, Jasus, Pandalus, Homarus
Equilibrium length based methods	LCA/LVPA	Addison, 1986; Bannister & Addison, 1986; Addison & Bennett, 1992. Garcia-Rodriguez & Esteban, 1999; ICES, 2001a	Homarus, Cancer, Aristeus, Nephrops
Yield per recruit analysis	Length based YPR	Addison, 1986; Bannister & Addison, 1986; Fogarty & Idoine, 1988; Addison & Bennett, 1992; Spedicato et al. 1995; Hobday & Ryan, 1997; Mohan 1997.	Homarus, Cancer, Aristeus, Jasus, Panulirus
Yield per recruit analysis	Stage based YPR	(Fogarty & Murawski, 1986.)	(Spisula)
Dynamic size based methods	Dynamic length based	Bergh & Johnston, 1992; Starr et al. 1997; Punt & Kennedy, 1997; Zheng et al. 1995; 1998; (Lai & Bradbury, 1998)	Jasus, Paralithodes, Chionoecetes, (Strongylocentrotus)
Age based methods	XSA	ICES, 2001a; ICES, 2001b.	Nephrops, Pandalus
Age based methods	VPA, Separable VPA	ICES, 2001a.	Nephrops

Assessment methods for Crustacean fisheries in the Mediterranean

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Crustacean fisheries

The capture fisheries production in the Mediterranean in 1999 was mainly composed of the following crustacean species (FISHSTAT, 2000): Aristeid or red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*), the caramote prawn (*Penaeus kerathurus*), the deepwater rose shrimp (*Parapenaeus longirostris*), the Norway lobster (*Nephrops norvegicus*) and the spot-tail mantis shrimp (*Squilla mantis*), Table 1. Other decapod species are also landed in Mediterranean ports, often as mixed-species crates, such as "shrimps" (Natantian in Table 1) or "crabs" (mainly portunid crabs, Table 1). The total fish catch was 1,536,388 t, according to FAO sources (FISHSTAT, 2000) and crustaceans made *ca.* 3% of the total catch (10% of the demersal catch). However, their relative economic importance is higher, due to the important unit price fetched by crustaceans in local markets.

The Mediterranean fisheries are characterized, in general, by fragmented fleets, usually composed of relatively small vessels, with a large number of landing sites, having multi-species catches and low CPUEs, compared to Atlantic fisheries (Lleonart & Maynou, 2003). Fish are commercialized mainly fresh and the prices are relatively high, especially for crustacean decapods, such as shrimps and lobsters. Furthermore, no TACs or adaptive management schemes are in place at present, so there little pressure on the administrations to routinely monitor landings or assess fisheries in order to manage the fisheries.

Many different fishing gears exploit the crustacean resources in the Mediterranean. Trawling is the most important fishing gear in terms of catch and fleet power, but the so-called artisanal gears are also important for some species: trammel nets, gillnet, and a number of different traps and drags. In almost all cases the exploitation consists in multi-species catches (Lleonart, 2002).

Data and assessments:

The factors discussed above make it difficult and expensive to get extensive and reliable data time series or to obtain adequate samples for routine stock assessment, although the knowledge on the biology of most commercial species is reasonably good. Specific studies on recruitment are lacking for most species (Lleonart & Maynou, 2003).

On the other hand the continental shelf is narrow (with some exceptions) and there are few stocks shared between two or more countries. As a consequence, the international management structures have not been sufficiently enforced, and, until recently, no regular assessments were made by international working groups (Lleonart & Maynou, 2003).

This has led to the current situation, where most of the assessments have been done in the framework of scientific projects, and, hence, these assessments do not have continuity along time (Lleonart & Maynou, 2003). The assessments of crustacean resources until now have largely been based on analytic (mostly length based) methods, bottom-trawl surveys, production modelling (almost abandoned nowadays), GLM and time series analyses.

Since 1999, some assessments on stocks of Norway lobster and red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*) have been presented to Scientific Advisory Committee (SAC) of the General Fisheries Council for the Mediterranean (GFCM) .
The output of the stock assessment should provide some parameters that can be related to reference points. Estimations of fishing mortality and stock biomass are particularly useful in this context (Lleonart, 2002). Most stock assessments performed on the main crustacean

species (Norway lobster and red shrimps) point to these resources being fully- or over-exploited, although the actual situation varies strongly across geographical areas.

On the other hand, a fishery is a complex system and it cannot be completely described in a simple form. A stock assessment method is a way to see a piece of this system from a very particular point of view, hence a perfect image cannot be obtained from only one method. Different methods are complementary and it is recommended to use several of them whenever possible (Lleonart, 2002). Likewise, considering the complexity and high degree of uncertainty of exploited ecosystems, it is recommended to use complementary --even redundant-- management measures (Anon., 2002) as a safeguard against the limited knowledge we have on these systems, based on the Precautionary Principle.

A classification with definitions, taken from Lleonart (2002) of assessment methods is:

Indirect assessment methods. According to the GFCM glossary the indirect methods are “Methods for stock assessment based on fishery-dependent data, such as catch and effort statistics and age structure of the catch”. Usually the methods based on mathematical models of population dynamics are included in this heading. There are several manuals of population dynamics: Cadima (2000), Csirke (1980), Guerra. & Sánchez Lizaso (1998), Hilborn & Walters (1992), Lassen & Medley (2001), Laurec & Le Guen (1981), Ricker (1975), Rothschild (1986) and Sparre et al. (1989).

Direct assessment methods. According to the GFCM glossary the indirect methods are “Fishery independent methods used in order to avoid the biases of commercial catch data by using research surveys. They are traditionally used for estimating abundance, demographic structure at sea, as well as for the collection of other biological information”. Assessments based on surveys give biomass, or densities, of fish present in a particular area, during the survey period. The availability of several years of surveys carried out with the same methodology allows for the computation of biomass trends. Foote (1996) and Gunderson (1993) present studies of surveys used in assessment.

Statistical methods. We include under this heading the analytical procedures based on the use of statistical methods such as GLM or time series analysis. They share with the direct methods the absence of any underlying mathematical model of the demographic structure, but according the definitions above it can not be included as direct because the input data can arise from commercial as well as survey sources.

Analytic versus **global assessment methods**. The indirect methods are analytic when the population structure is modelled by age or length. An indirect method is global when a model is used to simulate the whole stock without any internal structure ("black-box"). However for some models this distinction is not so clear-cut.

In recent years, the classical assessment methods have been expanded in different directions. Naturally, the following two approaches go beyond the strict framework of crustacean fisheries, but will need to be considered for fisheries where crustaceans are the main objective (e.g. the deep-sea fishery on red shrimps in the Mediterranean):

Ecological approach: The multi-species, ecological, simulation, analysis of environmental effects, and other methods that go beyond the single-species models.

Bio-economic approach. The development of models including both, the biology of stocks and the economics of the fisheries is a developing field and it is starting to be applied to Mediterranean fisheries.

A hierarchical classification of assessment methods is:

1 Indirect
    1.1 Analytical
        1.1.1 VPA, LCA, Y/R, S_R relationship
        1.1.2 LCA
        1.1.3 Y/R
        1.1.4 Stock-recruitment relationship
    1.2 Global or production model
2 Surveys
    2.1 Bottom trawl survey
    2.2 Echo survey (not analysed in this paper)
    2.3 Egg Production Methods
    2.4 Direct counts (not analysed in this paper)
        2.4.1 Aerial
        2.4.2 Underwater
3 Marking (not analysed in this paper)
4 Statistical methods
    4.1 Time series analysis
    4.2 GLM
5 Ecological approaches
6 Bio-economic approaches

Echo surveys, direct counts (aerial or underwater) and marking methods are not analysed in this paper because they are not applicable to crustaceans (e.g. aerial counts) or have not been applied to Mediterranean crustaceans.

Table 1. Landings of crustacean species in the Mediterranean in 1999 (according to FAO sources, FISHSTAT, 2000)

Species	**landings (t)**
Aristeid shrimps	4,757
Caramote prawn	5,947
Deepwater rose prawn	9,291
Norway lobster	4,068
Spot-tail mantis shrimp	6,019
Natantian	10,638
Crabs	4,431

ANNEX: Stock assessment methods

Method	**VPA (Virtual Population Analysis). Also called Cohort Analysis (particularly when the Pope's approach is used)**
Description	From catch data and some parameters, VPA reconstructs the past history of the stock in terms of number of individuals and fishing mortality. The VPA, and its variants are the most standard and reliable method of stock assessment.
Variants	The basis of the VPA is the catch equation. This equation does not have analytical solution, and algorithms of approximate solution (like Newton-Raphson). Pope (1972) developed an approach where, with a small bias, the catch equation can be solved analytically: this approach is usually known as Cohort analysis. Since VPA is the fundamental method for stock assessment many variants have been developed. The most important are: Separable VPA (Pope & Shepherd, 1982) which allows to split up the fishing mortality into two factors: a year component (related to the effort) and an age component (related to the selectivity pattern). XSA (eXtended Survivors Analysis: Darby & Flatman, 1994; Shepherd, 1999) and ADAPT (Gavaris, 1988; Lassen & Medley, 2001) that incorporate external information (biomass indices, CPUE from commercial catches or from trawl surveys) in order to tune the VPA.
Data needs	Catch-at-age of several years by operational unit, implying previous age estimations and length composition of catches M vector Terminals Fs (this imply tuning, through surveys or CPUEs) Length-weight relationship (if biomass are wanted in the output) Total catch in biomass by Operational Unit (OU) and year
Outputs expected	Numbers of individuals and biomass at sea by year and age (thus series of recruitment, total biomass at sea, etc.) Fishing mortality by year, age and operational unit
Pros	The most efficient standard assessment method
Cons	Many parameters are needed, some of them assumed (M). Tuning is required. It is difficult to get a general view of the resource.
Suitability to Mediterranean stocks and fisheries	Data series and parameter estimations to run a reliable VPA are available for few Mediterranean fisheries, but steps in this direction are being taken by different Mediterranean governments and intergovernmental organisations and the general application of VPA can be foreseen in the near future. Software: Mesnil (1989), Darby & Flatman (1994), Lassen & Medley (2001)
Applications to Mediterranean crustacean fisheries	Demestre & Lleonart (1993) applied VPA to *Aristeus antennatus* in the Catalan sea. They concluded that the stock is under- to fully-exploited (specially females). GFCM (2002) reported a state of overxploitation of the stocks in Spanish Mediterranean waters.
Method	**LCA (length cohort analysis)**
Description	A modification of VPA (Jones, 1984). Essentially is a VPA on a pseudocohort that can be run also on length frequency distribution of the catch. Steady state is assumed
Data needs	A length or age frequency distribution of the catch. M vector Terminal Fs (this imply tuning, through surveys or CPUEs) Length-weight relationship (if biomasses are wanted in the output) Total catch in biomass by OU
Outputs expected	Numbers of individuals and biomass at sea by age (thus series of recruitment, total biomass at sea, etc.) Fishing mortality by age and OU
Pros	With short data series (even one year) something can be said about the stock
Cons	Since the steady state is assumed, important biases can be obtained if this hypothesis is far from reality. Hilborn and Walters (1992) expressed a sharp criticism of this methed.
Suitability to Mediterranean stocks and	It has been extensively used in the Mediterranean fisheries because the problems in applying the VPA due to the generalised lack of long historical series. Mesnil (1989) and Lleonart & Salat (1997) have provided software for this analysis.

fisheries	
Applications to Mediterranean crustacean fisheries	Demestre & Lleonart (1993) applied LCA to *Aristeus antennatus* in the Catalan sea. They concluded that the stock is under- to fully-exploited (specially females). Sardà & Lleonart (1993) applied this method to a stock of *Nephrops norvegicus* in the Catalan sea and reported that the stock is fully-exploited.
Method	**Y/R**
Description	Computes the yield that produces one recruit given particular exploitation pattern (F vector) and effort level.
Data needs	Fishing mortality vector (F) Natural mortality vector (M) Age-length key or parameters of the growth model
Outputs expected	Equilibrium yield surface as function of overall F (or effort) and exploitation pattern (selectivity). Y_{max}, F_{max} and virgin biomass.
Pros	The output is very synthetic and gives a general overview of the state of the fishery. It is easy to put the results with relation to reference points (maxima, current stock *vs.* virgin stock, etc.). It is easy to detect growth overfishing and obtain the clues of management possibilities.
Cons	Assumes the steady state.
Suitability to Mediterranean stocks and fisheries	Very useful and applicable to the Mediterranean when combined with other analytical method providing the required data. It has been extensively applied to the Mediterranean fisheries using as input the output of LCA. The method developed by Thompson & Bell (1934) is an instance of this approach (Sanders, 1995).
Applications to Mediterranean crustacean fisheries	Yahiaoui et al. (1986) applied Y/R to stocks of *Aristeus antennatus* and *Parapenaeus longirostris* in the Gulf of Lions and concluded that both species are fully-exploited. Demestre & Lleonart (1993) and Sardà & Lleonart (1993) applied Y/R to stocks of *A. antennatus* and *Nephrops norvegicus* (coupled with VPA and LCA) in the Catalan sea. They showed that both stocks are fully- to over-exploited and steps should be taken to reduce fishing effort in this area. Spedicato et al. (1995) and Colloca et al. (1998) conducted a similar analysis to a stock of *A. antennatus* in the Central Tyrrhenian sea and concluded that the stock is fully-exploited. Recommendations towards improving the selectivity patterns, by reducing mesh size, were made. Ragonese and Bianchini (1996) applied Y/R to a stock of *A. antennatus* in the Straits of Sicily and found that the stock is fully-exploited, but improving the selectivity pattern would result in increased economic yield over the short term. Ben Meriem (1998) applied this methodology to *Penaeus kerathurus* in the Gulf of Gabès (Tunisia) and found that the stock is at an optimum level of exploitation. The GFCM (2002) reported a Y/R conducted on *Aristaeomorpha foliacea* and concluded that it is optimally exploited in Sardinian waters. Fiorentino et al. (1998) compared several assessments performed on *A. antennatus* stocks and pointed out the sensitivity of the Y/R method to the assumptions made on M.

Method	Stock-recruitment relationship
Description	It is properly not an assessment method, but an approach to understanding the factors driving the recruitment process, which is of fundamental importance in stock assessment.
Data needs	Historical time series of spawning stock and recruitment
Outputs expected	There are several stock-recruitment models (Beverton and Holt, Ricker, and generalisations thereof), but a simple examination of the stock-recruitment scatter plot helps understand the past history of the stock
Pros	It is the only way of detecting recruitment overfishing.
Cons	Inputs are difficult to obtain, can present important biases and is difficult to separate environmental factors from noise.
Suitability to Mediterranean stocks and fisheries	Good estimators during many years are required, which are difficult to obtain for Mediterranean fisheries. No application known for Mediterranean crustacean species.
Method	**Production model (also known as global model, surplus production model or catch-effort model)**
Description	Method of estimating the past and current levels of biomass and the state of the stock, from the analysis of the relationships between catch and effort. It is based on a population growth equation, the relationship $F=q \cdot E$ and the catch equation $C=F \cdot \bar{B}$
Variants	The fundamental approach is Schaeffer's model which is based on Verhulst's population growth equation. The Fox's approach uses a logarithmic population growth equation and the Pella & Tomlinson's approach uses a generalized growth equation. There are several dynamic (non-equilibrium) models. The composite production model is a modification by substituting time in the data series for different areas, supposed to be in different levels of steady state. Assumes equilibrium.
Data needs	Historical series of catch-effort data (usually on an annual basis) of each species.
Method	It is based on a regression procedure. Although it is very easy to fit the model in equilibrium, this procedure is incorrect. The dynamic approach, although more difficult is more appropriate.
Outputs expected	The three parameters of the production model are obtained: Carrying capacity (equivalent to Virgin Biomass), catchability and growth rate. These three parameters allow drawing the equilibrium curve in the catch-effort plane. If the observed path of the fishery are also drawn in the same graph, a very general and useful view of the fishery's history is obtained. MSY and E_{MSY}
Pros	Gives a very general view of the current state of the fishery and its history. Easy to put in relation to reference points.
Cons	Inapplicable in multispecies fisheries, mainly due to the difficulties of effort allocation. Not suitable when there are clear changes of catchability (although this parameter can also be modelled) or changes in selectivity. The only control parameter is the effort.
Suitability to Mediterranean stocks and fisheries	Not very much adequate to Mediterranean fisheries because of the multi-species character of these fisheries, the lack of long data series, catchability modifications, etc. Available software (based on the dynamic approach): Fréon et al. (1993), Punt & Hilborn (1996).
Applications to Mediterranean crustacean fisheries	Cirugeda-Delgado et al. (1976) applied Fox's and Schaefer's production models to *Aristeus antennatus* in the Balearic islands and concluded that the stock was over-exploited.

Method	Generalised Linear Model (GLM)
Description	An expansion of multiple regression. It attempts to explain a dependent variable (not necessarily normally-distributed) from a set of independent variables, quantitative as well as categorical. It can include interactions among independent variables.
Data needs	Any kind of multivariate data set in which one variable can be considered a dependent of the others. Data series: usually catch, cpue, effort, data on vessel characteristics, environmental, etc.
Outputs expected	It is possible to relate the dependent variable to the independent variables, as effects of environment, or fishing power as function of the vessel characteristics. Useful for vessel standardisation.
Pros	Absence of underlying hypothesis has both pros and cons. It has no constraints from limiting hypothesis. Useful to understand the relationships between fisheries variables (mainly catch and cpue) and environmental or technical variables.
Cons	It is difficult to accept predictions or any other extrapolation.
Applications to Mediterranean crustacean fisheries	Maynou et al. (2002, in press) analysed the *Aristeus antennatus* and *Nephrops norvegicus* fisheries off Barcelona. A GLM model accounted for *ca.* 52% of the cpue variability in the *A. antennatus* fishery, and the main factors affecting fish production in this species were seasonal and inter-annual variability, and vessel efficiency. The GLM model for *N. norvegicus* did not account for more than 13% of the cpue variability, probably because this species appears in a multi-species fisheries, while *A. antennatus* is the primary target of an almost single-species fishery.
Method	**Time series analysis**
Description	The standard ARIMA method is the analysis of a time series, which is split off into trend (including possible cycles), seasonality and noise. Some further developments, such as transfer functions, allow to associate these outputs with environmental or other external variables, or intervention analysis to detect anomalous events (Rotschild et al., 1996).
Data needs	Series of data, usually catch, cpue, effort, data on vessel characteristics, environmental, etc.
Outputs expected	Most frequently the trend and seasonality of the variable analysed are obtained. When additional information (i.e. environmental) are added it is possible to relate the variable behaviour to it variables, as effects of environment. Short-term forecasting.
Pros	Absence of underlying hypothesis has both pros and cons. It is a powerful method to reveal hidden structures in the data. Useful for short-term forecasting, with due caution in its interpretation.
Cons	Mainly descriptive.
Suitability to Mediterranean stocks and fisheries	Any good temporal series is suitable to be studied by this procedure. Applications to specific crustacean stocks are lacking in the Mediterranean, but Stergiou & Christou, (1996), Stergiou et *al*., (1997) and Lloret et *al*., (2000; 2001) included the analysis of some crustacean data series in their works on multi-species Mediterranean fisheries.
Method	**Bottom trawl survey**
Description	Estimation of abundance or indices of abundance (cpue, biomass and density) of demersal species using research vessels (regardless of the commercial nature of the vessel or the gear). The swept area method or geostatistical techniques (*kriging*) can be used to compute biomass and densities (Sparre et al., 1989; Rivoirard et al., 2000).
Data needs	Detailed knowledge of the nature (topography, kind of bottom) of the area under study. Well-calibrated sampler (bottom trawl). The efficiency of the trawl must be estimated. Trawl width and door spread must be also known, and are usually measured with remote acoustic devices (i.e., SCANMAR, Foote, 1996). A very detailed sampling strategy is required, allocating trawl samples using one of several methods available from sampling theory (stratified random sampling, etc., Foote, 1996).
Outputs expected	Relative indices of abundance, or absolute indices if trawl performance can be quantified. Biomass, density of cpue estimates by species and area. Spatial distribution of species and species assemblages. Like any other survey, the temporal series including some years gives an added value to them and allows to estimate trends.

Pros	The sampling procedure is under control. The data obtained are reliable and independent of that of commercial catch.
Cons	Representativity of sampling (Foote, 1996). The sampler (trawl) is selective so its product may not represent the exploited stocks (i.e., stocks exploited with long-lines, although this is clearly less relevant for crustaceans). Sampling is only possible on soft grounds.
Suitability to Mediterranean stocks and fisheries	Bottom trawl surveys has been used in the Mediterranean for long time, specially in Italy (Ardizzone & Corsi [eds.], 1997) From 1994 the project MEDITS has shown its suitability to the Mediterranean grounds and fisheries (Bertrand & Relini, 1998; Bertrand et *al*., 1998; Abella et *al*., 1999; Abelló et al. [eds.], 2002).
Applications to Mediterranean crustacean fisheries	Four crustacean species are considered target species of the MEDITS bottom trawl surveys: *Aristeus antennatus*, *Aristaeomorpha foliacea*, *Parapenaeus longirostris* and *Nephrops norvegicus*. The analysis of the 1994-1999 time series of abundance (kg/km^2) showed considerable variability among *reference areas* in the four species (Cau et al., 2002; Abelló et al. 2002), related to depth stratum and different fishing patterns in each reference area. A stock assessment of *N. norvegicus* by geostatistics was performed by Maynou et al. (1998)
Method	**Egg Production Methods**
Description	Spawning stock biomass evaluation from the quantity of eggs present in the sea. Particularly applicable to small pelagics.
Data needs	Sex ratio Weight of mature females Fecundity (and batch fecundity) of females Area of distribution and area of spawning Egg production at sea (by means of plankton sampling cruises in the appropriate areas and periods)
Outputs expected	Biomass of the spawning stock Egg mortality
Pros	Very efficient for small pelagics.
Cons	Delimiting the spawning area Ageing the eggs Estimating egg mortality
Suitability to Mediterranean stocks and fisheries	Appropriate sampling of eggs and larvae of the most important crustacean species in the Mediterranean is lacking, hence there are no data sets available.
Method	**Ecological approaches**
Description	Several approaches can be included under this heading: 1. Multi-species modelling (Rose et al., 1996): Some approaches are direct extensions of the indirect (population dynamics) assessment methods taking into account the biological interaction among species (technical, or technological interaction[1] can be studied by the classical methods). Multi-species VPA (MSVPA: Sparre, 1991; Magnússon, 1995) belong to this group. Other recent developments is the individual-based approach (IBM: De Angelis & Gross [eds.], 1992). 2. Ecological modelling of mass balance and food webs (Pauly et al., 2000)
Data needs	In addition to the single species analysis data needs, it requires the interaction factors, particularly the quantification of the predator-prey relationships.
Outputs expected	Quantified pathways of matter and energy between the different species (in steady state).
Pros	It approaches much better the real ecosystem than the single species does.

[1] According to the GFCM glossary a technological interaction is "An interaction between fisheries resulting from the impact of one fishery using a particular technology on another fishery, usually using a different technology but exploiting the same resources as target or bycatch. Because of their importance the cross-impact of various fleets targeting overlapping species groups must be assessed. Major source of failure in TACs and quotas management strategies for multispecies and multigear fisheries"

Cons	Large amounts of biological information are needed. The number of interaction parameters to be estimated grow with the square of species considered (hence the unknowns become more numerous than the equations)
Suitability to Mediterranean stocks and fisheries	For the moment is difficult to obtain the input data suitable for these models. However there are some scientific teams trying to develop projects in this direction. In any case, these developments are not specific to crustacean fisheries.
Method	**Bio-economic models**
Description	Bio-economic models include the population dynamics and the economic structure of fisheries. There are two main types of bio-economic models: Simulation and Optimisation techniques
Data needs	All parameters required for the analysis of population dynamics Economic parameters considering all aspects of extractive activities and commercialisation (cost structure, revenues)
Outputs expected	Depending on the type of methodology used, we can obtain a projection to the future of different variables (biomass, catch, costs, etc) and trends at short and medium terms, for the simulation approach, or optimum (biological, social or economic) points of the fishery, according to specified criteria, for the optimisation approach.
Pros	Since economics is an important aspect driving the fishery, bio-economic modelling is much more realistic than the purely biological approach. Very useful to analyse and compare the possible results of alternative management measures at short and medium term.
Cons	Many parameters are needed, and the models are very complex. Large uncertainties in the projections, due to uncertainty in the processes modelled (e.g. the stock-recruitment relationship).
Suitability to Mediterranean stocks and fisheries	Fisheries management in the Mediterranean is based on economic rather than on biological or technical measures (unlike the Atlantic where TACs are computed without economic considerations). Bio-economic fisheries modelling is particularly suitable to the Mediterranean fisheries reality. There are some models (and software) available: Sparre & Willmann (1993), Seijo et al. (1994, 1997), King (1995), Pascoe (1997) Ulrich et al. (2001). Some bio-economic models are being developed for Mediterranean fisheries (Lleonart et *al*., 1996; Placenti & Rizzo, 1998; Franquesa & Lleonart [eds.], 2001; Lleonart et *al*., 2003) In any case, these developments are not specific to crustacean fisheries.

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Technical Description of Stock Assessment Methods Applicable to Crustaceans

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Population Dynamics

Title:	Length Frequency Distribution (LFD)
Main Reference(s):	Gulland and Rosenberg, 1992; Gayanilo and Pauly, 1997
Short Description:	This is the initial step in population dynamics analysis and the main output is the organization of raw data in length classes.
Main Data Requirements:	Length of individuals in tabular format. A simple method of analysis is the use of standard spreadsheet software for office use.
Data Quality and Details:	The quality of analysis depends on many parameters related to the sampling design and sampling performance. The quality of sampling should be as high as possible, since any possible problem will be transferred to the subsequent steps of stock assessment analysis resulting to at least erroneous assumptions. There are 4 basic characteristics in the sampling design that should be taken into consideration: 1. Randomness of samples: in general, the samples must be random which means that all individuals in a certain stock have exactly the same probability of capture with the selected gear or gears. This is extremely difficult, however, since most of fisheries studies are based on a single gear which has a certain selectivity. On the other hand, the term 'randomness' indicates that all the individuals should be equally treated in all cases (different strata, depths, seasons, geographic locations, fleet segments etc.). 2. Bias: the randomness is clearly connected to the bias of the sampling. Bias, in general, can be considered as the establishment of a certain tendency during sampling. A most clear example is the tendency to select only the big sized individuals from the onboard catch. The selection should be random so that bias is reduced to a minimum. In addition to this kind of bias, there is bias originating from the stock itself. Biased samples can be obtained, for example, due to migration of the stock. 3. Accuracy or Precision: the measurement should be as accurate as possible. Therefore, the selection of a suitable measuring device should be made beforehand. The accuracy of measurements balances between the need of increased accuracy in the sampling measurements and the complication of the measurement procedure which should be kept to a minimum so that the worker will not tend to increase his bias. 4. Repeatability: repeatability of the measurement is the capacity of the measuring method to provide the same result over the same measure when performed more than once under the same conditions. Repeatability is usually reduced when high accuracy methods are used.
A table showing the conditions under which a certain accuracy or precision is selected is the	

following (Gulland and Rosenberg, 1992):

Precision	Condition
0.5 cm	size >15 cm for >95% of the cases
0.25 cm	size >10 cm for >95% of the cases
0.15 cm	size >5 cm for >95% of the cases

Generally, optimum length frequency histograms are composed of a number of length classes, usually anything between 20 and 40 classes and depending on the length range of the species. Class interval of 1 mm is commonly used in decapods. The following empirical rule of thumb could be used as well:

Class interval = 0.1x L_{max} / number of length classes

Title:	Growth functions
Main Reference(s):	Bertalanffy, 1934; Bhattacharya, 1967; Hasselblad, 1966; Ricker, 1975
Short Description:	The estimation of the statistical parameters of the relationship between the length classes and the corresponding age-at-length. The main output are the relationships of von Bertalanffy, the Gompertz and the Logistic growth equations. The general profile of those equations is sigmoidal. The form of the above equations is the following: $L_t = a_1 \cdot (1 - e^{-K(t-t_o)}),$ $L = a_2 \cdot e^{-e^{(b_2 - c_2 Age)}},$ $L = \frac{a_3}{1 + b_3 e^{-c_3 \cdot Age}}$
Main Data Requirements:	The data required to obtain the above equations is the age-length key obtained through the analysis of the length-frequency distributions using the Bhattacharya method or the Hasselblad NORMSEP method.
Data Quality and Details:	Finfish and many other species exhibit imprints of age on their body's hard structures such as bones, otoliths and scales. Such absence of age imprints on hard structures is the main characteristic of the decapod species (shrimps, lobsters and crabs). This main characteristic, gave rise to the length-based assessment theory in order to by-pass the problem of age readings in such species and still conform to the main rule of age composition identification for a given stock. Length-based methods can be, practically, considered as the intermediate step between age identification of a stock and the elaboration of its age composition. Length-based methods have the main advantage that the required data are quick and easy to obtain. There are also several disadvantages to these methods and mainly the fact that the data collection and sampling methodology should be extremely carefully designed and they often, have bias with uncertain origin. At the same time, age determination is not an easy task due to readability problems.

	The assignment of age to each length-class obtained from the LFD can be accomplished with various techniques. However, it must be noted that in every case, the good knowledge of the stock and experience are the key factors to success. Obviously, in order to obtain the correct growth equations, the correct age-key should be elaborated. The assignment is easy in the case of cultivated species, since the known growth rates in artificial rearing may help the organization of a age-key for the wild population. In addition, the use of lipofuscin pigment measurement in the nervous tissue of the decapod may help this task as well, if there has been such a study on the same species before.

Title:	Mortality and exploitation empirical functions
Main Reference(s):	Beverton and Holt, 1956; Hoenig, 1982; Hoenig and Lawing, 1982; Ault and Erhardt, 1991; Pauly, 1980; Rikhter and Efanov, 1976
Short Description:	Use of empirical equations and functions in order to estimate the values of total, natural and fishing mortality as well as the exploitation ratio. The main form of these empirical models are: ***<u>Total Mortality (Z)</u>***: Beverton-Holt model: $Z = K \cdot \left(\frac{L_\infty - \bar{L}}{\bar{L} - L'} \right)$ $ln(Z)=1.23-0.832 \cdot ln(t_{max})$ The Hoenig models: $Z=\frac{1}{c_1 \cdot (t_{max}-t_c)} \pm \sqrt{c_2 \cdot Z^2}$ The Ault-Erhardt model: $\left(\frac{L_\infty - L_{max}}{L_\infty - L'} \right)^{\frac{Z}{K}} = \frac{Z \cdot (L' - \bar{L}) + L \cdot (L_\infty - \bar{L})}{Z \cdot (L_{max} - \bar{L}) + K \cdot (L_\infty - \bar{L})}$ ***<u>Natural Mortality (M)</u>***: The Pauly formula: $ln M = -0.0152 - 0.279 \cdot ln L_\infty + 0.6543 \cdot ln K + 0.663 \cdot ln T$ The Rikhter and Efanov model: $M=\left(\frac{1.521}{[age\text{-}at\text{-}maturity_{50\%}]^{0.720}} \right)-0.155$ ***<u>Fishing Mortality (F)</u>***: F = Z – M ***<u>Exploitation Ratio (E)</u>***:

	E = F / Z
Main Data Requirements:	According to the above mathematical functions, the data needed are the following: • $\overline{L}$, the mean total length of all shrimps above L' • L', the length above which all shrimps are under full exploitation and which practically is equal to the total length of the smaller shrimp in all samples • t_{max}, maximum age in years or longevity or life span • L_{max}, the total length of the largest shrimp in the samples • T, the average temperature (annual mean)
Data Quality and Details:	One important issue is that if there has never been any assessment of a given stock, there are no previous estimates of mortality to compare with. In addition, if other historical information do not exist (for example, CPUE) the true mortality levels cannot be clearly established. An initial step, therefore, would be the use all available models to estimate M and Z, and then compare them with other values in the literature and attempt to propose a suitable value for the particular stock. The length frequency distribution of the studied population should be complete with sufficient frequencies to cover all the expected age groups. In the case of discrete recruitment the bias involved in using the abovementioned methods, and mostly the equation for mean length, can be very high. In this respect, Hoenig proposed an alternative equation that considers the recruitment as discrete phenomenon during the year. This equation requires as input the Von Bertalanffy growth parameters, the smallest length of individuals that are fully represented in catch samples (L') and the mean length in the catch with lengths higher than L'. The combination of these above approaches and mainly the Hoenig equations and the length-converted catch curves are expected to provide the best estimates of Z. However, most decapod species are under overfishing regime and most age groups close to maximum age are lost. Therefore, it is expected that the length-converted catch curve may produce overestimated Z values. Natural mortality rate (M) is generally estimated indirectly using empirical regressions which relate M to life history parameters, such as Von Bertalanffy growth parameters, maximum observed age and age at first maturation. Although some of these methods are widely used, they are considered as "guesstimates" since they have strong limitations or disadvantages. Natural mortality rate can be also estimated from catch-curve when there is no commercial fishing in the study area or the species of concern does dot undertake migrations and displacements into areas where commercial fishing occurs because in those cases F=0 and Z=M. The best estimates of M may be derived by tag-recapture information with high accuracy. However, there are also examples that even this direct method produces questionable results.

	Scientists working on *Penaeids* using this method in the Gulf of Mexico estimated values of M ranging between 1 and 28 $year^{-1}$ and noted that the higher mortality are most likely in error. The main issue in the estimation of M is that there are a few methods available. If the composition of the length-frequency distribution is considered, the Pauly formula should provide with overestimated values of M. The reason for this is the following: the $L\infty$ and the average temperature can be easily estimated by direct measures from the analysis of samples (von Bertalanffy analysis for $L\infty$ or even the literature for $L\infty$ if the samples are not complete). In the cases, however, that all age classes are not represented in the initial length-frequency distribution, the K (growth coefficient) value is influenced by the young and faster-growing individuals, thus the values obtained are expected to be higher than when the K is derived by samples of the whole population. Growth rates of young individuals (and especially shrimps that have a longevity of 2-3 years) are much higher than older individuals and therefore, K is overestimated. Since K is a positive component of the Pauly formula, the produced estimate of M should also be overestimated. Thus, an average value with the estimate from Rikhter-Efanov would reduce this bias significantly.

Title:	Total mortality (Z) catch curve methods
Main Reference:	van Sickle, 1977; Jones and van Zalinge, 1981
Short Description:	There are 2 basic methods for the estimation of Z from length-converted catch curves: the van Sickle method and the Jones-van Zalinge cumulative method. They are the common methods for Z estimation since they use directly the LFD profiles as main data input instead of estimates as the empirical equations for estimating mortality rates (see above). The general idea is to use the LFD keys to transform them to number of survivors and relate the results to their actual age. The main assumptions are: • Z is constant for every age group • The recruitment is constant or with insignificant fluctuations • All age groups are equally vulnerable to the gear • The sample covers all age groups and is random
Main Data Requirements:	The main data required for this analysis is the pooled LFD of all population and all samples for the period under considerations. This is considered as the catch curve.
Data Quality and Details:	The combination of these empirical methods and mainly the Hoenig equations with the results from the length-converted catch curves are expected to provide the best estimates of Z. However, most decapod species (especially *Penaeids*) are under overfishing regime and most age groups close to maximum age are lost. Therefore, it is expected that the length-converted catch curve may produce overestimated Z values.

	The pooling of the samples is particularly important in the cases of short-lived species such as many decapods. The pooling also helps to normalize the annual pulses of the populations due to recruitment or the case when one single sample is very large due to successful sampling and which will increase bias is used separately with the rest of the samples.

Title:	Size-at-maturity analysis
Main Reference(s):	
Short Description:	The methods aims to calculate the average total length (or carapace length) at which 50% of the population is mature or in other words, the age/length at first maturity. The method is based on the ratio of the mature (stage IV) females to the total number of females. The output is both the calculated length at maturity and the logistic (sigmoidal) equation which relates the mature and the total numbers of females. The relationship follows a logistic model of the form: $Stage\ IV\ (\%) = a + \frac{b}{1+\left(\frac{Length\ Class}{c}\right)^{-d}}$, where a, b, c, d: coefficients
Main Data Requirements:	The main data requirements are the length-frequency of the mature females alone and the length-frequency distribution of the total female population. The LFDs can be obtained from all samples pooled or from one sample alone at the highest gonad-somatic index month or season.
Data Quality and Details:	In several cases, some authors have used the pooled samples of females and mature females over the study period for this estimations. However, it is expected that the most accurate method is the selection of a certain sample close to or of the month when the highest gonad-somatic index appears. In some cases, the comparison of the results from the use of both data forms will help for a more accurate estimation of the length-at-maturity. Age-at-maturity can be estimated directly from the VBGF equation using the length-at-maturity.

Title:	Fecundity
Main Reference(s):	
Short Description:	This analysis is based on the estimation of the coefficients of the relationship between the number of eggs or oocytes and the total length or the carapace length of the individual. The form of the equation is simple and linear in raw or log format: *Number of eggs = a + b Length*
Main Data Requirements:	The main data requirements are the length and number of eggs or oocytes.
Data Quality and Details:	In decapods, there exist 2 types of reproduction processes: (a) with the release of fertilized eggs to the environment and (b) the attachment of fertilized eggs on the abdomen of the

	decapod. In the first case, fecundity is estimated based on the oocytes present in the gonad of the mature females while in the second, the measurement of the eggs masses attached to the abdomen of the individual. The sampling of zooplankton is also necessary, if possible, in order to examine the process of reproduction and estimate the mortalities associated for every stage (oocytes-fertilization-hatching-larva).

Title:	Gonad-Somatic Index (GSI)
Main Reference(s):	
Short Description:	The main goal is to estimate the gonad-somatic index for every sample (monthly, seasonal etc.) and construct the annual variation of GSI graph. The GSI is the percentage ratio between the gonad weight and the total length (or carapace length).
Main Data Requirements:	The data requirements are the gonad weight and length data pairs from the samples.
Data Quality and Details:	

Title:	Sex ratio analysis
Main Reference:	
Short Description:	The analysis is based on the per sample distribution of the ratio between males and females. This provides a good indication of the composition of the population per sample (season or location) and also provides good indications about the differential (if any) migration of males and females between locations.
Main Data Requirements:	The main requirement is the number of males and females per sample.
Data Quality and Details:	

Title:	Morphometry
Main Reference:	
Short Description:	Morphometrical analysis focuses on the estimation of the regression coefficients and the related statistics regarding the relationship between the various lengths and weights. The form of the relationships is linear in raw or log format (usually the latter). Carapace Height = a+b(Carapace or Total Length) Carapace Width = a+b(Carapace or Total Length) Abdomen Height = a+b(Carapace or Total Length) Abdomen Width = a+b(Carapace or Total Length) Rostrum Length = a+b(Carapace or Total Length) Carapace Length = a+b(Total Length) Total Length = a+b(Carapace Length) Abdomen Length = a+b(Carapace or Total Length) Telson Length = a+b(Carapace or Total Length) Total Weight = a*(Carapace or Total Length)^b
Main Data Requirements:	The data requirements are the weight-length or length-length data pairs from the samples.
Data Quality and Details:	The general approach assumed herein, is that the relationship

	between one-dimensional measurements (length vs. length) should exhibit a linear relationship (y=a+bx) while the relationship between a three dimensional parameter (weight) and a one-dimensional parameter (length) should follow the power model ($y=ax^b$). The value of the coefficient b will allow the determination of 'allometry' ($b \neq 3$) or 'isometry' (b close to 3 or 3).

Title:	Yields analyses
Main Reference:	Beverton and Holt, 1966; Pauly, 1984; Pauly and Soriano, 1986; Gulland, 1969
Short Description:	The main goal from the application of these models is to estimate the yields of a certain stock obtained from a given number of recruits and a given fishing regime. There are 2 basic methods for the yield per recruit and biomass per recruit analysis: (A) Yield per recruit (Y/R) and Biomass per Recruit (B/R) based on the relationship between the Y/R and B/R with the Exploitation Ratio (E=F/Z):

$$Y/R = \frac{F}{Z} \cdot \left[1 - \frac{L_c}{L_\infty}\right]^{\frac{M}{K}} \cdot \left[1 - \frac{3 \cdot \left(1 - \frac{L_c}{L_\infty}\right)}{1 + \frac{K}{Z}} + \frac{3 \cdot \left(1 - \frac{L_c}{L_\infty}\right)^2}{1 + 2 \cdot \frac{K}{Z}} - \frac{\left(1 - \frac{L_c}{L_\infty}\right)^3}{1 + 3 \cdot \frac{K}{Z}}\right]$$

and

$$B/R = \frac{\frac{F}{Z} \cdot \left[1 - \frac{L_c}{L_\infty}\right]^{\frac{M}{K}} \cdot \left[1 - \frac{3 \cdot \left(1 - \frac{L_c}{L_\infty}\right)}{1 + \frac{K}{Z}} + \frac{3 \cdot \left(1 - \frac{L_c}{L_\infty}\right)^2}{1 + 2 \cdot \frac{K}{Z}} - \frac{\left(1 - \frac{L_c}{L_\infty}\right)^3}{1 + 3 \cdot \frac{K}{Z}}\right]}{F}$$

(B) Y/R and B/R with fishing mortality (F):

$$Y/R = W_\infty \cdot e^{-M(t_c - t_r)} \cdot \left[\frac{1}{Z} - \frac{3 \cdot e^{-K(t_c - t_o)}}{Z + K} + \frac{3 \cdot \left[e^{-K(t_c - t_o)}\right]^2}{Z + 2K} - \frac{\left[e^{-K(t_c - t_o)}\right]^3}{Z + 3K}\right]$$

and

$$B/R = \left[W_\infty \cdot e^{-M(t_c - t_r)} \cdot \left[\frac{1}{Z} - \frac{3 \cdot e^{-K(t_c - t_o)}}{Z + K} + \frac{3 \cdot \left[e^{-K(t_c - t_o)}\right]^2}{Z + 2K} - \frac{\left[e^{-K(t_c - t_o)}\right]^3}{Z + 3K}\right]\right] \cdot F$$

Main Data Requirements:	The main data requirements as the above functions show are: • L_c the mean length at first capture, • $L\infty$, K, t_0, from VBGF equation • Z, F, M, the mortality indicators • t_c the mean age at first capture • t_r the mean age at recruitment (practically equal to the age

	at which the shrimps leave their planktonic phase and become benthic, ~ 3 months old) • W∞, is the maximum weight for L∞ (from the overall length/weight relationship)
Data Quality and Details:	The Yield per Recruit analysis is an essential management tool for managers and provides with basic reference points, which can be used to compare actual data on F (fishing mortality) and t_c (minimum age at catch). The importance of both parameters is that F is proportional to fishing effort and t_c is a function of gear selectivity. If there are no historical data on the population studied to compare the results with, there are a number of assumptions and considerations set in order to provide some basic results and information on the state of these populations. The application of the Y/R model provides with a relationship between Y/R and Biomass/R in relation to F. The curve usually exhibits a maximum point which is considered as the maximum yield per recruit (Y/R_{MAX}) and the corresponding F value which is considered as the optimum fishing mortality, F_{MAX}. Earlier documents of stock assessment models have clearly linked the Y/R_{MAX} obtained from the curves with the Maximum Sustainable Yield (MSY). For shrimps in particular, it has been stated that the only magnitude, which corresponds to the letter of the term “Maximum Sustainable Yield” is the quantity that would be caught whatever the inter-annual variations in biomass and thus, it is the lowest predictable production on average. In practice, however, this implies poor use of the good production years but for species with very short life-spans with variable and unpredictable production, the Y/R technique could be the only feasible one. Furthermore, when the annual variations in production seem to mask possible connections with parental stock, it is enough to keep F at the level which is considered as optimum on the yield per recruit curve. The last 20 years, the above statements do not seem to have changed significantly and thus, one can assume that the results from Y/R analysis could be connected with Maximum Sustainable Yield reference points and thus F_{MAX}=F_{MSY} and Y/R_{MAX}=MSY. There have been numerous cases – mainly in fish stock management – for which when the above considerations were followed, the stocks collapsed. Further calculations lead to the result that F_{MSY} is much lower than F_{MAX} from the Y/R curves, which led to uncertainty concerning the applicability of the Y/R results for management purposes. This is owed to the fact that F_{MAX} does not account for the fact that recruitment must decline at some point for low spawning stock sizes as well as because in many cases the relationship between Y/R is asymptotic and F_{MAX} is unreasonably high or infinite. In the latter cases the maximum Y/R cannot be obtained, and then management cannot be established. In those cases, the $F_{0.1}$ has been used as a cautious proxy for MSY levels. But even this approximation to MSY is considered as a conservative harvest level measure and not the actual MSY level. $F_{0.1}$ always exists as a value from an Y/R curve but it is an arbitrary value that has no optimal properties

	or theoretical basis; it has gained acceptance because it seems to work well with various stocks. In addition, $F_{0.1}$ is used because F_{MAX} is now well defined since the Y/R curve is flat-topped and therefore, there exist many F_{MAX} values for which Y/R maximizes within a non-significant range (for example ±10-15%).To make the issues more complicated, papers on shrimps published in high quality journals, still consider MSY=Y/R_{MAX} as derived by the Y/R curves. In data poor cases, the F_{MSY} proxies that have been proposed are in the range of 0.75M and 0.8M and in many cases, the F_{MAX} level has been connected to the M values of the certain stock. The main question in the present situation is whether the stocks that are studied are in steady-state conditions, so that one may estimate an F value that will create sustainable fishery conditions. If the stocks are in steady-state condition, then according to the general theory F_{MAX}~F_{MSY}. If not, then other F_{MSY} estimates should be proposed, with F_{MSY}>F_{MAX}.

Stock Assessment

Title:	Jones Length Cohort Analysis (LCA)
Main Reference(s):	Jones, 1974; 1979; 1981
Short Description:	The main difference of this method and the VPA model is that it considers time periods that are not equal and constant. In that case, the number of fish at i period is: $$N_i \approx \left(N_{i+1} \left[\frac{L_\infty - L_i}{L_\infty - L_{i+1}} \right]^{\frac{M}{2K}} + C_i \right) \left[\frac{L_\infty - L_i}{L_\infty - L_{i+1}} \right]^{\frac{M}{2K}}$$ In the case of decapods, the age transformation of the lengths based on the VBGF equation parameters is required: $$t_i = \left(\frac{1}{K} \right) \ln \left[1 - \left(\frac{L_i}{L_\infty} \right) \right] + t_o$$
Main Data Requirements:	L∞ from VBGF and M/K LFD
Data Quality and Details:	The main advantage of the method is that it does not require the individual estimation of M and K values but only the M/K ratio and the solution is direct without iterations. Since the virtual population analysis methods such as this require good records of catches and landings, the different logging systems between countries and regions hinder the quality of the results.

Title:	Extended Survivors Analysis (XSA)
Main Reference(s):	Shepherd, 1992
Short Description:	Virtual population analysis and cohort analysis are essentially accountancy methods whereby a stock's historical population structure may be reconstructed from total catch data given a particular level of natural mortality. Firstly, however, numbers at age in the last year and age have to be found since both methods iterate backwards dozen a cohort. The main problem in Enjoy sequential age based assessment methods is therefore to estimate these terminal population numbers. In XSA these are found from the relationship between catch per unit effort (CPUE), abundance and year class strength.
Main Data Requirements:	Catch-at-age array M Start and end of fishing period CPUE per fleet
Data Quality and Details:	

Title:	Virtual Population Analysis (VPA) & Cohort Analysis
Main Reference(s):	Beverton and Holt, 1957; Gulland, 1965
Short Description:	This method aims to estimate the actual number of a given stock at sea using catch-at-age keys or age converted LFDs. The main feature of the method is the estimation of past cohorts based on a known future catch level. The terminal catch is actual the last catch taken from a cohort before it

	went extinct. The main model for this method is the following: $\frac{C_i}{N_{i+1}} = \frac{F_i}{Z_i}\left[e^{Z_i} - 1\right]$ The terminal population N_t is estimated by, $N_t = Z_t \frac{C_t}{F_t}$ Since the main model equation does not have a direct solution, the Pope approximation on cohort analysis is used: $N_i = \left(N_{i+1}e^{-M} + C_i\right)e^{\frac{M}{2}}$ and $F_{i+1} = \ln\left(\frac{N_i}{N_{i+1}}\right) - M$. Working these 2 equations backwards, the values of N_i are estimated for every N_{i+1} value. In the case of decapods, the age transformation of the lengths based on the VBGF equation parameters is required: $t_i = \left(\frac{1}{K}\right)\ln\left[1 - \left(\frac{L_i}{L_\infty}\right)\right] + t_o$
Main Data Requirements:	Catch-at-age M Initial guess of F terminal
Data Quality and Details:	The main characteristic of the method is that it requires the individual estimation of M and K values and the solution is produced iteratively. Since the virtual population analysis methods such as this require good records of catches and landings, the different logging systems between countries and regions hinder the quality of the results. In addition, the time interval between age groups should be constant and not variable.

Title:	Separable Virtual Population Analysis (sVPA)
Main Reference(s):	Pope, 1977; 1979; Pope and Shepherd, 1982
Short Description:	The model assumes that the fishing mortality-at-age is the product between a fishing mortality component in a year and an age dependent exploitation pattern effect. The catch-at-age data re used to derive a matrix of log catch ratios in order to remove the year class strength effects
Main Data Requirements:	Catch-at-age key F of oldest age Oldest age selectivity Reference age and selectivity of reference age Natural mortality, M
Data Quality and Details:	

Title:	Surplus models or Stock Production Models
Main Reference(s):	Schaefer, 1954; Fox, 1970; Pella and Tomlison, 1969
Short Description:	The main aim of the surplus models is the estimation of time series of population biomass and expected catches by a non-equilibrium fitting of the (a) the Fox model, (b) the Pella-Tomlison model and (c) Schaefer model.

	The stock production models are summarised by the main form: $B_{t+1} = B_t + g(B_t) - C_t$ where B is the biomass and C, the catches. Depending on the model, the g parameter can be: $g(B_t) = rB_t(1 - \frac{B_t}{K})$ $g(B_t) = rB_t\left[\ln(K) - \ln(B_t)\right]$ $g(B_t) = rB_t\left(1 - \left[\frac{B_t}{K}\right]^Z\right)$ for the Schaefer, Fox and Pella-Tomlison models respectively.
Main Data Requirements:	The main requirements are: Fleet catch and effort Estimates of population at the start of time series as a proportion to the carrying capacity
Data Quality and Details:	

Title:	Thomson-Bell model yield analysis
Main Reference(s):	Thomson and Bell, 1934
Short Description:	The method aims to the prediction of the development of a fishery given assumptions on future recruitment and values of fishing effort expressed in terms of size/age specific fishing mortality and gear selectivity. The method of Thomson-Bell consists of 2 parts: (a) the *virtual population analysis* based on F at age, size, catches, deaths, yields and biomasses and (b) the *prediction* part of the F array on the catches and numbers. The first part is based on a VPA based on the following assumption adjusted for the conversion of length to age or relative age when t_o is known: $N_i \Delta t_i = \frac{(N_i - N_{i+1})}{Z}$ The resulting mean biomass values can then be computed iteratively: $\overline{B} = \sum(B_i \Delta t_i)$
Main Data Requirements:	The data required are grouped in 3 groups: (a) species group, (b) fleet group and (c) links between (a) and (b). The data per group are: (a) class size, maximum fishing mortality, natural mortality, L∞, K from VBGF, a and b from length-weight relationship. (b) Gear selectivity (c) Gear selection and catch index
Data Quality and Details:	One major characteristic of the method is that it provides predictions for the future from a certain starting point. On the contrary, normal VPA methods run backwards iteratively. The actual method is the VPA inverted.

Title:	Monte Carlo LFD simulations
Main Reference:	Sparre and Venema, 1992
Short Description:	The main aim of this method is the elaboration of theoretical length-frequency samples based on actual and known dynamics parameters such as mortality, gear selectivity and growth. The initial step is the simulation of the catch at each length group as a random number taken from a typical random number generator.
Main Data Requirements:	Depending on the type of software used, the input parameters vary significantly. The most common option is the use of FiSAT software which requires at least the following as input: Migration locations Number of fish in the simulation samples Number of age groups expected $L\infty$, K from VBGF and their variance 50%, 75% retention lengths of the gear (ogives) Maximum F
Data Quality and Details:	The advantage of Monte Carlo LFD simulation is that it allows the modelling of the behaviour or stocks based on actual and known dynamics parameters. This analysis is an alternative approach to the direct age reading methods used in fish or the testing of length-based methods for the growth parameter estimation accuracy. The disadvantage of the method is that the simulated population may not behave realistically in the model. The results of the simulation can be easily compared to the actual experimental catches based on statistical methods such as chi-square tests etc. so that one may conclude on what to expect from the actual data in hand.

Title:	Metapopulation Theory and models
Main Reference(s):	Hanski, 1999
Short Description:	By term, metapopulation is a set of local populations connected by migrating individuals. Obviously, the degree of isolation between the population patches or simply, the geographical distance between them is of major importance. Metapopulation modelling is based on probabilities rather than simple quantified proportions. Metapopulation models consider the local populations of the same species as individuals. The dynamics of the local populations are either not considered at all or are considered in an abbreviated way. Most metapopulation models are based on the colonization extinction equilibria. In such form, a metapopulation system could be identified as: • several patches colonized from complete populations for the same species (stratified dispersal)

- several patches colonised by certain stages of the same species (larva, fry, young, adult)
- patches temporarily colonized by individuals through their life cycle (reproduction/coupling ground, nursery ground, feeding ground etc.)

A metapopulation system and model is able to approach the movements of the individuals between the patches or from a large patch/pool to other smaller patches in the vicinity. Metapopulation models can be very simple or extremely complicated as they should take into consideration some of the following:

- dispersal patterns
- geomorphology and barriers
- diffusion model
- life tables to estimate intrinsic rates of growth, r
- 'random walk'
- ecological niche
- interaction between species sharing localities and resources\
- intra-specific competition, within the population
- carrying capacity of ecosystems and patches
- predator-prey relationships (*Holling* equations, *Lotka-Volterra* models)

In the very basic form, metapopulation models are 2: (a) the production-extinction models and (b) the migration-colonization models. In most cases the latter are the most important models. These models have again 2 forms: (a) the source-sink model where we have a pool of the population somewhere and colonization of suitable patches and (b) dispersion model between patches.

The first type of model is based on the following relationship:

$$ln\frac{\hat{p}}{1-\hat{p}} = ln\, c_o - ln\, e_o - \beta D + \alpha S = ln\left(\frac{c_o}{e_o}\right) - \beta D + \alpha S$$

This is a typical linear regression of the form $y=a+bx+cz$ and which relates the number of Individuals that colonise the i patch when the origin has a certain number of individuals and the patches have a certain size, S, and are located at D distance from origin.

Exactly in a similar way as above, if we consider just a series of patches without an origin pool, the above equation becomes:

$$\frac{dp}{dt} = c \cdot p \cdot q - e \cdot p \quad \text{with} \quad \hat{p} = \frac{c-e}{e}$$

Main Data Requirements: VPA results per patch
Population growth rates
Carrying capacity

	Estimates of the habitat quality index or any relationship between abundance or presence/absence with environmental parameters
Data Quality and Details:	There are several assumptions in metapopulation theory. Those are: • the patches are colonised by full populations (all life stages) • the capacity of the individuals to migrate between patches is equal for all • there is no variation in dispersal capabilities among individuals • all individuals can disperse and reproduce • there is a single pool of the population in the vicinity of the patches or we set a patch as the 'origin'

Title:	Bioeconomics and Socio-Economics
Main Reference(s):	
Short Description:	Bio-economics of fisheries is a scientific field of growing interest. In general terms, it involves the coupled modelling of biological and population dynamics data with the economy of the sector in terms of fleet and fishermen. The elements of a bio-economic model include: (A) Daily profit model: A plausible function of the daily or trip profit may be the following: $Daily\ profit\ (P) = Y \cdot EVP - [Costs]$ where *Y*, is the daily production (kg), *EVP*, is the ex-vessel price (€/kg) and *Costs*, the cost function of a daily trip. Al of the above are actual statistical functions and not values. The model, once realised may be reduce by using Taylor approximation algorithms. The functions may also have the form of more complicated differential equations, though this adds laborious calculations in the process. (B) The Seasonal Price Model: This basic form of seasonal model at first includes lagged forms of the dependent variable(s) in order to account for the effects of the previous fishing period on the next fishing period both in terms of landings (harvested from the natural population) but also the possibility of accumulation of surplus that the market has not yet absorbed: $Price_t = a + bQ_t + cQ_{t-1} + dQ_{t-2} + Income_t + error\ term$ where: a,b,c,d, coefficients; P, is the undeflated ex-vessel shrimp price (fishermen price); Qi, are the quantities landed during the i month; $Income_t$, is the average income during the t month/season/period. The number of lagged variables (t-1, t-2,t-3) may go back indefinitely and is a matter of statistical trial and error to determine the lagged phase which will be included in the model. (C) The Flexibilities: Important information concerning the behaviour of the various variables in a model can be identified from the flexibilities of these variables. Once a model of the above forms

has been established, then the flexibilities will identify, for example, what will happen to the ex-vessel price (increase/decrease and how) when the landed quantity increase or decrease by a certain amount or percentage. Also, flexibilities will provide information on how fast these responses of the ex-vessel price will be. In general, flexibilities can be estimated as follows. After the evaluation of the seasonal price model, it is solved backwards for the whole period. The flexibilities between the independent variable and any variable in the model is calculated as the ratio between the average price values of the period and the average values of variable for the same period *i*.

In addition, the flexibilities are equal to the coefficients of the log form of the same model. In a general log equation with two independent variables and a constant, we have:

$$log\ P = a + b\ log\ q + c\ log\ i =$$

$$\left[log\ H\right] + b\ log\ q + c\ log\ i \Rightarrow$$

$$P = a \cdot q^{b} \cdot p^{c}$$

where: q,i are dependent variables and a,b,c are coefficients. [logH] denotes a numeric coefficient input here as a log to simplify calculations. Obviously, a=logH and $H=10^{a}$.

(D) The Average ex-vessel Price Model: In some ways, a year is the ideal unit of time for price analysis. When we use annual data on quantities and prices, the difficulties due to seasonal changes are avoided. Moreover, to answer some of the major economic problems, details about monthly, weekly or daily price changes are not necessary. One disadvantage of using annual data is that we need long series of such data with comparable observations on landings, prices, consumer incomes, and perhaps other related variables. Howeer the longer the time series, the less comparable are the data. Over long periods, there may be substantial changes in consumer tastes, in processing and packaging, in competing foods, or in other factors. It is often difficult to quantify these variables. Some preliminary analyses indicated that the annual prices are closely related to the quantity landed and to the consumer income. It is suggested that within the range of the observed data the relationships could be expressed fairly well either directly or in a log form of the average income (annual), and the per capita consumption (kg/year).

$$Average\ Annual\ Price = a_1 + b_1 \cdot Consumption + c_1 \cdot Income$$

or

$$log\ Average\ Annual\ Price = a_2 + b_2 \cdot log\ Consumption + c_2 \cdot log\ Income$$

where ai, bi, ci (I=1,2) are coefficients and a_2,b_2,c_2, the flexibilities.

(E) The Competition: Decapods, fish, meat and poultry are consumed primarily as a part of the main course of meals. When one is served, generally the other is not. Therefore, the fishing industry competes with the livestock industry for a place in the meals. This indicates that the price of decapods (shrimps, lobsters etc.) is determined not only by the quantities of shrimp available on

	the market but also by the quantities and prices of meat, poultry, other fishery products as well as processed product types of them or imported types etc. Before this analysis can be realised, it is recommended that the true competiting products are recognised beforehand so that the model is simple. Also imported products compete with domestically harvested ones. A simplified model to analyse this competitive relationship, is a raw or log form linear regression: $Consumption_{shrimp} = a + b \cdot Price_{meat} + c \cdot Price_{poultry} + d \cdot Income$ *or* $log\left(Consumption_{shrimp}\right) = a_1 + b_1 \cdot log\,Price_{meat} + c_1 \cdot log\,Price_{poultry} + d_1 \cdot Income$
Main Data Requirements:	• Time series of fleet, effort, landings, prices, market network and price rates • Economic data on fishing activities as cost of fishing – fixed and variable • Data on stock, recruitment and survivors (or escapes) • Water Quality Data • Social data of fishing activities by the use of questionnaires
Data Quality and Details:	

Fisheries Software

adapt
ALCON 3.0
ANACO
ANALEN
aspic
BEAM 1
BEAM 2
BIOPAK
Capture
CEDA
CEFAS Fishlab
CLIMPROD
contrast
ECOPATH
ELEFAN11
estimate
FAO Beam 4
FAO SPATIAL
FindFMSY
FISAT
FISAT 2000
FISHBASE
FishLab Excel add-in
FishParm 3.0S
FSAS
gpstrak
hamsfile
heicalc

ICA
LFSA11
map
MARK
maxims
mfan
MFDP
mfypr
MLA
MS SURVIV
MSFP
MultiFAN for DOS
Noremark
PaPlot
PaSoft Excel add-in
PoPan 4
PoPan 5
PopDyn for MathCad
puma
randsel
RCT3
Rd Surviv
Release
sdp_dist
sizetran
spads
SPERICH
Stochastic Dynamic Programming
SURPH
transan
trends
twinspan
VIT fishery analysis
VONBIT FAO
vpa
vpa suite

6.2. Metapopulation software

VORTEX
ADAPT 3.0
ALEX
MAXXAN
MEAPO
POPULUS
SIMCOAL

6.3. Bayesian theory in fisheries software

Bayes-SA FAO software
BACC
Bayda
Decision Plus
Expert Choice 2000
First Bayes

Netica Bayes
XBAIES

6.4. Supplementary software

Calculus (DOS)	derivatives, approximations
Eureka	Simplex approximations
NLREG	non-poarametric programming
CurveExpert	regression

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Concerted Action Project number QLK5 1999 01272

Workpackage 3: Draft Final Report

Metapopulation dynamics and stock assessment of decapod crustaceans

I. Introduction and conclusions
II. Conference program and abstracts

Main Contributors

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Contents

Introduction

A metapopulation is a set of local populations or subpopulations within some larger area (usually the population's range) where movement from one subpopulation to another subpopulation is possible (Hanski & Simberloff, 1997). Metapopulation theory describes the spatial dynamics of interconnected subpopulations. The metapopulation concept was proposed in order to study population dynamics in a binary landscape of suitable and unsuitable habitat patches (Hanski & Gilpin, 1996; Hanski, 1999). These patches of individuals are regarded as local populations if they sustain themselves over several generations and exhibit dynamics partially independent from other such populations within a region. Local extinction events and limited dispersal may cause a fraction of suitable habitat to remain empty. The degree of segregation among subpopulations may range from slight to almost complete isolation, depending upon factors such as a) the distance between areas occupied, b) geographic (or oceanographic) barriers between areas, and c) the dispersal ability of the species (e.g. Harrison & Taylor, 1997). Exchange between the subpopulations of the metapopulation prevents the development of separate, autonomous or locally isolated populations. As a result, subpopulations may not (and need not) be genetically distinct, although such differentiation is suggestive of the existence of metapopulation structure with low levels of exchange between subpopulations (Smedbol & Wroblewski, 2002). According to Reich & Grimm (1996) the most accurate definition of the metapopulation, is a "(regional) population of (local) populations which fulfils the following four criteria

1. The local populations have their own dynamics, i.e. they are clearly able to be delineated from other local populations
2. At least some of the local populations are so small or so threatened that they face a considerable risk of becoming extinct
3. The local populations or patches, respectively, are interacting by dispersing individuals
4. Dispersers are able to establish new local populations on empty patches. "Establish" means, in particular, that the new population in turn starts to produce dispersers

The metapopulation concept differs from the classic stock complex concept. The metapopulation concept considers the local populations of the same species as individuals. The traditional way of viewing stock structure is static. The spatial patterning of subpopulations within a marine metapopulation is regarded as temporally dynamic; subpopulations may undergo extinction and recolonization, and new subpopulations may develop in suitable areas within the range of the metapopulation (Smedbol & Wroblewski, 2002).

In the simplest metapopulation model first proposed by Levins (1970), there are three assumptions: (1) subpopulations have the same geographic extent and degree of isolation, (2) each subpopulation has separate local population dynamics, and (3) the rate of exchange of individua1s among subpopulations is too low to affect local population dynamics. Hanski and Simberloff (1997) suggest that of main importance is the idea of discrete local breeding populations connected by immigration and emigration. In the Levins model, areas that can support subpopulations, are considered either occupied or unoccupied. The abundance of a local subpopulation is assumed to be either nil (empty area) or at the carrying capacity of the environment (fully occupied area). Although abundance is not explicitly included in the Levins model, investigations by Hanski (1991) have shown that colonization is proportional to overall metapopulation abundance, due to a "rescue effect" at high abundance in which immigrants from other subpopulations enhance subpopulation persistence. Extinction is considered to be equally likely for all subpopulation (Smedbol & Wroblewski, 2002).

Grimm et al. (2003) pointed out that the metapopulation concept should not be viewed as a means to categorize populations in different classes, but as a working hypothesis. The metapopulation concept forces us to ask important questions which we probably would not have asked optherwise. These questions are

1. Are population dynamics on a patch more or less independent from other populations?
2. Is small population size a problem?
3. Are there environmental factors which affect more than one patch simultaneously?
4. Are there source populations which are more productive in terms of emigrants and persistence than other habitats? Such populations would be important to protect if conservation is a concern
5. How far do emigrants go, and where? Where do immigrants come from?
6. Which patches are really connected in a network, and which are more or less isolated?

All these questions, and probably a suite of further more detailed questions, are relevant both scientifically and for solving applied problems. However, is all this equally significant for terrestrial and marine populations, or are there fundamental differences?

Despite its success and usefulness for terrestrial systems, the question still remains as to whether the metapopulation concept is also useful for marine populations. We can propose that the range of spatial population structures of the terrestrial animals is much the same in the marine environment. Thus, whales, herrings, salmon, eels or euphausiid shrimps, for example, perform regular migrations just as mammals, birds and some insects do on land. However, most species of the marine fauna are holobenthic without regular pelagic dispersal, particularly the diverse meiofauna in mud and in the interstices of sand. Their means of dispersal are rather limited, and adaptations to specific substrates, depths, water qualities and food supplies entail insular populations separated by vast stretches of unsuitable habitat (Grimm et al., 2003). Special marine cases are benthic invertebrates with external fertilization and an extended pelagic larval phase as well as holoplanktonic species. In organisms with these modes of dispersal the occurrence of distinct populations depends on particular current regimes such as gyres, permanent fronts or the alternating flow of tides. In the absence of such hydrodynamic patterns, their spatial population structures may indeed be largely ephemeral and fortuitous. It has been argued that the “openness” of such marine populations prevents the application of the metapopulation concept because it seems impossible to speak of local population dynamics (e.g. Reich & Grimm, 1996). The main problem in applying the concept to marine systems is to delineate local and regional populations or to delineate populations and their spatial scale in the first place (Camus & Lima, 2002). Obviously, this is hard to determine for purely pelagic species. Also benthic species, which often occupy identifiable habitat patches, may not have local population dynamics because of pelagic larval stages which are dispersed over long distances by oceanic currents. Because of all these open questions, it has been assumed that the metapopulation concept does not apply to marine populations, but nevertheless it is used (Reich & Grimm, 1996). Even by relaxing some of the requirements of the Levins model (1969, 1970), the life-histories of the most abundant, highly mobile or dispersive marine species initially do not appear to fit the classical metapopulation concept defined by Levins. First, while the existence of discontinuous habitat structure is apparent in rocky shores, benthic and reef systems, it is more difficult to identify suitable habitat for populations occupying demersal and pelagic ecosystems. A second issue centers on the connectivity among marine populations. The larval phase of the life history is common in marine species. The possibility of long distance dispersal by passive larval dispersal (e.g. Scheltema, 1986) has long been cited as resulting in “open” marine populations (e.g. Roughgarden et al., 1985), and genetic analyses from marine species with great spatial dispersal may provide evidence of scant population structure, except over large spatial scales (e.g. Palumbi, 1996). Additionally, metapopulation models usually assume that, except for dispersers, individuals remain within their home area for their entire life, whereas adults of many mobile marine fish and invertebrate species can traverse much the population’s range over the course of a single year, and often undergo geographically extensive spawning-feeding migrations. Obviously, this is hard to determine for purely pelagic species. Also benthic species, which often occupy identifiable habitat patches, may not have local population dynamics because of pelagic larval stages, which are dispersed, over long distances by oceanic currents. At the coast, metapopulations are likely to occur in species which are confined to estuaries or lagoons separated from each other. Metapopulation structure may also be detected in intertidal rock pools.

Larval dispersal is an important factor in marine metapopulations. The possibility of long-distasnce dispersal of larvae in wind-driven surface currents has received particular attention (Fogarty, 1983). Recent studies have further pointed to the importance of directional orientation and active swimming by post-larvae in reaching coastal locations (Cobb et al., 1989; Katz et al., 1994). A number of mechanisms may be involved in the formation of metapopulation structure in “open” marine systems. Mesoscale physical events such as upwelling, jets, gyres, tides, fronts, eddy currents, temperature, salinity, winds can affect the distance and direction of egg and larval dispersal and present temporary barriers to the exchange of propagules among neighboring populations (Smedbol et al., 2002). Botsford et al. (1998) referred that both biotic and abiotic aspects of the immediate environment of an invertebrate larva can affect growth and development rates in ways that influence recruitment success and to evaluate this they formulated an equation model that described the way in which the distribution of larvae over developmental stage changed with time.

The transport for settlement is also an important factor in marine metapopulations. There are several modelling methods for evaluating the transport of larvae for settlement. Some models have been developed to compute the possible transport but do not yet adequately describe all of the important mesoscale features (e.g. Hobbs et al., 1992; Song & Haidvogel, 1995). Management of metapopulations will likely benefit from the increasing number of studies attempting to identify physical influences on larval dispersal and settlement variability. While many studies have provided descriptions of temporal variability in settlement, relatively few have investigated spatial variability in settlement, and fewer still have provided predictable physical mechanisms for spatially varying settlement rates (Wing et al., 1998). This kind of data is less common for data with larger scale larval dispersal. For example, research into the larval distribution and settlement patterns of lobsters has led to some information on possible transport patterns of American lobsters (*H. americanus*) in the NW. Atlantic (Hudon, 1994) and spiny lobster (*Panulirus cygnus*) in the Indian Ocean (Pearce & Philips, 1994).

Genetics studies are also very important in metapopulation analysis. In testing for metapopulation structure empirically, it is necessary first to demonstrate that extinction and recolonization of populations may occur. Determining the presence of metapopulation structure in the majority of marine environments, particularly open-ocean regions, is not a trivial task, especially when compared to terrestrial systems. However, genetic data may be of use for either direct or indirect inference of population turnover. Direct inference could be undertaken by analyzing temporally-spaced samples from the same populations e.g. extracting DNA (Smedbol & Wroblewski, 2002). A more indirect approach to assess the occurrence of metapopulation dynamics is to look for discrepancies between estimated ecological and population genetic parameters (Planes et al., 1996).

Mark-recapture studies also help the identification of subpopulations, as well as their dispersal activity, constituting important data in metapopulation studies.

Metapopulations and the management of European crustacean fisheries

1. Connectivity between populations

The spatial structuring of populations of exploited decapod crustaceans is not well incorporated into the assessment and management process in Europe. In fact as the conference papers presented in report of WP3 by Wahle, Butler and Sale indicate this is a relatively new area of research and as Sale point out there are particular difficulties in developing methods to determine the relationship between source and sink areas in decapods as the larvae cannot be aged and back calculation to birth date and location is not possible. Nevertheless high resolution bio-physical models can provide information on probable rates and directions of dispersal. It is the lack of data on larval behaviour, longevity in relation to temperature, depth distribution rather than limited computer power or capacity to mathematically define the physical process of dispersal or advection that currently limits the application of advection diffusion models i.e the biological rather than the physical input to the model is the limiting factor. For example in the papers given in the proceedings by Pedersen and Eaton et al the larval population are passively drifting particles with a longevity that has only been partially modelled in relation to the prevailing environmental conditions.

2. Larval supply

Larval distribution data is lacking for the majority of species. In the case of *Nephrops* in northern Europe and to a lesser extent *Cancer* and *Homarus* distribution data, information on development rates and in some cases mortality estimates are available. Mechanisms that control the dispersal of larvae and the supply of larvae to the sea bed have generally not been studied although this is relatively well understood in the case of *Carcinus* in Portugal. In southern Europe and the Mediterranean species larval distribution data is generally lacking and for many of the important species such as *Arisetus, Aristeomorpha* and *Parapenaeus* larvae records are sparse and incidental. Probably more is known concerning the distribution and migration of adults but this is generally less important or at least completes only half the picture as far as determining the population structure of the species. Data on migrations of the deep sea shrimp in the Mediterranean are becoming available while tagging studies on *Cancer* and *Homarus* in northern Europe have recently given new insights into migrations in these species.

3. Post settlement

Even when data on larval and adult distribution and dispersal are available the distribution of suitable settlement habitat for post larvae is not well known. Data on settlement of post larvae and substrate choice are extremely sparse and the distribution and amount of suitable habitat available has not been mapped. The role of post settlement processes in determining recruitment to the fishable stock has been studied in *Carcinus* and to a lesser extent in *Cancer*. These however are local studies may not be applicable to other areas of the distribution of these species. Case studies from outside of Europe and a general review are provided by Wahle (abstract 28). Increasing attention is being paid to mapping of the physical landscape using single and multibeam acoustics. In Ireland large scale mapping of the seafloor is underway and high resolution surveys in shallow water are being used to map habitat suitable for the settlement and early recruitment of crab.

Future Research

The growing number of marine invertebrate populations in which metapopulation aspects have been shown to be important indicates that better understanding of the dynamic implications of metapopulation structure is needed (Botsford, 1995). Results at the metapopulation level indicate that even if we had a complete understanding of the larval-dispersal phase of a species and could predict dispersal patterns we would not have a complete understanding of the behavior of the metapopulation. We need to know how various spatio-temporal patterns arise from specific life-history characteristics and dispersal patterns.

It would also be beneficial to know what subpopulation dynamics tell us about metapopulation dynamics. Increased understanding of similar spatio-temporal patterns in population biology provides some hope that this will be possible (e.g. Hastings, 1992). Although these results help to increase understanding of these mechanisms, other recent results (Hastings & Higgins, 1994) indicate that metapopulations present new, poorly understood characteristics. In making predictions, we often assume that population dynamics go to some qualitative type of behavior and remain there. Botsford et al. (1998) believed that to date we need to expand our view of expected behavior in population analysis and stock assessment where metapopulations are involved. In particular, we need to consider possibilities other than just synchrony over large spatial scales and complete lack of synchrony. Metapopulations can exhibit more complex spatio-temporal patterns in which some subpopulations covary, but are out of phase. Discovering these underlying patterns will require ingenuity because they will probably not be as regular as in population models and they may be obscured by observation error.

In cases, where true metapopulation exist in the marine environment, managers must consider the spatiotemporal scale of the system. For instance, there is growing evidence for extinction-recolonization dynamics in a number of systems, usually comprising sessile species and populations of limited spatial scale, however, the evidence is less conclusive for highly abundant, geographically extensive, and mobile populations. Even if metapopulation structure is ultimately verified for mobile marine species, it is almost certain that the timescale under which their dynamics operate will be much greater than the annual scale of (i) events often documented in terrestrial systems, and (ii) fishery management regimes of exploited marine populations.

The fact that larval dispersal among subpopulations is usually unknown presents a problem for management of invertebrate populations (e.g. Walters et al., 1993). For discrete adult populations connected by larval dispersal, those subpopulations that receive few propagules may be particularly sensitive to local decline from harvest pressure, yet they could be an important source of propagules for the metapopulation as a whole (e.g. Pulliam, 1988). For example, in some invertebrate fisheries, management relies on remote or offshore refuge populations to seed more heavily fished grounds (e.g. American lobster; Fogarty, 1998). Loss of those potentially sensitive larval sources may result in recruitment overfishing. However, decline of such local populations may not be immediately detectable from fishery catch statistics as effort shifts to the remaining grounds (Collie & Walters, 1991). These considerations are particularly important when a fishery expands over a large area, affecting per capita survival rates in remote areas that have refuges from harvest and are also sources of recruits to the rest of the population. Wing et al. (1998) have demonstrated the potential management value of knowledge of larval exchange among subpopulations of a model metapopulation in marine invertebrates, but not explored the optimal management of such stocks. It is apparent that continued specific accounting of metapopulation structure in management policy, and continuing pursuit of the biological-physical mechanisms underlying larval transport among them can lead to a quantum improvement in the management of harvest of invertebrate (and other) stocks.

Conclusions

A change in emphasis in research and monitoring of decapod populations in Europe is required if the metapopulation structure of these species are to be taken into account in assessment and management. The implications for not using this information is potentially serious. Depletion or extinction of important source populations, loss of genetic diversity in the species and sub-optimal harvesting regimes may result. The report of WP5 of EDFAM points to the need to identify appropriate scales for the institutional arrangements and design of management. The management structure needs to map onto the biological structure or reflect the sub-population structure and its spatial organisation. If the latter is unknown then management cannot be optimally designed. If the species is not a single panmictic population or indeed a series of isolated regional or local populations then management should be local and hierarchical rather than centralised or 'control and command'. Inclusion of stakeholders and local interests in the system will be necessary certainly where the population is more structured than simple, open and panmictic. This designing and mapping of management to reflect the system of connectivity between local stocks is not commonly practised in Europe. In the newly revised CFP the development of regional management through Regional Advisory Councils (RAC) is an attempt to 'scale down' management. Whether this is sufficiently local and flexible to account for the many different species biologies and population structures remains to be seen.

In order to provide management with more information on stock structure, distribution and connectivities research on decapod crustaceans should be directed towards ecology with emphasis on the processes that control the supply and survival of larvae and early juveniles. The following areas of research are important.

1. Physical habitat mapping so that the landscape available to the species is known.
2. Bio-physical modelling of larval dispersal in order to identify the system of connectivity between local populations
3. Studies on habitat choice of post larvae
4. Post settlement processes particularly in species where larval supply does not appear to limit recruitment
5. Identifying and providing rationale for the existence of metapopulations in European crustacean fisheries
6. Evaluation of the possibility of adopting management systems that are specific to the scale of distribution and structure of individual species metapopulations.

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EDFAM Workpackage III: Metapopulations and stock assessment of crustaceans

Life Histories, Assessment and Management of Crustacean Fisheries (La Coruna, Galicia, Spain, October 8-11th 2001) Program of oral presentations

WP3 of EDFAM organised and hosted an international conference in La Coruna, Galicia, Spain in October 2001 on the '*Life History Assessment and Management of Crustacean Fisheries*' emphasising the need to incorporate, and inviting plenary speakers specifically on, metapopulation analysis in crustacean fisheries assessment and management.

Important reviews by Wahle, Butler, Sale and Caputi and 7 other papers at the conference specifically deal with or touch on the topic of metapopulations. The program for the conference, which follows, also identifies EDFAM funded contributions to WP2 (Assessment of the local population) by EDFAM partners and associates or invited speakers. Of the 107 abstracts originally received 33 papers were, following peer review, accepted for publication in *Fisheries Research* (Volume 65, 2003). The Conference Program and the 107 abstracts are presented below. The full text of the 33 papers are presented in Sections III and IV of the report of WP3. The special issue of *Fisheries Research* will be published in December 2003.

Theme 1 : Relevance of life history characteristics in assessment and regulation (13 papers)

(Contributions from authors in bold print were funded by EDFAM)

No.	Author	Title
1	**Stanley Cobb and Sarah Twombly**	Decapod Life History Characteristics: Implications for Management
2	**Mark Butler**	Incorporating ecological process and environmental change into spiny lobster population models using a spatially-explicit, individual-based approach
5	Michaela Aschan & Hege Ø. Hansen	Variation in population fecundity of shrimp (*Pandalus borealis*) in the Barents Sea
6	Tone Rasmussen & Michaela Aschan	Growth performance at different temperature regimes in shrimp larvae (*Pandalus borealis* Krøyer 1838) in the Barents Sea
9	Kosmas Kevrekides & Maria Thessalou-Legaki	First results on the fisheries biology of *Penaeus (Melicertus) kerathurus* from Thermaikos Gulf (N. Aegean Sea)
10	Peter A. Koeller, M. Covey & M. King	Is size at sex transition an indicator of growth or abundance in Pandalid shrimp?
11	Jie Zheng	Uncertainties of Natural Mortality Estimates for Eastern Bering Sea Snow Crab, *Chionoecetes opilio*
14	Hector A. Lizárraga-Cubedo, I. Tuck, N. Bailey, G.J. Pierce and J.A.M. Kinnear	Comparisons of reproductive parameters of two Scottish populations of the European lobster, *Homarus gammarus*
16	**Alexis Conides, F. Lumare, K. Kapiris & G. Scordella**	Reproduction and life-history of the native shrimp *Penaeus (Melicertus) kerathurus* in Greece and Italian coasts, North Mediterranean
19	**Agnes –L. Agnalt, Tore S. Kristiansen & K.E. Jørstad**	Should we protect the berried females? : Reproduction cycle, growth and migration of mature female European lobster (*Homarus gammarus* L.) off southwestern Norway
22	Bradley G. Stevens	Timing of aggregation and larvarl release by Tanner Crabs, *Chionoecetes bairdi*, in relaion to tidal current patterns
81	Michel E. Hendrickx	Size and abundance of deep water shrimp on the continental slope of the SE Gulf of California, Mexico
99	Astrid K. Woll	Observations of ovigerous *Cancer pagurus* in situ in Norwegian waters
110	Diele K, Koch V. & Saint-Paul U.	Population structure, abundance and biomass of the exploited mangrove crab *Ucides cordatus* (Linnaeus, 1763)(Ocypodidae) in the Caeté estuary, North Brazil

Theme 2 : Metapopulation concepts (11 papers)

	Author	Title
24	**Peter F. Sale & Jacob P. Kritzer**	Determining the extent and spatial scale of population connectivity: decapods and coral reef fishes compared.
26	O. P. Pedersen, M. Aschan, K. Tande, D. Slagstad & T. Rasmussen	Larval dispersal and mother populations of *Pandalus borealis* investigated by a Lagrangian particle tracking model
27	**Derek Eaton, Juan Brown, Julian T. Addison, Steve P. Milligan & Liam J. Fernand**	Edible crab (*Cancer pagurus*) larvae surveys off the east coast of England: implications for stock structure.
28	**Richard A. Wahle**	Post-settlement processes and the search for the stock-recruitment linkage in lobsters and crabs: Is experimental ecology the key ?
31	**Nick Caputi, C. Chubb, R. Melville-Smith, A. Pearce and D. Griffin**	*Relationships between life history stages of the western rock lobster (Panulirus cygnus) fishery of Western Australia*
33	Bruce F. Phillips, Jaime G. Cano , Armando V. Velazquez	Sustainable management of community based spiny lobster fisheries and the problems of metapopulations
34	Jie Zheng & Gordon H. Kruse	Stock-recruitment Relationships for Alaskan Crab Stocks
36	Bruce F. Phillips Roy Melville-Smith & Yuk W. Cheng	Measuring the effects of pueruli removals and habitat improvement in assessing sustainability of spiny lobster populations
48	Armando Vega Velázquez	Reproductive patterns of the spiny lobster *Panulirus interruptus*, as related to sea temperature and Ekman transport off central Baja California, Mexico: implications for fishery management
112	Mauricio Ramírez-Rodríguez, Francisco Arreguín-Sánchez & Daniel Lluch-Belda	Recruitment patterns of the pink shrimp *Farfantepenaeus duorarum* in the southern Gulf of México, and the collapse of its fishery

Theme 3 : Assessment of the local population (24 Papers)

	Author	Title
39	**Julian Addison & Mike Smith**	*A review of stock assessments methods for crustaceans*
40	**Andre Punt**	*The performance of a size structured stock assessment method in the face of spatial heterogeneity in growth*
41	**Elmer Wade**	*Research surveys for studying crustacean populations*
42	**Julian Addison, Andy Lawler & Mike Nicholson**	Adjusting for variable catchability of brown shrimps (*Crangon crangon*) in research surveys.
45	**Francesc Maynou, Montserrat Demestre, & Pilar Sánchez**	Analysis of the deep-water crustacean fisheries off Barcelona (NW Mediterranean) by Generelised Linear Models
46	A.C. Fariña & I. González	Trends in catch-per-unit-of-effort and recruitment in the North and Northwest Iberian Atlantic *Nephrops* stocks
47	**Aina Carbonell , M. Azevedo, E. Román, & V. Lauronce**	Application of non-equilibrium production models to red Shrimp fishery (*Aristeus antennatus*, R. 1816) in the North-Western Mediterranean
51	**M.C. Bell, D.R. Eaton, R.C.A. Bannister & J.T. Addison**	A mark-recapture approach to estimating population density from continuous trapping data: application to edible crabs, *Cancer pagurus*, on the east coast of England
53	**Elmer Wade, Denis Marcotte & Mikio Moriyasu**	A Matlab® based geostatistical analysis tool for assessing and mapping marine invertebrate stocks: Application to snow crab stock assessment in the Southern Gulf of St. Lawrence (Northwest Atlantic).

58	J.C.H. Combes, I.D. Tuck & R.J.A. Atkinson	A comparison of population estimates derived from trap-based assessment methods applied to the velvet swimming crab *Necora puber*
59	Bellchambers, L. M., de Lestang, S. & Thomson, A. W.	Sampling selectivity of different gear types on the blue swimmer crab, *Portunus pelagicus*
60 A	S. D. Frusher, J. M. Hoenig & C. Gardner	Have changes in selectivity masked recruitment declines in crustacean trap fisheries?
60 B	S. D. Frusher & J. M. Hoenig	Recent developments in estimating fishing and natural mortality and tag reporting rate of lobsters using multi-year tagging models
62	M.F. O'Neill, A.J. Courtney, C.T. Turnbull, N.M. Good, K.M. Yeomans, J.S. Smith & C. Shootingstar	Comparison of relative fishing power between different sectors of the Queensland Trawl Fishery, Australia
63	Neil A. Gribble	GBRprawn: Modelling ecosystem impacts of changes in fisheries management of the commercial prawn (shrimp) trawl fishery in the far northern Great Barrier Reef
65	C.M. Dichmont., A.E. Punt, A. Deng, Q. Dell & W. Venables	Application of a weekly delay-difference model to commercial catch and effort data for tiger prawns in Australia's Northern Prawn Fishery
78	M. García-Rodriguez & A. Esteban	An Assessment of a Red Shrimp (*Aristeus antennatus* Risso, 1816), Decapoda, Dendrobranchiata) Fishery off the Alicante Gulf (S.E. Spain).
82	Michel Comeau & Manon Mallet	Difficulties estimating mortality rates by capture-recapture, catch-effort and change-in-ratio models for a spring American lobster (*Homarus americanus*) fishery in Canada
89	Shelly ML Tallack	The crab claw bycatch from a demersal fish gillnet fishery and its impact on Shetland's crab stocks
94	Daniel Valentinsson	Incorporating effects of error propagation in yield-per-recruit models for the common whelk (*Buccinum undatum*)
95	**Sbrana M., P. Sartor & P. Belcari**	Analysis of the factors affecting crustacean trawl fishery catch rates in the Northern Tyrrhenian Sea (western Mediterranean)
97	**Raquel Goñi, Antoni Quetglas & Olga Reñones**	Differential catchability of male and female European spiny lobster *Palinurus elephas* (Fabricius, 1787) in traps and trammel nets.
109	J.C. Groeneveld, G.M. Branch, D.S. Butterworth, A.C. Cockcroft & J.P. Glazer	An experimental assessment of the impact of fishing effort on an abundance index for a heavily exploited rock lobster
111	Ernesto .A. Chávez & Salvador García	Assessment of the brown shrimp, *Farfantepenaeus californiensis* (Holmes) fishery of Bahia Magdalena, Baja California, Mexico

Theme 4 : Regulatory policies and methods (7 papers)

	Author	**Title**
66	P.Stone & D Carter	Experiences in changing the management of Australia's northern prawn fishery. A case study in evolutionary fisheries management
67	Linda-Jane Eaton	The impact of quota management on the fleet dynamics of the Tasmanian Rock Lobster fishery
69	Silvia Salas	Are lobster fishers generalists or specialists? fishers' preferences and implications for fisheries management
70	Shareef M. Siddeek	Determination of biological reference points for Bristol Bay red king crab

71	Margarida Castro, Artur Araújo, Pedro Monteiro, Ana Margarida Madeira and William Silvert	The Efficacy of Releasing Caught *Nephrops* as a Management Measure
76	**Chryssi Mytilineou, Politou, C.-Y., Kavadas, S., Fourtouni, A., Kapiris, K. & J. Dokos**	Crustacean fishery in the Greek waters during the period 1990-1999
83	**J. Molares & J. Freire**	Fisheries and management perspectives of the goose barnacle *pollicipes pollicipes* of Galicia (NW Spain)

Book of abstracts

One hundred and seven abstracts of oral and poster contributions were submitted to the conference organisers. These are presented below. Numbers refer to the number in the Conference Program above.

Oral Presentations

1. *Decapod Life History Characteristics: Implications for Management, John Stanley Cobb and Saran Twombly*

The life history characteristics of decapods vary enormously among species and within groups. These traits are shaped by natural selection in such a way that individuals which replace themselves most efficiently are favored. Because they are so intimately related to reproduction and population growth rate, life history traits have great implications for management of exploited species. We will first briefly review some examples in which management take has taken decapod life histories into account. Then we will examine implications of differing life histories (e.g. *Nephrops, Homarus, Penaeus* and *Callinectes*) to decapod harvesting strategies and fishery management using matrix projection models. We will use elasticity indices derived from these models to assess the contribution of various life history traits to population growth.

2. *Life history, individual variability, and environmental structure: incorporating ecological process into spiny lobster population models, Mark Butler*

Individual variability in life history is a feature of crustacean biology. This presentation will discuss individual based modelling approaches in spiny lobster research and the importance of incorporating life history features and the relationship between the species and it's environment in regulation of fisheries

3. *The scientific basis for assessment and management of Canadian snow crab (Chionecetes opilio) resources, Earl G. Dawe and Bernard Sainte-Marie*

This paper provides an overview of the major life history characteristics of snow crab (*Chionoecetes opilio*) that represent the basis for conservation and fishery management measures throughout Atlantic Canada. Methods and the extent of applying conservation measures through such fishery regulations as size limits and fishing seasons are compared among Canadian Atlantic regions. The scientific knowledge base is thoroughly reviewed in relation to the state-of-the-art in assessment methodology, based predominately on annual trawl surveys. Results of recent field and laboratory studies are reviewed in relation to potential implications for management. Current hypotheses concerning recruitment patterns and mechanisms are presented and research priorities are discussed.

4. *Aspects of the Newfoundland and Labrador Snow Crab (Chionoecetes opilio) Biology and its Effects on Commercial Fishery Harvesting Strategies, David M. Taylor*

The Newfoundland and Labrador snow crab fishery began in 1968 as a groundfish gillnet bycatch fishery and has expanded at a very rapid pace since the early 1990's. Currently, landed value exceeds 300 M $ Can. with landings approaching 60,000 t. Management of this valuable resource incorporates a complex integrated strategy utilizing resource surveys, mandatory logbooks, seasons, size limits etc. The fishery is a male-only fishery with females reaching sexual maturity and terminal molt well below the commercial size limit. Aspects of male biology related to growth and maturity present unique challenges to scientists attempting to provide advice on resource status based on the interpretation of research survey and commercial fishery data that may be contradictory. The harvest is governed by a three year management plan developed via a complex set of inter-related protocols which consider input from various sources including fishers, processors, resource management and science.

5. *Variation in population fecundity of shrimp (*Pandalus borealis*) in the Barents Sea, Michaela Aschan and Hege Ø. Hansen*

The relationships between egg number, egg weight, female length and age at sexual maturity of shrimp (*Pandalus borealis*) are explored. Samples for *per capita* fecundity analysis were sampled from the northern and the southern Barents Sea in 1999 and 2000. Length at maturity data are available for 9 sub-areas from annual surveys since 1990. The relationships between number of eggs and carapace length, L_m (Length at maturity, first time spawning female) and reproductive performance are compared with studies performed in this area in the 80's. L_m is known to be the major determinant of lifetime egg production in fish and crustaceans. The age of first time spawning females has decreased within 20 years. The per capita fecundity is combined with data on L_m and abundance estimates and the population fecundity is estimated for the population. The reason to the variation in population fecundity is discussed in relation to change in temperature, predation by cod and fishing pressure. The relevance of these life history parameters for stock assessment and prediction is discussed.

6. *Growth performance at different temperature regimes in shrimp larvae (*Pandalus borealis *Krøyer 1838), in relation to recruitment in the Barents Sea, Tone Rasmussen and Michaela Aschan*

Pandalus borealis is a coldwater species with a wide distribution area. The larvae hatch in the spring, and are pelagic for 2-3 months. At hatching, the larvae are released into water-masses with temperatures ranging from 0-12 °C. The larvae undergo 5 zoeal stages, and a megalopa before entering the post-larvae stage. Some studies have provided an optimum temperature of 9°C for *P. borealis*-larvae, which is only experienced by larvae in the southernmost distribution area. In the Barents Sea and Balsfjord, the larvae experience temperatures of 1-4°C at hatching, increasing to 4-10°C at settlement. In this study, larvae originating from ovigerous females from the Barents Sea and Balsfjord, were reared in compartments at *ad libidum* food conditions and given two temperature treatments; naturally increasing temperature (1-8°C) and constant temperature (2°C). At hatching, both size and dry weight were significantly higher in larvae originating from the Barents Sea. The increase in dry weight and developmental stage in the naturally increasing temperature was regular (first megalopa reached after 57 days). At constant temperatures the inter-moult period duration increased with increasing stages and the dry-weight development was significantly lower. The mortality at constant temperatures was very high, but significantly higher in larvae from Balsfjord than from the Barents Sea. The results are discussed in relation to the oceanographic conditions in the different areas and compared to the recruitment indices observed in the Barents Sea.

7. *Deep-sea shrimp* Aristeus antennatus *risso 1816 : a long-term study and perspectives, Francesc Sardà, Joan B. Company and Francesc Maynou*

The shrimp *Aristeus antennatus*, is a species mainly characterized by their wide distribution in the Mediterranean Sea. It range 200 m to more than 2 200 m. This means that this species ocupied several habitats adapting their population structure and feeding habits to each one of them, and finally adapting its life cycle to the colonized habitats (canyons, upper and middle slope –fishing grounds- and lower slope –virgin grounds-). After more than 10 years of experience in the deep fishing of this species in the western Mediterranean, new results are presented about the efficiency of the samplig gears used, and comparison between fishing and virgin population are made. An increase of the abundance around 1 400 – 1 500 m depth is pointed out, which was not detected previously. New data from very recent studies until 3 000 m in Mediterranean are also presented. In basis of this observations three hypothesis about the possible exchange of individuals between fishing and virgin grounds are made.

8. *Differences in population characteristics for* C. pagurus *on an exposed and a sheltered region in North-western Norway, Astrid K. Woll*

During June to November 1978 and 1979 and March to July 1993 monthly crab surveys with pots were conducted on an exposed and a sheltered region in Romsdal, North-western Norway. CPUE (crabs per pot haul) were estimated. Carapace width, sex and shell condition were registrated for all crabs (n=5107), as well as sexual maturity and meat quality for a limited part of the catches. A total of 1497 crabs were tagged during the study.

From June to November fishing was conducted on depths equal to the commercial fishery in both regions, while the spring fishery in the sheltered area was conducted in deeper waters. Crabs from the exposed region were in average smaller and sex ratio about 1:1 compared to the larger crabs from the sheltered region where females dominated. In the whole study CPUE in the exposed region showed small variation, ranging from 4.0 - 6.7 in monthly average. In sheltered areas, CPUE was considerably lower, and from March to June only a few crabs were caught. Recapture in the exposed region was less than 4%, while in the sheltered areas 19-25%. In the latter, recapture showed that females could migrate at least 20 km, while no males had moved more than 5 km. No connection between the regions was observed.

The population characteristics, based on data from the pot catches, are discussed with regard to temperature, bottom substrate, recruitment and migration. A resource study of these region and others commence in 2001.

9. *First results on the fisheries biology of* Penaeus (Melicertus) kerathurus *from Thermaikos Gulf (N. Aegean Sea), Kosmas Kevrekides and Maria Thessalou-Legaki*

The prawn *P. kerathurus* is an important target species for the Mediterranean fishery in terms of value. However, its study in the Greek Seas has been initiated only until recently. One of the main fishing grounds for the species in Greece is situated in Thermaikos, a gulf receiving the fresh water inflow of some of the largest Greek rivers such as Axios, Aliakmon and Loudias. The stock is exploited both by trawlers and coastal fishermen. Nevertheless, no information on the biological aspects of that stock was available until now.

During the fishing period of 2000-2001 (beginning of October to end of May) a fortnight sampling schedule was followed onboard a commercial trawler following the fishermen’s practices. Data collected refer to the prawn catch rates (CPUE) and population characteristics of the catch (sex, size, ovary maturation stage and spermatophore presence). In the present study, the variation over time of the CPUE values is given for the depth range sampled (35-55 m). Moreover, data concerning the population structure such as sex ratio and size frequency distribution are presented. Finally, the reproductive activity during the fishing open season is followed based on the ovarian maturation and the mated condition of the females.

10. *Is size at sex transition an indicator of growth or stock status in Pandalid shrimp?, P.A. Koeller, M. Covey and M. King*

Growth and sexual development of northern shrimp *Pandalus borealis* was determined in 4 areas on the Scotian Shelf during two periods, one of low and one of high population abundance, using deviation and modal analysis. Growth was slower during the period of high abundance, particularly at older ages, possibly due to density dependant effects and lower temperatures. Faster growth during the first period was associated with a smaller size at transition (L_t) from male to female and a smaller maximum size (L_{max}), while slower growth during the later period was associated with a larger size at transition, and a larger maximum size (and older age). In general, results are consistent with Charnov's sex allocation theory as it pertains to pandalids, in that smaller size at transition occurred during the period of low abundance, and vice versa. However, size at transition was not a good indicator of short-term changes in abundance that would be useful during annual assessments. Results are also generally consistent with Charnov and Skuladottir's (2000) theory of "approximate" invariance in the ratio of Pandalid L_t/L_{max}, although small scale differences in this parameter were found between times and areas for *P. borealis* on the Scotian Shelf. This invariance allows determination of von Bertalanffy growth curves from measurements of L_t and $L_{max.}$ alone. L_t (or L_{max}) are therefor more directly indicators of individual growth rates rather than changes in population abundance. While an increase in average L_t in the population could indicate an increasing population due to density dependant effects on growth rate, it could also be due to decreasing growth rates from decreasing temperatures or other factors. Consequently size at transition should be viewed as an indicator of individual growth rate for stock assessment purposes. The terminal moult implied by the invariance of L_t/L_{max} was confirmed by a laboratory study.

11. Uncertainties of Natural Mortality Estimates for Eastern Bering Sea Snow Crab, Chionoecetes opilio, *Jie Zheng*

Instantaneous natural mortality (*M*) estimates are very uncertain for eastern Bering Sea snow crab, *Chionoecetes opilio*. An *M* of 0.3 has commonly been used for the mature population whereas the only published study concluded that *M* is larger than 1.06 for morphometrically mature males. In this study, I constructed catch-survey models with trawl survey data from 1989 to 2000 to estimate *M* for the eastern Bering Sea snow crab stock under different assumptions on molting probability of morphometrically mature males, handling mortality rate of bycatch, and survey catchability. Male abundance was categorized by size (80-99 mm, 100-119 mm, and >119 mm carapace width), shell condition (newshell and oldshell), and morphometrically mature status. Mature female abundance was grouped by shell condition. *M* estimates for males vary greatly, ranging from 0 to 0.98, depending on model assumptions. Molting probability of morphometrically mature males and survey catchability for large males (>99 mm) are the two most sensitive factors. Allowing morphometrically mature males to molt fit the data significantly better than a zero molting probability assumption, and assuming a low survey catchability for large males resulted in a high estimate of *M* for mature males. Different *M* values for small mature, large mature, and immature males also fit the data significantly better than a constant *M*. Because of no retained catch, very low bycatch, and no molting after maturity, *M* estimates for mature females are not so sensitive to model assumptions. The *M* for mature females was estimated as 0.52 using the data south of 61.2^{o} N and 0.56 using all data.

12. Energy reserves and survival of Alaskan snow crabs, Thomas C. Shirley

Alaskan snow crabs (*Chionoecetes opilio*) in the Bering Sea have supported one of the world's largest and most valuable crab fisheries in recent decades. Annual harvests commonly exceeded 100,000 metric tons until a drastic decrease in biomass of mature crabs resulted in sharply lower harvest quotas beginning in 2000. Molting in snow crabs is rare after the molt to maturity (anecdysis), and anecdysis may occur at a variety of sizes. Post anecdysial crabs have an extended life of unknown duration, but at least 5 years; older crabs have progressively more carapace fouling. The commercial fishery (males only) targets new shell males, which command higher prices than older crabs with more fouling, resulting in a larger stock of older males. The natural mortality of the different life history stages is unknown, but crucial to understanding the dynamics of the stocks, forecasting standing stock, and establishing rebuilding plans. We reared new shell and old shell snow crabs in laboratory tanks for one year, measuring survival, feeding rates, absorption efficiency, and correlates of well being. At termination, wet and dry weights of all organ systems were measured, and energy content of somatic muscles and hepatopancreas were determined with bomb calorimetry. Although we could not discern differences in mortality rates between the age groups, older crabs were more lethargic, ate significantly less, had lower energy stores, and were more susceptible to stress-induced mortality than younger crabs. Funding: Alaska Dept. of Fish & Game under Cooperative agreement from National Oceanic and Atmospheric Administration.

13. The reproductive biology of the blue swimmer crab, Portunus pelagicus *in Western Australia, Simon de Lestang*

Blue swimmer crabs, *Portunus pelagicus*, were collected from two marine embayments (Koombana Bay and Cockburn Sound) and two estuaries (Leschenault and Peel-Harvey estuaries) between 32 and 33^{o} S on the lower west coast of Australia and from a marine embayment (Shark Bay) much further north at *ca* 25^{o}

S. Comparisons between the data obtained from these samples were used to elucidate aspects of the reproductive biology of *P. pelagicus*.

The pattern of development of the ovaries and testes of *P. pelagicus* have each been separated into four stages, based on a combination of macroscopic and histological criteria. The prevalence of the different stages in gonadal development in each month demonstrated that (i) *P. pelagicus* spawns between September and January in the southern part of its range and throughout the year further north where water temperatures are greater and (ii) spawning occurs outside of estuaries. The attainment of sexual maturity was best determined in females by examining the shape of the abdominal flap and in males by ascertaining the stage in testis development. The carapace width of females and males at first maturity (CW_{50}) were significantly greater in Shark Bay (92.4 and 96.5 mm) than in either Koombana Bay (87.3 and 88.8 mm) or Cockburn Sound (86.2 and 89.7 mm). During a spawning period, small mature female crabs produced only one small batch of eggs, while larger females produced three large batches of eggs.

14. Comparisons of reproductive parameters in two Scottish populations of the European lobster, Homarus gammarus, *Hector A. Lizárraga-Cubedo*

The *Homarus gammarus* fishery is very important on the coasts of Scotland, and has been recognised as an important source of income for fishermen since the turn of the 19th century. Although studies of population dynamics have been exhaustively recorded mainly for the American lobster, *H. americanus,* in the American and Canadian waters and for the European lobster in the coasts of Wales, England, France, Norway and more recently in Ireland, very little information is available for Scottish stocks. Sampling on commercial boats and regular visits to the local ports was carried out during 1999-2001 for the Fife of Forth and Hebrides fisheries. Data recorded comprised biological information such as size, sex, weight, morphometric measurements and egg samples. Length frequency distributions were also analysed. Comparisons of size at onset of sexual maturity (SOM), fecundity and egg development between populations are made.

15. Size at first maturity, mating behaviour and fecundity in the spiny lobster Palinurus elephas *Fabricius 1787 on the West Coast of Ireland, John P. Mercer*

First maturity in female *Palinurus elephas* was assessed by the presence or absence of ovigerous setae on the exopodites of the pleopods. Internal examination of the ovaries verified the accuracy of this method. External assessment of first maturity in males was more difficult. Generally the fleshy protuberances at the base of the 5th walking leg were almost lacking or proportionally much smaller in immature males. In doubtful cases microscopic examination of the testis for the presence or absence of spermatophores was required.

Prior to mating initial recognition/attraction between the sexes is by sound. The female stridulation or “mating call” attracts males from surrounding areas from a distance of at least 15-20 metres. The female ceases stridulation when the first suitably sized male makes antennal contact and other males discontinue directional movement until another female begins to call and the process is repeated. Early courtship is followed by what is probably a pheromonal release from the female which initiates the final stages of mating, cumulating in the deposition of a pair of external gelatinous spermatophores on the sternum of the female.

Total counts were made of extruded eggs and the relationships of egg numbers to morphometric features such as carapace length is discussed. The number of eggs is size related and ranges from approximate 30,000 + to over 200,000.

16. Reproduction and life-history of the native shrimp Penaeus kerathurus *in north Mediterranean, Alexis Conides, F. Lumare, K. Kapiris and G. Scordella*

EDFAM Workpackage III: Metapopulations and stock assessment of crustaceans

The shrimp *Penaeus kerathurus* is a product of high commercial value in the area of North Mediterranean. Major producing European countries are Italy and Greece. The species is not abundant along the coastal zone. In Italy, the population is scarcely distributed along the eastern and western coasts and is considered as a by-catch of commercial trawling. In Greece, the main areas of distribution are Amvrakikos Gulf, the coastal zone from Amvrakikos Gulf and south to Patraikos Gulf as well as the North Aegean Sea.

Reproduction of the shrimp in Italian waters followed the expected normal patterns. The initiation of the maturation in females (with the appearance of stage IV females) occurs during spring. The first maturation of females is confirmed by the arrival of broodstock in the coastal reproductive grounds. The reproduction period spans from May to August. Spent stages appear in late summer (August). The smallest female shrimp with a Stage IV mature gonad measured 174 mm (TL). GSI increases with the ovary development stage reaching a maximum at Stage IV (mature females) around 10.58% (up to 15.9%). GSI peaks in June and July. The fecundity was estimated 67,125 oocytes per g of ovary.

In Greece - as evident from the Stage IV females - the reproduction period spans from late April to late September. The increase of the percentage of spent females during the same period indicates that the release of eggs starts almost immediately (approximately within 15 days) after the first appearance of Stage IV females. The stimulus for the initiation of the reproduction of the shrimps is the rapid increase of temperature during March. In the following 30-40 days, the females and the males arrive at the reproduction grounds and copulation occurs. The smallest mature female was found to measure 30 mm in carapace length. GSI increases with the ovary development stage reaching a maximum at Stage IV (mature females) around 9.62%. GSI peaks in May and not in June-July as expected. The estimated fecundity was 154,600 oocytes per g of ovary.

The life-history patterns described show great differences. In Italy, the life-history pattern is the expected Type I (adult population is located offshore – reproduction occurs nearshore – young stages enter lagoons – recruitment migration follows towards offshore). However, in Greece a deviation to this expected pattern was determined in Amvrakikos Gulf. The adult population is located nearshore, the reproduction occurs nearshore and the young stages are distributed nearshore. Therefore, the lagoon stage is absent while the reproduction ground and the normal wintering grounds are mixed.

17. Brood care in Brachyuran crabs: the relationship between female behaviour, embryo oxygen consumption, and the cost of brooding, Miriam B. Fernández, Antonio Ruiz-Tagle & Nathaly P. Miguel

Investment in reproduction ranges from gamete production to active parental care, and marine invertebrates span this range. However, the cost of parental care has neither yet been systematically quantified, nor incorporated into life history studies of marine invertebrates, in contrast to most other animal taxa. Since oxygen is a limiting factor in egg masses of marine invertebrates, and Crustaceans are among the largest brooders in nature, we studied patterns of oxygen partial pressure over time in embryo masses of Brachyuran crabs and correlated these results with the cost of providing oxygen to the embryos and oxygen requirement of the embryos. We found that: (1) oxygen is limiting in the embryo masses of several species of Brachyuran crabs (e.g., Xanthidae, Cancridae), (2) female crabs show an active brooding behavior that provide oxygen to the embryo mass, (3) abdominal flapping is associated with an increase in oxygen availability in the center of the brood mass (in contrast, maxilliped beating and pereiopod probing occurs when oxygen availability in the center of the embryo mass is low), (4) the frequency of abdominal flapping strongly increased with embryonic development, as oxygen demand of crab embryos increases, and (5) there is a substantial parental investment associated with brooding behaviors (that also increases throughout embryonic development, in accordance with higher female activity). These results suggest that reproductive output (weight of egg masses) is not an indicator of investment in reproduction among Brachyuran crabs. Oxygen limitation and parental investment seem to be associated in many taxa of marine invertebrates, and we suggest that oxygen provision to the embryos may be a critical factor determining parental investment.

18. *The* Nephrops norvegicus *(Decapoda: Nephropidae) biological clock through cardiac rate analysis, J. Aguzzi and J. P. Abelló*

Aspects of the circadian activity rhythm of the Norway lobster *N. norvegicus* (L.) have been assessed from a physiological point of view. The cardiac activity rhythm has been studied with an infrared electrode technique developed by Depledge and Andersen (1999). A total of 43 adult males with a carapace length ranging from 32 mm to 44 mm, freshly collected from 400 m depth have been surveyed in constant conditions of darkness and temperature (13°C) equalling that of the natural environment for a period of time shorter than one week. The number of heart beats per minute has been obtained and time series analysis revealed the occurrence of heart rate peaks with a periodicity of 24 h along with smaller percentages of individuals showing shorter periods of 12 h and 18 h. Estimate forms revealed multiple peaks profiles and indicated that the timing of peaks in cardiac activity corresponded to the expected night phase. Cluster analysis based on estimate forms profiles revealed a great similarity independently from the number of peaks expressed. Correspondence analysis confirmed the link between peaks and the nocturnal hours. Implications of heart rate rhythmicity with other aspects of *N. norvegicus* biological clock will be discussed.

19. *Should we protect the berried females? : Reproduction cycle, growth and migration of mature female European lobster (*Homarus gammarus *L.) off southwestern Norway, Agnes –L. Agnalt, Tore S. Kristiansen and K.E. Jørstad*

In 1998, a project financed by Directorate of Fisheries aimed to evaluate the feasibility and effect of protecting the berried lobster females in a small fishing area off western Norway as a management restriction. A total of 1 472 berried females were bought from fishermen from spring 1998 to spring 2000 and tagged with a stream-tag released into the capture areas after the fishing season. All females were prior to release individually tagged, measured and weighed and release location was recorded, which enabled us to elucidate aspects of reproduction cycle, growth and migration.

The proportion of females being egg berried varied between years. Normally between 25 and 35% of the females are berried at a given time However, in autumn 1998 this ratio was 47%, and in autumn 1999 only 18% were berried. By spring 2000, 25% of the tagged females had been recaptured at least once, and 3% had been recaptured two ore more times. On average, moult increment was 7.2 mm in carapace length and independent of premoult size. The results indicated that reproduction and growth alternates in a 2-year cycle. However, a small number of females moulted and spawned few weeks after hatching. These females had similar growth increment as other moulting female. A small study that took place in spring 1998 revealed that about 15% of the females had developing ovaries as well as being berried. Of the releases made in autumn 1998 42 have been recaptured with information on recapture site. Of these 10 individuals (24%) had remained on the release site, while the others had moved from 100 to 350 m. The potential increase in larvae production due to the protection of berried female, under the current and alternative fishing mortalities, was modelled and these results and the question whether we should protect the berried females are discussed.

20. *Trawls catches circadian rhythmicity of* Nephrops norvegicus *(Decapoda: Nephropidae) in the north-western Mediterranean: a perspective through depth and season, J. Aguzzi & F. Sardá*

The circadian activity rhythms of the Norway lobster, *N. norvegicus* (L.) has been surveyed, in the northwestern Mediterranean through the perspective and depth. Circadian rhythmicity has been surveyed with continuous 24-h cycles of trawls tows during four days at 100 m and 400 m in autumn and spring. Each one of the four days series of trawls tows has been overlapped with a periodicity of 24 h, creating an estimate form.

The profiles revealed the presence of two peaks of cathc at 100 m (sunset and sunrise) and a single peak at 400 m (toward midday). These patterns were respected independently from sex and followed also by berried females in October.

Size class analysis, through estimates from profiles, indicated the presence of a different timing in the burrow emergence behaviour in animals with a carapace length smaller and bigger than 35 mm. Smaller animals exit from the burrow before the bigger animals.
To reveal the exact periodicity of recorded rhythms the temporal series of data have been analysed with periodogram software. Results indicate an exact periodicity of 12 h at 100 m and 24 h at 400 m.

21. *Influence of the rhythmic behaviour of the Norway lobster (*Nephrops norvegicus *L.) on it's catchability by trawl fishery in the western Mediterranean (NERIT), F. Sardà*

This project aims to increase the basic and applied knowledge which would allow a better and rational management of the Norway lobster resource of the Spanish Mediterranean, by introducing the circadian and seasonal rhythmic behaviour as a source of catch variability .

During the last years we have seen fisheries collapse in many places of the world for different causes, from the failure of the scientific predictions l to consider the mathematical models as paradigms of the assessment and fishing management. We will surely find successes and failures of each one of the previous examples, but all the fishing agents agree practically that the future fishery should considere more in depth the autoecology and environmental conditions that affects populations. In this context the goal of this presentation consists on the description of a project, at this moment in its final phase of development, that seeks to establish the existent relationship among different biological scales that can be implied in a multidisciplinary way in a specific fishery, from each individual's physiology, to the catch by trawling, going by the population's behaviour. This scenario is developed on the fishery of Nephrops norvegicus in the Catalan Mediterranean sea. Here are presented some main results, hypotheses and the interest of the behavioural studies useful for management beyond the technical knowledge. Concrete objectives of the project are: 1.- To determine, by means of field sampling at short time intervals, the existence of circadian rhythms in two distinct Norway lobster populations present at different depths: Ebro delta shelf, between 70 and 120 m depth, and continental slope, between 400 and 500 m. 2.- To determine the patterns of individual activity and related physiological parameters in relation to the photoperiod and food availability (endogenous and exogenous factors) by experimentation in the laboratory. 3.- To determine the rhythmic activity effect of the Norway lobster population in the catchability, in order to optimize the fishery under a sustainable management scheme and to introduce this parameter in the catch predictive models and assessments , by hourly registering of catches by the commercial fleet.

22. *Sex, Tides, and Videotape: Do tidal rhythms control the timing of aggregation and hatching in Tanner Crabs,* Chionoecetes bairdi*?, Bradley G. Stevens*

Female Tanner crabs form high density aggregations each spring, wherein crabs form mounds containing hundreds to thousands of animals, at 150 m depth. Over 100,000 crabs may be present in an area of about 2 ha. Previous studies suggested that aggregation and mating were synchronized with spring tidal cycles. In 1999, we placed a current meter near the aggregation, then observed aggregation behaviour with a remotely operated vehicle over an 8-week period. We also collected crabs from the aggregation, brought them into the lab, and determined numbers of larvae hatching daily. The median dates of hatching coincided with the peak of mound formation, and the strongest tides in May. During this time, net tidal flow totally reversed for 3-4 days. In the lab, 95% of larvae hatched between 8 and 12 pm. This data suggests that tidal flux is the zeitgeber for a biological clock that synchronizes larval hatching. It also implies that the timing of larval hatching for *C. bairdi* changes in monthly steps, and is not a linear function of temperature or degree days, thus disconnecting it somewhat from environmental control and synchrony with plankton blooms.

23. Persistence and Stability of Marine Meroplanktonic Metapopulations : The difficulties in studying the dynamics of crustacean metapopulations, Loo Botsford

The available theoretical results regarding when these populations will persist under various perturbations such as fishing and marine reserves, and what effects they have on stability will be reviewed. These will be related to existing concepts such as sources and sinks and other types of metapopulations. The results of this comparison are not particularly enlightening Knowledge of the dispersal paths appears to be crucial. A case study from the west coast of the US shows how important this is and how that affects persistence, stability, fishery management and the design of reserves.

24. Determining the extent and spatial scale of connectance: Are there lessons from coral reef fishes?, Peter F. Sale and Jacob P. Kritzer

Patchily distributed demersal marine organisms that possess a pelagic larval stage have the potential to form metapopulations with connectance provided by larval dispersal. Unfortunately, determining whether this potential is realized in specific cases is quite difficult: larval dispersal is a complex result of several biotic and non-biotic processes, and marine larvae are minute creatures that are difficult to track or manipulate. Nevertheless, effective management of such populations requires that we know how they are organized and if metapopulation processes are involved. Coral reef fishes are not crustaceans, but they share patchy demersal distributions and pelagic larvae. We review progress made in determining connectance among reef fish populations, considering the questions that need to be answered and the techniques that have been applied. We consider the ecological similarities among reef fish and selected decapods, and suggest ways in which knowledge gained about either group can lead to new insights about metapopulation structure in demersal marine taxa.

25. Ecology of the dispersive phase of marine decapod crustaceans, Henrique Queiroga

The literature on the ecology of the larval phase of decapod crustaceans is being reviewed. The analysis is concerned with 3 main questions: 1) Which are the types of dispersal mechanisms displayed by larval stages throughout ontogenic development? 2) How does cyclic vertical migration interact with the physics of the ocean to control the dispersal of larvae? 3) Which are the estimates of larval mortality? This review is mainly interested in marine and estuarine genera that are exploited commercially, although reference to other species is made whenever those constitute the best examples of processes that are thought to be relevant for commercial species.

The transport of marine larvae among local populations is a regional process. It has become increasingly clear that transport of larvae is accomplished by a complex interaction of the physics of ocean circulation, the behaviour of the larvae and the duration of the planktonic stages. The behaviour that has the greater potential to affect dispersal is vertical migration, both ontogenic and cyclic. In shelf or oceanic waters, the nocturnal type of vertical migration (ascending to surface or subsurface layers during dusk and descending somewhere during the night or at dawn) appears to be a common pattern. Moreover, the phasing and the extent of the migration change during the course of development. Another type of rhythmic vertical migration is tidally synchronized migration, which constitutes the base for the selective tidal stream transport exhibited by larvae of all estuarine species that have been investigated.

There is a general agreement that larval mortality in decapod crustaceans is high. Mortality is a crucial parameter to understand flux of larvae between local populations, because even if the dispersal range of the larvae and the transport mechanism are known, that does not tell much about the fraction of the larvae that are going to settle. However, very few, if any, realistic estimates of natural mortality exist. One of the difficulties of estimating larval mortality arises from the habitat where the larvae develop, which is, by definition, the plankton, be it estuarine, shelf or oceanic. If larvae somehow control their dispersal through behavioral mechanisms that change during the course of ontogenic development, then the first and last larval stages will have a very different distribution than the intermediate stages. This mismatch between hatching, development and settlement areas will also arise even if there are spawning or juvenile migrations. Therefore, synoptical studies that are usually employed to estimate abundance and mortality will provide unrealistic estimates unless the same proportional sampling effort is used in all habitats/areas that the larvae use during the course of development. This is difficult to accomplish, because in many cases larvae hatch/settle in areas that are difficult to sample, such as the nearshore, or in areas that require different sampling programs from the ones used to sample the intermediate stages, such when hatching/settlement take place in estuaries and larvae develop on the shelf.

The patterns identified will be related to variables such as taxonomic group, habitat of adults, habitat of larvae, length of the larval period, number of eggs produced, geographical area, etc.

26. The advection and population dynamics of Pandalus borealis *investigated by a Lagrangian particle tracking model, O. P. Pedersen, M. Aschan, K. Tande, D. Slagstad and T. Rasmussen*

The main objective of this study is to identify mother populations and the area of post-larval settlement by a particle-tracking model and a biological model including ontogenetic migration and temperature dependent development.

The shrimp (*Pandalus borealis*) is a protandric hermaphrodite changing sex from male to female at an age of 4 to 7 years in the Northeast Atlantic. The shrimp spawn in autumn and the eggs are carried externally by the females until spring when the larvae hatch. Within a period of 2-3 months the shrimp larvae pass through seven developmental stages where after they settle to the.

Hydrodynamic models have been developed for dispersal of particles (e.g. plankton) in the sea but the lack of accurate biological data on shrimp larvae has made the use of such models unreliable. We have included new data on larval hatching, development and behaviour to be used as input data in a particle tracking model and an associated biological model. By the use of indvidual-based particle tracking models it is possible to assess the life history of every individual, as opposed to an eulerian model. The concept of particle tracking modelling requires three main constituents to function operationally: A hydrodynamic model capable of delivering flow fields, a particle tracking model (advection scheme) and a biological model.

The years simulated in this study is 1996, -97 and -98. The input data for the model is provided through cruises performed at Fiskeriforskning AS providing estimates of spawning females. The biological model incorporated simulates the population dynamics of shrimp undertaking a stage progression from larvae to ZVI, along with vertical migration imitating the ascent to the surface as larvae and the descent to the bottom.

The results indicate large inter-annual variability with respect to dispersion. This is most likely explained by the position of the Polar Front and the inflow of Atlantic Water into the Barents Sea. The particle tracking simulations is in good agreement with field data showing spatial patterns in post larval settlement.

27. Distribution of Cancer pagurus *larvae in relation to hydrography on the east coast of England: implications for stock structure and management, Derek Eaton, Julian Addison, Steve Milligan, Juan Brown and Liam Fernand*

Edible crab (*Cancer pagurus*) fishing areas are distributed along the English east coast with significant offshore fisheries off North Norfolk and the Humber. Previous tagging studies showed directed northerly movements of mature females suggesting that recruitment was strongly influenced by larval drift southwards. Comparison of results from a larvae survey undertaken in July 1999 with two previous surveys in 1976 and 1993 suggests that the epicentre of crab spawning, as perceived by the density of stage I zoea, was consistent over the 23 year period, being centred to the south-west of The Dogger Bank approximately 70km offshore. Recent hydrographical evidence suggests that there is a seasonal jet-like circulation which extends southwards along the coast as far as Flamborough Head before turning offshore along the northern edge of The Dogger bank. The front forms in April/May and breaks down again in October/November, and once established there is very little interchange between water masses north and south of the Dogger Bank. South of the Dogger Bank, there appears to be a fairly stable water mass with only a slow residual drift in an easterly direction. The areas to the north and south of the front are effectively isolated therefore during the period of crab spawning activity challenging the accepted wisdom that the main crab fishery is reliant upon recruitment from spawning areas to the north. The crab population south of the Dogger Bank may be effectively a separate, self-sustaining stock and may provide recruitment of adult crabs to northern areas.

28. Post-settlement processes and the search for the stock-recruitment linkage in lobsters and crabs: Is experimental ecology the key ?, Richard A. Wahle

Field experiments demonstrate that post-settlement processes can be important determinants of local recruitment success in crabs and lobsters, but for most species the stock-recruitment relationship remains poorly understood. Here I give a critical overview of advances in assessing the relative importance of pre- and post-settlement processes to the recruitment of commercially and/or ecologically important lobsters and crabs. It is noted that cases such as the rock lobster of western Australia, in which there is direct link between larval supply and recruitment to the fishery, may be uncommon. There are more examples of species in which density-dependent processes decouple that linkage during early benthic life. Over the past decade or so, a combination of innovative field experiments, monitoring, and modeling has improved our understanding of the influence of competition, predation, cannibalism, and sperm limitation on the demography of these species. Still, for some crabs and lobsters the influence of density-dependent processes on recruitment remains unclear. For example, density-dependent mechanisms were long suspected to limit harvests of the American lobster, but in the late 1980¹s an unexplained manifold increase in abundance spread over the entire species¹ range that continues over some areas today. This phenomenon has raised doubts about the existence of habitat "bottlenecks" in early benthic life despite contradictory evidence of shelter competition on a local scale. Uncertainties about age-determination and the relevant spatial scale have posed further challenges to evaluating recruitment in these marine crustaceans. Here I draw from several examples to underscore the need to design ecological studies at a geographic scale that will reveal the stock-recruitment relationship.

29. Why fishery biologists should pay attention to early juvenile processes: The shore crab example. Per-Olav Moksnes

Understanding whether local recruitment is limited by larval supply or by juvenile resources is critical for management of marine benthic species. I used juvenile populations of shore crabs *Carcinus maenas* along the Swedish west coast, as a model system for benthic decapod species, to test if nursery habitats could limit local recruitment, and if density-dependent juvenile cannibalism and competition could act as regulating mechanisms.

In a large-scale field study I continuously measured larval supply and distribution of microhabitats in six small nursery areas and subsequently compared the recruitment patterns of juvenile shore crabs between areas and years. I found no correlation between the recruitment of juvenile shore crabs and larval supply, despite a 10-fold difference in relative larval abundance between populations, but instead found a strong and significant correlation between juvenile recruitment and the local abundance of nursery habitats. Complementary laboratory and field experiments demonstrated that density-dependent growth, cannibalism and emigration from the refuge habitats occurred at natural crab densities, which decoupled settlement and recruitment patterns within days.

These results suggest that density-dependent juvenile interactions can regulate the recruitment of juvenile shore crabs and that the availability of shelter represents a demographic bottleneck for local populations. Thus, this study suggests that effective management of Swedish shore crabs should focus on the conservation of shallow water habitats since local population size may be controlled by the distribution of nursery habitats. A management based only on conserving the adult population sizes (e.g. stocks) at present levels may be less effective since the density-dependent processes affecting young juvenile stages appear to decouple any stock-recruitment relationship.

30. *Changes in* Homarus americanus *recruitment in the Gulf of Maine—Larval Subsidy, Local Supply or Post-Emergent Survival?, Lewis S. Incze, Richard A. Wahle and Nicholas Wolff*

During the past decade there has been up to a 3-fold increase in landings of American lobster, *Homarus americanus*, along part of the Maine coast. We know that YOY recruitment is highly correlated with postlarval (planktonic) supply, and we have measured both high and low settlement years. The source of the larvae is undoubtedly mixed. Circulation features exist to transport lobster larvae and postlarvae long distances around the Gulf of Maine, but it is not clear how often the necessary across-shelf exchange processes bring postlarvae into shore, or how important this process is compared to inshore (more local) egg production and larval survival. Spatial patterns of hatching, which could vary from year to year, could be a factor. We will evaluate how much of a change in these three parameters would be required to account for the observed interannual variability in postlarvae/YOY and the increase in landings over the past decade. Another factor that could have caused the population increase is increased survival of benthic, post-emergent juveniles. This is an appealing hypothesis because the underlying mechanisms (such as reduced predation) could have some persistence that would explain the decade-long build-up in the population. However, that would not account for the dramatic decrease in early life stage abundance that we have seen over the past five years, something that we feel must be due to changing patterns of egg production, reduced survival of planktonic stages, or unfavourable transport. The increase in landings and later decline in early life stages are not necessarily inverses of the same processes. We will conduct a sensitivity analysis for each of the potential factors in the observed population and recruitment changes: egg production, planktonic mortality, external planktonic subsidy, and post-emergent mortality.

31. *A review of life history stages of crustacean fisheries in Western Australia and their implications for research and management of fisheries, Nick Caputi*

This presentation reviews and updates some of the relationships between life history stages in western rock lobster in a way that provides insight into the processes controlling the development of the local population (larval dispersal, spatial scales and source sinks and stock recruitment, effects of fishing on spatial distribution of egg production).

32. *Metapopulation dynamics in the spider crab* Maja squinado*: implications for fisheries management, J. Freire, A. Corgos, C. Bernárdez, l. Fernández, A. García-Allut, E. González-Gurriarán and P. Verísimo.*

Coastal decapods exhibit a complex spatial population dynamics, but their consequences are not usually incorporated in fisheries management. We summarised different studies carried out in the Galician coast (NW Spain) to determine the existence and characteristics of the metapopulation structure of the spider crab *Maja squinado* and the incorporation of these findings in the design of alternative management policies.

A combination of experimental and sampling methodologies were applied: experimental sampling using suction pumps, beam-trawls, traps and gillnets; mark-recapture experiments; telemetry and electronic data storage tags; observations of fishery operations; and fishers' ecological knowledge. Our results indicate that spatial structure of *Maja* populations are driven by ontogentic habitat shifts involving both bathymetric and habitat changes; aggregative behaviour of juveniles in shallow areas; and reproductive migrations of adults to deep waters. *Maja* presents a complex metapopulation structure characterized by chains of subtidal juvenile local populations (segregated by age/size) along the coast with a dynamics dominated by recruitment and mortality. These juvenile populations show a source-sink dynamics because only some of them provide adults whereas in others, although there is recruitment, juvenile mortality is almost absolute. The juvenile populations show a scale of 100s m and their connectivity is based in larval recruitment and ontogenetic shifts. Adults constitute local populations in deep waters (30-150 m) with scales of 10s to 100s km, and migratory movements dominate their dynamics.

Fisheries management in this species has been based in minimum sizes and effort limitations without any spatial regulation. The effort control has revealed to be ineffective. Using the above findings, spatial-explicit yield- and egg-per-recruit analyses were carried out. The incorporation of the spatial dynamics of the population was showed to be critical to understand the impact of the fishery and regulations based in the protection of shallow habitats could be more effective and robust to uncertainties than effort controls for the sustainability of the fishery. New management systems based in territorial rights and co-management are proposed to implement these policies.

33. Sustainable management of community based spiny lobster fisheries and the problems of metapopulations, Bruce F. Phillips, Jaime G. Cano and Armando V. Velazquez

Many of the world fishery resources are over-exploited or fully exploited. For this reason, and parallel to traditional methods of control, new “incentive-type” mechanisms were designed to work for sustainable marine fisheries by promoting responsible, environmentally appropriate, socially beneficial, and economically viable fisheries practices, while maintaining the biodiversity, productivity and ecological processes of the marine environment. The Marine Stewardship Council (MSC) is an initiative dedicated to promoting “well-managed” or “sustainable” fisheries. It identifies such fisheries through means of independent third-party assessments and once certified, these fisheries are awarded the opportunity to utilize an MSC promoted eco-label to gain economic advantages in the marketplace.

To gain such certification the fishery is examined against a set of MSC “Principles and Criteria for Sustainable Fishing”. These principles and criteria, form the basis for qualifying fisheries as certified and hence ability to utilize the MSC eco-label. In principle, the eco-label and criteria were thought most suitable to be met by large industrial fisheries. In reality, semi-industrial and small-scale fishery type fisheries may also meet the principles of MSC. However, community based fisheries are commonly targeting species which are part of metapopulations. Thus, sustainable management of these fisheries is difficult because of the lack of independence of the population being fished from the total stock, and often-political problems of differing regulations or approaches to management, where the other populations of the stock are in different countries, or perhaps different States or Provinces of the same country

Spiny lobsters are good examples of such metapopulations. They are fished in coastal areas of many countries. Specific examples are *Panulirus argus* and *Panulirus, interruptus*, found around the Caribbean Sea and along the Pacific coast of Mexico and the USA, respectively In this paper we examine the methods of assessing the sustainability of these spiny lobster fisheries, and discuss to what degree sustainability depends on the successful management of the local resource as opposed to management of distant resources, and how these relate the certification standards of the MSC for well managed fisheries. It analyses different metapopulation structures and the types representing each of the lobster fisheries under consideration. The implications of each arrangement and the “sink-source” processes that provide or contribute to the stability of the population as a whole.

In the case of *P. argus* at Banco Chinchorro, is a relatively stable fishery within a Biosphere Reserve and is therefore subject to a comprehensive management system. The source of the larvae is unknown, but it is a sink and postlarvae from other southern areas of the Caribbean region contribute to the settlement and standing stock in this atoll. The area has geographical barriers that impend the emigration of lobsters to other areas. But it is a source, because breeding females at Banco Chinchorro contribute larvae to the metapopulation. Although a direct stock-recruitment relationship cannot be demonstrated due to the openness of the system, the fact that larvae are supplied to the rest of the population complies with the principles of the MSC.

In Baja California, the red lobster (*P. interruptus*) fishery in Mexico has recently had catches that are at record levels in the catch series. The range distribution is smaller than *P. argus* and it is shared by only two countries, Mexico and the USA. The fishery is partly in a Biosphere Reserve and the management of the area producing at least 85% of the catches is from an area which are well managed, where the communities are well organized in cooperatives, and who have established a co-management system where all major stakeholders participate. The origin of larvae in this case is known but been a metapopulation, the relationship between the Mexico and USA fisheries cannot be understood without reference to both populations and to the system as a whole. The eographical gap between the two fisheries conforms a system where one fishery probably behaves as a main source of larvae while the more northerly population behaves more like a sink due to the immigration of larvae.

It is concluded that sustainable management in community based fisheries is very dependent on the organization and the participation of the community in the management system. That in a metapopulation situation some of the areas will behave as “sinks” and other as “sources” or both. That good management can be supported (certified) in one subset, even in the absence of comprehensive analysis of the entire metapopulation, as long as the fisheries under examination are stable and the management systems of the other sections of the metapopulation do not appear in danger of collapse, which might lead to inadequate post-larval supplies.

34. Stock-recruitment Relationships for Alaskan Crab Stocks, Jie Zheng and Gordon H. Kruse

Stock–recruitment (S–R) relationships have important implications for harvest strategies but are difficult to develop for crab stocks because crabs lack retainable hard body parts, like scales, to age them. Moreover, lack of sufficient knowledge about complex reproductive biology complicates estimation of effective spawning biomass. To evaluate harvest strategies, we developed S–R relationships for three major crab stocks in Alaska: Bristol Bay red king crab, *Paralithodes camtschaticus*, Bristol Bay Tanner crab, *Chionoecetes bairdi*, and eastern Bering Sea snow crab, *C. opilio*. We estimated recruitment from length-based models based on growth data for recruitment age, and effective spawning biomass from male and female abundance, male fertilization capability, sex ratio, size and shell structures of males, molting period duration of the female population, and duration of male attendance during mating. For all three stocks, a Ricker-type model fits the observations better than a Beverton-Holt model, and an autocorrelated or general Ricker model has a better fit than an ordinary Ricker model. For both Tanner and snow crab stocks, recruits are not strongly associated with effective spawning biomass and much variation of recruitment can be explained by autocorrelation or cycle; thus, environmental factors are likely to play a very important role in recruitment success. Weak recruitment is associated with extremely small spawning biomass and strong recruitment is produced by intermediate spawning biomass for the Bristol Bay red king crab stock, suggesting possible density-dependent effects.

35. Use of artificial habitats to increase production of juvenile crabs: habitat selection and post-settlement processes, Miriam Fernández, David Armstrong and Oscar Iribarne

Habitat selection and survival in artificial and natural habitats by megalopae and young-of-the-year (YOY) Dungeness crab were evaluated by a combination of laboratory and field experiments. Under laboratory conditions oyster shell (artificial habitat) was the most preferred habitat by megalopae and YOY, while other natural, complex habitats (eelgrass) ranked second. Megalopae and YOY showed the highest survival rate in the most preferred habitat; the main predator in each habitat type was different. In open mud sculpin and larger crabs (> 100 mm carapace width) were the main predators while in protected habitats cannibalism among YOY was the main source of mortality. These results show that the potential to increase production of YOY crabs in artificial habitats is limited, because cannibalism among YOY is greatly increased. Furthermore, this results also suggest that the pattern of larval arrival within a settlement season may have important effects on the size of a cohort.

36. Measuring the effects of pueruli removals and habitat improvement in assessing sustainability of spiny lobster populations, Bruce F. Phillips, Roy Melville- Smith and Yuk W. Cheng

A study was made to examine the impact of possible puerulus exploitation on future catches in the wild western rock lobster (Panulirus cygnus) fishery in Western Australia, and to determine management measures which might be required to maintain 'biological neutrality'. A primary aim of management to maintain sustainability of the Western Rock Lobster Fishery, is to maintain the reproductive capacity of the breeding stock at its current level. Biological neutrality is in this context, the level of catch that would need to be forgone to compensate the reproductive capacity of the breeding stock if pueruli were removed for aquaculture. This study was made using existing data on puerulus settlement, juvenile densities and mortalities, and Recruitment rates to the fishery. Density dependent mortality is very high between the time that pueruli settle on inshore reefs and when they move offshore as juveniles to recruit to the fishery. Estimated mortality of P. cygnus during the first year after settlement (from ages 1-2 years) in the central area of the fishery, was estimated as being either as low as 80% or as high as 97%. Only very small numbers of the settling pueruli survive to recruit into the fishery at about 4.5 years of age. The impact of puerulus removals on subsequent catch was estimated to be minimal except in the case of removal of very large numbers of pueruli and it would be possible to counter these losses by effort reductions. Studies of habitat improvement to increase juvenile survival in the first year after pueruli settlement, and eventual recruitment to the fishery are being conducted.

37. Population structure and gene flow in the European lobster Homarus gammarus*: an overview of results of the GEL project, Andrew Ferguson, P. Apostolidis, E. Farestveit, P. Heath, M. Hughes, K. Jørstad, V. Katsares, E. Kelly, J. Mercer, P. Prodöhl, J. Taggart, A. Triantafyllidis, C. Triantaphyllidis*

In the course of the Genetics of the European Lobster (GEL) project, samples of c100 individuals of European lobster have been collected from more than 30 localities throughout the range from northern Norway to Morocco and the Aegean Sea. In addition to tissue biopsies, information was recorded on basic biological parameters and specimens were photographed for subsequent morphometric analysis. The samples were analysed for variation in microsatellites, mitochondrial DNA, and allozymes. Details of these genetic analyses and results will be presented in associated posters. Combined data from these different approaches are currently being analysed with respect to population structure and gene flow and an overview of conclusions will be presented. The relationship between genetic variability and population dynamics, and the use of microsatellite DNA profiling for assessing the efficiency of V-notching, artificial enhancement and other management procedures will be considered. Results of the project provide a model for the application of modern molecular genetic analyses to understanding the stock structure, population dynamics, life history strategies, and management of many exploited crustacean species. Further details of the project are available at: www.qub.ac.uk/bb/prodohl/GEL/gel.htm.

*38. The decline of spiny lobsters (*Panulirus marginatus*) in the Northwestern Hawaiian Islands: An alternative hypothesis using metapopulation theory, Gerard DiNardo*

The decline of spiny lobster (*Panulirus marginatus*) in the Northwestern Hawaiian Islands (NWHI) has generally been attributed to environmental factors; the recruitment of spiny lobster was found to be correlated with the strength of the North Pacific Subtropical Countercurrent, suggesting that ocean circulation patterns impact the transport and survival of lobster larvae during their 11-12 month pelagic larval cycle. While environmental factors may provide a plausible explanation for the decline of NWHI spiny lobster, recent improvements in our understanding of the spatial structure of the NWHI spiny lobster population, the dynamics of larval transport, and commercial fishery data suggests that spiny lobster populations in the NWHI constitute a metapopulation, and the observed decline may have resulted from localized depletion. As overfishing reduces the population size, the chance of population collapse or extinction due to environmental stochasticity increases, particularly when the population is structured into relatively isolated patches that are connected by the dispersal of individuals between patches. Also, when spatial correlation among local populations is high, area-specific relationships between population size and fishing can become decoupled, masking the true impact of fishing. The decline of spiny lobsters at Laysan Island may provide an example of this decoupling. Concurrent with the decline in spiny lobster abundance at Laysan Island was the systematic fishing down and local depletion of spiny lobster populations at adjacent banks that are potential sources of recruitment for Laysan Island. Here, I briefly review the data and use a metapopulation perspective to demonstrate how localized depletion could lead to the decline of a spatially-structured population, such as NWHI spiny lobster.

39. A review of stock assessments methods for crustaceans, Julian Addison and Mike Smith

A key objective of the European Union-funded EDFAM project is an evaluation of stock assessment methods used currently in Europe for crustacean fisheries. This review provides such an evaluation, but extends to cover stock assessment methods used throughout the crustacean fisheries world. Methods covered include surplus production models, equilibrium yield- and egg-per-recruit models, delay-difference models, dynamic age- or size-structured models, individual-based models, purpose-designed population models, bio-economic models, and fishery-independent methods for assessing stock abundance. For each stock assessment method we consider the assumptions underlying the model, the data requirements and the problems associated with collecting accurate and representative data in the appropriate format. We then discuss the benefits and disadvantages of each assessment technique, the implications for uncertainty in parameter estimates and model structure through, for example, Bayesian approaches to risk analysis, and how this uncertainty may be translated into specific management recommendations. Finally we speculate on how crustacean fisheries assessment and modelling may evolve over the next decade.

40. The performance of a size structured stock assessment method in the face of spatial heterogeneity in growth, Andre Punt

Getting the stock boundary wrong – underdividing or overdividing- can introduce bias into the stock assessment process. This presentation will use a rock lobster case study to demonstrate the impact of this. It is a fundamental issue in provision of management advice

41. Research surveys for estimating biomass of crustaceans. Application to stock assessments in the stocks in the Northwest Atlantic and Alaska, Elmer Wade

We will study research surveys used in assessing snow crab stocks in the gulf of Saint Lawrence and eastern Nova Scotia (North Atlantic), King crab stocks off the coast of Alaska, and finally a survey design used in assessing egg herring abundance near Prince Edward Island (North Atlantic). We will look at possible estimates for gear efficiency in the case of the gulf snow crab survey. The effects of species behavior will be discussed in the eastern Nova Scotia survey, along with its implications in estimating the fishable biomass. The various approaches in analyzing the survey data, including geostatistics, will be described and studied. Where applicable, the survey data will be compared to the fishery data, to gain an insight into possible links between the two population measures.

42. Adjusting for variable catchability of brown shrimps (Crangon crangon) in research surveys, Julian Addison, Andy Lawler and Mike Nicholson

Monthly research surveys of brown shrimp (*Crangon crangon*) have been undertaken in The Wash fishery in England over the last five years. These surveys use a commercial fishing vessel, but for obvious logistical reasons stations are sampled at different times of day. This means that light conditions, tidal states and environmental conditions may vary across stations. Catch rates are determined by both catchability and abundance of shrimps. Catchability of *Crangon* is influenced primarily by emergence behaviour which is controlled by light levels and endogenous rhythms. Field experiments showed that catch rates were higher at night than in daylight hours, and that proportionally more smaller shrimps were caught at night. Light intensity clearly influences catchability, but since light covaries with turbidity and depth, these variables may also influence catchability. We used generalised linear modelling techniques to examine the influence on catch rates of 18 environmental and physical factors recorded during the surveys. This approach allowed us to convert raw catch rates of shrimps into an index of abundance adjusted for variable catchability. Comparison of raw survey catch rates, the model's index of abundance and catch rates from the commercial fishery suggests that our model predictions of abundance are generally closer to catch rates in the commercial fishery than our raw survey data. This approach should help to counter criticisms that, by fishing in areas and at times not targeted by fishermen, research surveys do not provide a true representation of stock status.

43. *Moulting growth in an individual-based model of Australian giant crab (*Pseudocarcinus gigas*): egg-, yield-, and value-per-recruit for evaluation of legal minimum length, Richard McGarvey, Janet M. Matthews and Andrew W. Levings*

Giant crabs exhibit an extreme life history, with intermoult periods of years. Females appear to bear eggs only in non-moulting years. To describe the moulting growth dynamics and reproduction cycle of giant crabs, a stochastic individual-based fishery model was developed. This generated predictions of harvest yield by weight, revenue to fishers, and female egg production per recruited crab. All data was from commercial pots. An estimator for intermoult period was developed for tag-recovery data that improves on the assumption of uniformly probable times to most recent moult prior to tagging. Intermoult periods at 150 mm CL were 2-3 (males) and 5-15 years (females), increasing with length. Continuous moult-increment distributions as functions of length were estimated as likelihoods. Seasonality of moulting by sex was obtained from monthly percentages with new shells. Percent virgin egg production at current legal minimum length (LML = 150 mm CL) was estimated at ~40% in Victoria and Western Australia, 50% in South Australia, suggesting high protection of female spawning stock. The majority of population egg production came from protected females below legal minimum length. However, sperm limitation is a potential problem for population sustainability. Model software is available for Windows PC's.

44. *The role of Underwater Television in the assessment of Scottish* Nephrops *stocks, Nick Bailey and Ian Tuck*

The Norway lobster, *Nephrops norvegicus*, has annual International landings of about 60,000 tonnes, making it one of the largest lobster fisheries in the world. Around 20000 tonnes of *Nephrops* are landed in Scotland, mostly from 6 main fishing grounds. Within the Common Fisheries Policy, output control through Total Allowable Catches forms the principle management approach for *Nephrops* with scientific advice largely based on analytical assessments provided by ICES. In common with their application in the assessment of many other shellfish stocks, the underlying assumptions of these methods may not always be met and the availability of relevant input parameter values to run the assessments may be limited. Partly as a consequence of this, assessments for *Nephrops* are not straightforward and have not always performed well. As a fishery independent alternative to the analytical approaches, underwater TV surveys to estimate *Nephrops* abundance from burrow density have been carried out for Scottish stocks since the early 1990s.

In this paper, underwater TV survey data are presented for a number of Scottish *Nephrops* stocks together with recent outputs from assessments based on catch data. The spatial distribution of animals within grounds is examined and interesting temporally consistent differences in overall density between grounds are discussed. Trends observed in the TV data over time are compared with fishery dependent data and the scope for using the independent method to tune assessments is discussed.

Since estimates from the TV method are now used directly in making a catch recommendation for one of the stocks, there has been new emphasis on refining and improving the method. A short summary of new developments will also be provided, including, the methods of raising abundance estimates to stock biomass, discriminating between different size classes of animal and improving the estimation procedure through survey design.

45. Analysis of the deep-water crustacean fisheries off Barcelona (NW Mediterranean) by Generelised Linear Models, Francesc Maynou, Montserrat Demestre and Pilar Sánchez

The landings per unit effort (LPUE) of *Aristeus antennatus* and *Nephrops norvegicus* in the port of Barcelona (NW Mediterranean) were analysed by Generlised Linear Modelling. The data series used was based on the daily landings of the two main decapod species targeted by the trawl fleet, from 1992 to 2000. Ancillary information on the technical characteristics of the boats (HP, GRT) and overall catch composition were also used to fit the models. The results of the analysis showed that the trawl fleet can be divided in *métiers* which follow different strategies to conduct the deep-water crustacean fisheries. The technical characteristics of the boats were also important in explaining the variability in the data series at seasonal and interannual scales.

46. Trends in CPUE and Recruitment in the North and Northwest Iberian Atlantic Nephrops *stocks, A.C. Fariña and I. González*

Nephrops norvegicus, a burrowing crustacean with patch distribution, is a by-catch species of the bottom trawl mixed fisheries on the shelf and upper slope of N and NW Spain. The ICES Working Group on *Nephrops* stocks consider three Nephrops Functional Units in this area, the so-called Cantabrian Sea, North, and West Galicia. From a relatively buoyant *Nephrops* fishery in the period 1980-1990, with annual average landings of 1040 t for the whole area, the landings and catch per unit effort were downward and the stocks status consideration is currently matter of concern. In this paper the trends in the time series of *Nephrops* fishery data are described and evidence of sharp declines in stock biomass and recruitment from age-based assessment are given.

*47. Application of non-equilibrium production models to red Shrimp fishery (*Aristeus antennatus, *R. 1816) in the North-Western Mediterranean, Aina Carbonell , M. Azevedo, E. Román, and V. Lauronce*

Previous studies using age or length cohort analysis and yield per recruit analysis suggested that red shrimp was slightly over-exploited or close to the optimum. However age was determined using length-classes as a proxy which is not yet validated and the remaining analysis were based on equilibrium assumptions. In this study non-equilibrium production models are used to provide guidance on the exploitation level of the main deep-crustacean fishery in the Western Mediterranean. A sampling program on board the trawl fleet located in the Balearic Islands was carried out between 1991 and 2000 aiming to estimate the annual catch per unit effort, CPUE. This fleet is the most important one within the multi-species trawl fishery of the Balearic Islands and represents 70% of the red shrimp total catch. The fleet is defined according to vessels size and activity and differences in fishing power between vessels may be considered minimal. The red shrimp fishery started in late 1940s and catches rapidly increased to peek in 1958 with 309 t. From early 1960s to mid 1980s catches fluctuated but with a general increase tendency and reached around 360 t in 1985. From 1991 to 2000 catches have reduced from 357 t to 141 t. The estimated CPUE for the period 1991-2000 is considered to be a reliable abundance index and was used to fit the non-equilibrium Fox (Yoshimoto and Clark, 1993) and Schaefer (Schnute, 1977) production models. The parameter triplet (k, r, q), that is, carrying capacity, intrinsic rate of biomass increase and catchability coefficient as estimated from the fitted models were (1202 t, 0.633 $year^{-1}$, 0.0073) for the Fox model and (1525 t, 0.133 $year^{-1}$, 0.0068) for the Schaefer model. However the model`s fit to the data was poor. The time series used in the analysis is short but perhaps more importantly, however, is the influence of the CPUE from 1991-1992. CPUE from these years are lower than expected probably as a delayed reaction to the catches decrease observed between 1985 and 1989. Therefore, the results from the Fox model, that provided slightly better fit to the data, were used to calculate biological reference points and to perform short term projections of the catches for 2001. Maximum sustainable yield, Y_{MSY}, is estimated to be 280 t. At present catches are well below this level but it is seen along the fishery history that catches exceeding 280 t resulted in periods of catches decline. The fishing reference point f_{MSY} is estimated to be around 86700 trawling hours. Given the uncertainties in the parameter estimates and the fact that the fishery takes place on the upper slope that is where red shrimp abundance is highest, it is considered that as a precaution fishing effort should not exceed that corresponding to a biomass level of 60% of the carrying capacity, $f_{60\%k}$, which is estimated to be 44300 trawling hours. At $f_{60\%k}$ red shrimp catches in 2001 are projected to be 248 t while at current fishing effort would be around 100 t. Despite the simplifying assumptions of production models, proper application of these can provide insight into the species/fishery dynamics and can be used to analyse the effect on catches of changes in the fishing level. However, it should be noted that the perception of the exploitation level of red shrimp presented in this study should be further validated with a longer CPUE time series.

48. *Modelling the population dynamics and stock assessment of the red spiny lobster (*Panulirus interruptus*) fishery off central Baja California, Mexico, Armando V. Velázquez and Rafael P. Millán*

Panulirus interruptus has sustained a high priced fishery over around 100 years, both in California and the Baja California peninsula. As the central Baja California zone accounts for about 81% of the total lobster catch, a population dynamics study was conducted in order to perform a stock assessment. Several alternative methods were used in order to compare their results and determine some biological reference points (BRP). The traditional surplus production models and analytic methods were the modelling approaches applied. The analytical approach includes length-based cohort's analysis, length and age-based prediction models, depletion models and sequential population analyses (SPA). Independently of the different methods and the type of data input required by each one, the stock assessment results are very coincident. Both the depletion and SPA methods show that recruitment and the population biomass followed an upward tendency during the last 10 years. This is consistent with the increase of lobster catches in the same period. The abundance level estimated by the SPA method is notably coherent with the highest yield in the 2000-01 fishing season. It is concluded that this fishery present an outstanding stability and its exploitation level is near to the level of maximum sustainable yield. This is a case of a well-managed resource and a sustained lobster fishery, achieved under a co-management strategy. The limited entry, through delimited fishing territories to fishermen Cooperatives, has been the milestone of its management system. The implications of the BRP are discussed in order to strength the management strategies.

49. *Depletion and mark-recapture experiments with* Cancer pagurus*: how to account for population turnover and changing catchability, Mike C. Bell, Derek R. Eaton and Julian T. Addison*

Depletion approaches to estimating local population size require assumptions of population closure and unchanging catchability. Experimental fishing for edible crabs (*Cancer pagurus*) off the south coast of England demonstrated that neither assumption was tenable for this species. A marked downward trend in catch per unit effort (CPUE) over four successive fishing occasions at first suggested successful depletion. However, CPUE increased dramatically after a storm event, indicating a large increase in catchability. Thus, previous changes in CPUE could not safely be interpreted as depletion rather than declining catchability. Furthermore, tagging showed clear directional movements across the fishing area, demonstrating considerable population turnover during the experiment. We develop an extended depletion model in which expected CPUE is formulated in terms of population size and catchability, fidelity and immigration values specific to individual fishing occasions. These values become separately estimable when depletion fishing is combined with a mark-recapture experiment. Catchability and fidelity parameters are shared between the depletion and mark-recapture components of the model, so that population size is estimable under assumptions about the balance between immigration and emigration. The combined depletion and mark-recapture model framework was used to design a second crab fishing experiment. We discuss the outcome of the experiment in terms of the applicability of the combined model and the assumptions necessary for robust estimation of local population size. We also consider the wider implications for crab stock monitoring and assessment.

50. Methods for the estimation of habitat and abundance of Scylla serrata *in northern Australia, Tracy Hay and Neil Gribble*

The trap fishery for mud crab, *Scylla serrata*, is the most valuable fishery in the Northern Territory, currently valued at $A13 million per annum. Reported catch for this fishery has increased substantially over the past five years with little corresponding increase in reported effort. The underlying assumptions required for assessment methods and models based on catch-effort data, cannot be met for this fishery. Generally fishing effort for the mud crab fishery follows a non-random spatial pattern, where fishers sequentially deplete then spell areas, resulting in hyperstability in catch per effort. High variability in growth rates and/or mortality has also made length-based assessment methods difficult and as yet, no stock estimates are available for Australian mud crab fisheries.

Two priority areas will be addressed in the current study;

1. Mapping of critical mud crab habitat.
Critical habitat such as tidal mangrove creeks, mudflat/foreshore areas, and saltmarsh areas will be mapped across northern Australia using the interpretation of satellite imagery and aerial photography.
2. Assessment of techniques for mud crab abundance estimation.
Techniques combining mark- recapture and depletion studies will be assessed. Pilot studies have been undertaken in northern Australia to test for robustness and appropriateness in each habitat area.

The aim of the project is to provide the fishing industry and managers with an:
Estimate of the size of the northern Australian mud crab stocks for sustainable development of the fishery;
Identification and quantification of critical mud crab habitat, and;
Advice on future monitoring methods for northern Australian mud crab stocks.

51. Estimating density of Cancer pagurus *from trap catch data: results of short-term mark-recapture experiments, Mike C. Bell, Derek R. Eaton, R.C.A. Bannister and Julian T. Addison*

Conversion of catch per unit effort (CPUE) to density of a target species requires estimates of both catchability and effective area fished. Such estimates are difficult to obtain for trap fisheries, where capture areas are not easily defined and catchability depends principally on behavioural responses to the gear. We describe the results of two short-term mark-recapture experiments for edible crabs (*Cancer pagurus*) off the east coast of England. Capture probability in strings of baited traps is shown to be strongly related to the semilunar tidal cycle, with highest capture rates after tides of the highest magnitude. In explaining tag recapture rates we need to account for crab movement rates as well as capture probabilities. We show that there is high population turnover at the spatial scale of the experiment, though not necessarily at the scale of the population as a whole. After accounting for movement of tagged crabs out of the capture area, capture probability is estimated to be in the order of 0.3 for every 100 trap-days of fishing effort. Selecting the best-fitting model for the data is complex, with several models fitting the data equally well. However, estimates of population size derived from conversion of trap CPUE are shown to be relatively robust to different assumptions about short-term temporal variation in capture probabilities. In order to convert population size, which is hitherto measured over an undefined capture area, to actual density on the sea bed, we use the trap-by-trap pattern of catch rates to obtain a tentative estimate of trapping area for a string of traps. Effective area fished per trap, combining information about trapping area and capture probability within the trapping area, can be used to estimate density from CPUE data in a wider context.

52. *Use of a new tagging model to estimate fishing and natural mortality of southern rock lobster (*Jasus edwardsii*) in Tasmania, Australia, Robert J. Latour, John M. Hoenig and Stewart D. Frusher*

We present a new multiyear tagging model that can be used to infer about fishing and natural mortality without knowing the tag-reporting rate. Two groups of animals are released simultaneously, one just above and one just below the minimum legal size limit.
It is assumed that the sublegal sized contingent of the tagged population grows to become legal sized in one year, that they experience no fishing mortality during that first year, and that the two size groups experience the same natural mortality rate. Consequently, this model may be most appropriate for a crustacean fishery in which growth of the sublegal tagged animals takes place in a single annual molt between fishing seasons. We applied this model to tagging data from southern rock lobsters (*Jasus edwardsii*) in northwest Tasmania, Australia, and derived estimates of natural mortality and year-specific fishing mortality rates. Since other assessments have been conducted to estimate fishing mortality rates for rock lobsters, we were able to compare our results and base our conclusions about the status of the fishery on a more comprehensive base of information.

53. *A Matlab® based geostatistical analysis tool for assessing and mapping marine invertebrate stocks: Application to snow crab stock assessment in the Southern Gulf of St. Lawrence (Northwest Atlantic), Elmer Wade, Denis Marcotte and Mikio Moriyasu*

Snow crab is the most important commercial crab species in Atlantic Canada with total landings exceeding 80,000 t in 2000 with corresponding landing value of 450 million Canadian dollars. Starting in 1988, a post-season trawl survey, has been conducted in some snow crab stocks in the southern Gulf of St. Lawrence (Northwestern Atlantic). The survey has provided better understanding of stock dynamics and better management. A Matlab® based computer software was developed for performing geostatistical analysis. The software incorporates features that would be useful in the analysis of many other invertebrate stocks. Data files are read as X Y Z1 Z2 Z3…Zn text formats, enabling several variables or categories to be analyzed at once. Positions can be described as latitude longitude or distance from a given reference point. Variograms models, either isotropic or anisotropic, can be obtained via an automatic or manual fit option. The ordinary kriging routine produces grid files which can be mapped directly within this software or exported to other GIS software. Features such as land, depth contour or other constraints on the interpolation may be taken into consideration using a mask. Population estimates and kriging variance estimates may be given for population within an arbitrary or a predefined polygon (i.e. fishing zone). Stochastic simulations can also be performed based on the autocorrelation and frequency distribution information, enabling the user to estimate conditional variance above a given reference density and probability of local density being above a given level. Densities of population may also be interpolated onto DFO standard 10 minutes x 10 minutes grids, enabling the scientist to directly link population estimates with fishermen's logbook information which are most often reported using the same grid system. Examples of analysis on snow crab populations in the Gulf of St. Lawrence are shown.

54. *Methodologies used in assessing populations of snow crab (*Chionocetes opilio*) and northern shrimp (*Pandalus borealis*) off the coasts of Newfoundland and Labrador, D.C. Orr, D.G. Parsons and Earl Dawe*

This paper outlines techniques used in research trawl set allocation, environmental and invertebrate data collection, and analysis of data. Usage of the juvenile shrimp net is discussed as a cost-effective means of obtaining early instar crustacea that otherwise pass through the research trawl. Population distributions are mapped using expanding symbol representation and contouring techniques. Finally, Ogmap is presented as a non-parametric means of determining biomass and abundance estimates.

55. Spatial patterns of lobsters and fishing activity in the eastern Gulf of Maine: consequences to assessments, conservation and management, Douglas S. Pezzack, Peter Lawton, C.M. Frail & M.B. Strong

Using spatial data from fishermen daily logbooks and at sea size frequency sampling, the distribution of size class and egg bearing females in the catch were mapped for the Canadian Lobster Fishing Area 34 in the eastern Gulf of Maine. Estimates of relative egg production and loss of future egg production due to harvesting are estimated and mapped to determine areas of high and low egg production and areas and sector of the fishery that are having the greatest impact on reproduction. This provides a useful tool for assessing the fishery and may provide a reference point to be used in addition to the present egg per recruit values. The spatial data supplemented by movement data and patterns of larval drift also gives information on the importance of different areas to the reproduction of the stock. The management implications is looked at as it relates to potential metapopulation in the Gulf of Maine

56. Putting lobsters on the map: Integrating spatial information in American lobster, Homarus americanus*, habitat research and fishery assessment, Peter Lawton , R.W. Rangeley, D.A. Robichaud and M.B. Strong*

We review implementation of geographic information system approaches over the last 4-5 years in research programs related to American lobster populations in the Canadian portion of the Gulf of Maine. We describe survey approaches (diving, remote video, and trap sampling) used for mapping and interpretation of lobster habitat occupation at various scales. Adoption of relational database approaches required adaptation of historical data sets, and development of a suite of intranet- and internet-based data entry and query tools. Following development of this informatics infrastructure we are now better placed to respond to demands for scientific advice from a wider range of clients.

In addition to traditional stock status evaluation, lobster fishery scientists in Canada are increasingly asked for advice on the location of sensitive habitats in relation to coastal zone planning (e.g. aquaculture development) and new fishery access issues (e.g aboriginal fisheries). This requires the ability to assess local populations at relatively fine spatial resolution in terms of habitats used year-round by defined life history phases (e.g. juvenile nursery areas), or habitats occupied seasonally by a range of lobster sizes (e.g. adult spawning areas). Concurrently, lobster fishery scientists are being asked to contribute data sets to regional-scale coastal ecosystem mapping programs that require synthesis on habitat utilization and sensitivity at broad spatial scales.

Fully georeferenced databases such as those we have recently developed provide the basic foundation for development of spatially-explicit models of lobster population dynamics, and for definition of conservation objectives to meet varied challenges from coastal zone multiple-use.

*57. Adjusting lobster (*Homarus americanus*) cpue trends for temperature effects, Ross Claytor and Paul Rago*

Changes in fishery catch rates are often used in lobster assessments to evaluate exploitation rate trends. Changing catchability from environmental effects may severely bias exploitation rate estimates that rely on changes in catch rates. We simultaneously measured catch rate changes of sub-legal lobsters released after trapping, and legal sized lobsters removed during each fishing day to separate environmental and fishery effects on catch rate changes. Simulation experiments were used to investigate the properties of various analytical methods for partitioning these effects on catch rates and for tracking relative changes in exploitation rate in lobster fisheries. Our results indicate that analysis of covariance with four parameters provides the simplest method for tracking relative changes in exploitation rates during fall Canadian fisheries where temperature is steadily declining. During spring Canadian fisheries temperature is increasing, and models with additional parameters were found to be necessary. Our results indicate that this approach provides a useful method for tracking relative changes in exploitation rates in lobster fisheries. However, there is a requirement to conduct annual trap monitoring experiments where the catch and effort on all size groups can be simultaneously recorded. These results will be important in determining the utility of broad scale trap monitoring programs for the assessment of lobster fisheries. These data were collected over broad scale geographic during a project sponsored by an organization of fishers and scientists in Nova Scotia, Canada (Fishermen Scientists Research Society)

58. A comparison of trap based assessment methods applied to local populations of the velvet swimming crab Necora puber, *J.C.H. Combes, I.D. Tuck and R.J.A. Atkinson*

The velvet swimming crab, *Necora puber*, is the target of an important trap fishery on the West Coast of Scotland for live export to Continental European markets. Recent Scottish landings of 2845 2436 & 1351 tonnes have had a first sale value of £4.91M. £4.20M & £2.33M for 1997, 1998 & 1999 respectively. Local populations of *Necora* were investigated in commercially exploited and unexploited sites on the West Coast of Scotland, using several stock assessment methods. Results were used in order to compare and contrast the applicability of the different approaches, and consistency between them. In all cases the sampling methodology was based on commercial baited traps (creels) designed for this species. Contrasting sampling strategies included; recording biological information (size, numbers, sex) from crabs sampled when on commercial fishing vessels; tag-recapture studies and experimental population depletion exercises (with and without animal removal) through intensive fishing in discrete areas. Data were analysed using various population estimation models and the usefulness of each approach evaluated. Comparisons were made between the populations studied in relation to state of exploitation and habitat.

Life history characteristics influenced population sampling. Sampling the populations with baited traps, whether of commercial design or not, inevitably resulted in selective capture. The implications of life history and selectivity effects on the results obtained by the various methods are discussed, as are approaches adopted in an attempt to minimise these influences.

*59. Sampling selectivity of different gear types on the blue swimmer crab (*Portunus pelagicus*), Linda M. Bellchambers, S. de Lestang, S. and A.W. Thomson*

Although various methods have been used to target crabs, until the early 1990s the majority of the commercial catch in Western Australia was taken with gill nets. However the versatility of pots has led to them now being the main gear type used by commercial fishers in WA. As far as commercial fishers are concerned, pots provide a simple and effective means of capturing crabs. However, to ensure the efficient management of blue swimmer crab stocks researchers require an unbiased method of assessing not only abundance but also size and sex distribution of the stocks. Therefore, between 1995-1998 several types of gear were trialed for their effectiveness in catching blue swimmer crabs. The types of gear trialed included pots, with two different mesh sizes 12 mm and 72 mm stretch mesh, a seine net and an otter trawl. Catches indicated that there was a significant difference in the size of the catch between the two pots with different mesh sizes and the 8mm seine net ($p<0.03$). Similarly there was a significant difference in the size of catch between the two mesh pots ($p<0.01$), with the catch composition varying by month. A comparison of the seine net and 72mm mesh pot catches indicated that the total catch of each gear type varied depending on the sampling period. However, the 72 mm mesh pot had a consistently higher composition of males (2:1), legal sized crabs (2.3:1) and sexually mature crabs (2:1) than the seine net. Analysis of the three gear types (72 mm pot, seine net and otter trawl) indicated that there was a significant difference in the size of the catch between methods ($p<0.01$); catch composition also varied according to the sampling method used. Therefore, while pots are a popular method of capture with commercial fishers, catches taken in crab pots are an inadequate representation of the relative size and sex composition of the total population for research purposes. Similarly, caution must be utilised when selecting both sampling methods and periods, as the selectivity of various gear coupled with the target species behaviour may result in biased data sets.

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60. Have inappropriate selectivity curves masked recruitment declines in crustacean trap fisheries, Stewart D. Frusher, John M. Hoenig and Caleb Gardner

Recent developments in fishery assessment models are focused on management strategy evaluation. In these models, future trends in specified fishery parameters, such as biomass, are evaluated against a range of different harvest strategies (quotas, closed seasons, effort reductions etc.). The forecasting potential of such models is reliant on an accurate representation of what has occurred in the past. Several of the parameters used in these models are based on 'once off' studies after which the estimated parameter is fixed and has no temporal variability. In the Tasmanian rock lobster assessment model, selectivity is such a parameter. Recent research has found selectivity to vary with the size composition of the population being sampled. Larger lobsters were found to inhibit smaller lobsters from entering traps. We applied different selectivity plots to a population of lobsters that had seen a substantial decline in large legal sized lobsters by harvesting over the last 35 years. Application of selectivity plots that accounted for the behavioural impact of larger lobsters on smaller lobsters indicated that smaller lobsters had been under-represented in the catch in earlier years. When appropriate selectivity plots are applied a more realistic representation of the abundance of smaller sized lobsters is achieved. Application of selectivity plots that don't account for behavioural interactions may have masked true recruitment declines in crustacean trap fisheries. This could explain the lack of a stock-recruitment relationship found in most crustacean fisheries.

61. Population dynamics and stock assessment of the velvet swimming crab, Necora puber *(Portunidae) in the Orkney Islands, UK, Alex Hearn*

The fishery for the velvet swimming crab in Orkney began in the mid-1980s as a response to demand from Spain, where stocks were becoming depleted. The fishery is currently valued locally at over £1m per annum at first sale. The only legal restriction on the fishery is a minimum landing size of 65mm carapace width (CW), although it is common practice not to land ovigerous females or recently moulted (soft) individuals.

As part of a three-year study of the Orkney stock, the growth and population dynamics of *N. puber* were investigated. The sex ratio of juveniles was found to be 1:1. The adult sex ratio fluctuated seasonally but was overall male biased (1.86:1), and could be explained by changes in behaviour affecting likelihood of capture throughout the year. Size-frequency analysis showed distinct year classes among juveniles, but not for adults. There was no significant difference in the von Bertalanffy growth parameters between males and females ($L\infty = 98.4$ cm CW, $K = 0.268$). The life span was estimated at around 10 years, with puberty occurring at the third year. Age at first capture is around 4 years. Total mortality (Z) was estimated using length-converted catch curves (males = 0.95-1.07, females = 1.08-1.22).

Yield per recruit analysis suggested that the current minimum landing size was close to the size of optimal yield per recruit, but that higher yields could be obtained by increasing fishing mortality. Preliminary length-cohort analysis also suggested there was room for expansion of the fishery.

Preliminary stock assessment is carried out, and the petition by local fishermen for a Regulating Order to cover the fishery in Orkney is discussed, focusing on the relevance of the biological data from this research to the management options available under the auspices of the Order.

62. Comparison of Relative Fishing Power between Different Sectors of the Queensland Trawl Fishery, Australia, Michael F. O'Neill

The effects of improvements in fishing gear and technology on prawn and scallop catches from the Queensland trawl fishery were investigated. We partitioned the fishery into five main sectors, based on the spatial distribution of the stocks and gear types used, and compared the findings for each sector [Torres Strait tiger prawns, north Queensland tiger prawns, shallow water (< 50 fathoms) eastern king prawns, deep water (> 50 fathoms) eastern king prawns and saucer scallops]. For each sector, annual changes in average relative fishing power were calculated as a function of the parameters estimated in a generalised linear model and the average and/or percentage use of different gears and technologies in the sector. Between 1989 and 1999, fishing power increased from a low of 0.2% per year in the saucer scallop sector to a high of 1.6% per year in the shallow water eastern king prawn sector. Fishing power in the shallow water eastern king and tiger prawn sectors had the highest rates of increase and was attributed to vessels upgrading to larger engines. Increases in the number of vessels using global positioning systems and computer mapping software also contributed to increased fishing power in the two tiger prawn sectors. In the deep water eastern king prawn sector, fishing power increased with net head rope length, however current management controls over engine size and head rope length are likely to control this source of increase in fishing power. Fishing power in the scallop sector was associated with an optimum trawl speed of about 2.2 knots, which differed from the prawn sectors where fishing power was found to increase with trawl speed. The results should be used to standardise fishing effort and incorporated into stock assessments for each sector.

63. A model of the ecosystem, and associated penaeid prawn community, in the far northern Great Barrier Reef, Neil A. Gribble

GBR-prawn is a “mass-balance” trophic-based ecosystem model of the Great Barrier Reef, which combines a model template for a Caribbean coral reef ecosystem with results from extensive cross-shelf surveys of the far northern Great Barrier Reef. The new model incorporates both the trawl and line fisheries, but focuses on the effect of trawling on the penaeid prawn community in the lagoon and inter-reef habitat. Trawl and line-fishing bycatch is specified and monitored, as is the biomass of sea-birds and endangered sea turtles. Network analysis of the mixed trophic impacts predicted by the model showed only a minor negative impact on prawn populations by trawling. The balance of positive effects, such as removal of predators or competitors as bycatch, and the negative effects of direct harvest resulted in the apparent minor impact. The impact was also reduced by positive feedback from the discarded trawl bycatch, which either made up a proportion of the diet or were consumed by animals that made up a proportion of the diet of the prawns being harvested. Dynamic and spatial simulations of the model showed that different species of prawn were effected differentially, with *P.esculentus* (tiger prawn) a dominant at low levels of trawling effort and *M. endeavouri* (endevour prawn) a better performer at higher levels of trawling. *Penaeus longistylus* (reef-associated, red spot king prawn) did poorly when trawled unless a refugia was available. The management strategy of gradual reduction in trawl effort to 50% of current levels resulted in a 59% reduction in *P.esculentus* and a 64% reduction in *M. endeavouri* catch. Catch of *P.longistylus* was also lower than expected due to a spatial concentration of the reduced effort in the more economically attractive inshore lagoon. The effect on by-catch species of a reduction in trawl effort include a dramatic increase in sea-turtle biomass and an increase in small fish omnivores (comprising most of the discards), but also resulted in a decrease in species that feed on discards such as sea-birds, groupers, and sharks/rays.

64. Enhancing decision making in European fisheries management: The application of information technology, Geoff Meaden

Recent pressures on many fish stocks are serving as a catalysts towards improvements, revisions and adaptations in fisheries management. In order to achieve a goal of sustainability, and an ecosystems-based approach to fish exploitation, an equilibrium must be re-established between the fishing activity process and the marine environmental milieu. This balance will not be achieved without greater data inputs and the means to manage this. Since the present dis-equilibrium is manifest mainly in the spatial domain, then Geographical Information Systems (GIS) are likely to provide a convenient and adaptable fisheries management tool. Here the progress in adoption of GIS in the fisheries sphere is reviewed, including relevant case studies. An analysis of the problems and prospects is also made. The presentation concludes by showing a scenario of how GIS, when integrated with electronic catch and effort logging systems, can be utilised to significantly enhance the fishery decision making environment.

65. Risk and reward relationships in the Northern Prawn Fishery of Australia, C.M. Dichmont., A.E. Punt and Q. Dell

The Northern Prawn Fishery (NPF) is the most valuable Commonwealth-managed fishery in Australia, with the value of production exceeding $100 million a year. The NPF is currently managed by input controls and is based on three prawn species groups, each with at least two species. Common banana prawns are heavily influenced by the environment and less affected by fishing pressure than the other species. Tiger prawns on the other hand have been shown to be prone to recruitment overfishing. Excessive fishing effort in the 1980's led to the decline in tiger spawning stocks, which was only halted through large, controversial and costly, fishing effort reductions. These reductions were achieved through a combination of licence buy-backs, proportional licence surrenders and new seasonal closures and bans on daylight fishing. Assessment of tiger prawn stocks suggest that these adjustments slowed the decline in spawning stock biomass but were not sufficient to allow the stocks to recover to their most productive state.

A Deriso-Schnute model is used to assess the status of the tiger prawn resource. In-depth analysis of model sensitivity to input parameters and model assumptions were undertaken. Future projection of the model was undertaken for the first time to consider recruitment variability and serial correlation in the stock-recruitment function. The projections indicated distinct risk-reward relationships for both tiger prawn species, with the mid-season closure being extremely beneficial for *P. semisulcatus*. This, combined with the fact that little effort is directed towards the species in the first half of the year, allows many prawns to spawn before capture. This is not the case for *P. esculentus* as a large portion of the effort in recent years occurred in the first half of the year. At low levels of effort, the largest component of risk is recruitment variability. Due to serial correlation in recruitment, constant effort levels can at certain times be sequentially higher than is appropriate for the below average recruitment. The low productivity of the resource does not easily allow full recovery during above average recruitment years.

66. Experiences in changing the management of Australia's northern prawn fishery, P.Stone and D. Carter

The northern prawn fishery is one of Australia's most valuable fisheries. The fishery is large - covering an area of over 771,000 sq kilometres of water in the most isolated and sparsely populated area of Australia. Managing this large and remote fishery presents unique challenges particularly in terms of the type of regulation used for the fishery.

The fishery is managed using a suite of input controls which are developed through a partnership process involving government, the fishing industry, environment groups and the broader community. The measures in place include a suite of temporal, seasonal and spatial closures designed to protect key features of the environment and critical habitats of juvenile and spawning prawns. Fishers have also been granted Statutory Fishing Rights which grant them secure, tradeable access to the fishery.

Recently there have been a major changes to the management regulations in the fishery. For many years effort was limited through controls on the size of vessels and engine size, but over recent years the effectiveness of these measures, and the ability to enforce them with in the face of changing technology, was questioned. These limits have been replaced with tradeable gear units which limit the length of gear a fisher can use. While there are many improvements to the system of using the new method of management regulation there are also a number of challenges involved with new system.

67. Impact of ITQ's on the Fleet Dynamics of the Tasmanian Rock Lobster Fishery, Linda-Jane Eaton

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A need for management controls in the Tasmanian Rock Lobster fishery was recognised in the late nineteenth century. Since then the fishery has implemented a number of different management strategies to protect the abundance of the stock including closed fishing seasons, limitation on the number of licences and vessels, and restrictions on pot type and numbers. During the eighties the fishery saw improvements in technology and an expansion of fishing grounds and yet there was a marked decline in catch rates. This prompted an assessment of future management options. After heated debate between biologists, fisheries managers and industry representatives the decision to introduce individual transferable quotas (ITQ) was made in 1996 and the new management plan was implemented in March 1998.

Since then and in fact over the whole of the nineties the fishery has seen a number of changes. Most noticeably there has been a decrease in licence owners and vessels operating in the fishery. In addition there has been spatial and temporal changes in the distribution of effort in the fishery. But changes in biomass and variations in the beach price of lobsters are confounding factors which also affect the dynamics of the fleet, and so must be taken into account to obtain a clear assessment of the impact of ITQs. Using catch and effort data collected from fishers catch returns we will investigate the changes in the effort distribution and fleet dynamics apparent over the decade and discuss the possible relationships between these and changes in management.

68. The Effects of Gear-Specific Limitation on Landings in the Florida Spiny Lobster Fishery, Thomas R. Matthews and William C. Sharp

In Florida, the Caribbean spiny lobster, *Panulirus argus*, supports both an intensive commercial fishery and a popular recreational dive fishery. The fishery has been dominated by the use of wooden-slat traps since the 1950's. From the early 1970s to 1991-92 fishing season, the numbers of traps increased dramatically from approximately 200,000 to 939,000. Responding to the industry's concerns about the excessive number of traps, the State of Florida implemented a management program in 1993-94 that has reduced the numbers of traps to 530,000 in 2000-01. Additional reduction of the number of traps to 400,000 is scheduled. Lobster landings have been, on average, higher since the implementation of trap limitation compared to any eight-year period prior to the implementation of the program. However, the proportion of the landings by commercial trap fishermen decreased progressively soon after the implementation of the program from a high of 75% in 1994-95 to 67% in 2000-01, while the proportion of the landings by commercial divers increased from 3% to 7%. Additionally, the proportion of the total landings by recreational divers has recently increased. Such a shift in landings away from the commercial trap fishery toward commercial and recreational divers was recognized as a potential, but unintended, effect of restricting the number of traps. Fishery managers must now consider the implications of gear-specific limitation on all user groups in the fishery. We will examine potential effort control measures on both the commercial and recreational dive fisheries.

69. Are lobster fishers generalists or specialists? fishers' preferences and implications for fisheries management, Silvia Salas

Spiny lobster are fished mainly by small-scale boats in the Yucatan coast of Mexico. This fleet fishes other species in the same region simultaneously or sequentially. Under these conditions it is difficult to identify the effective fishing effort imposed on different fisheries, and consequently to define management schemes according to the changes taking place. A comparative study was undertaken using daily catch data and survey data in three fishing communities of Mexico, Yucatan coast, to test: a) the folk concept of specialization claimed in one of the communities, b) the fishers' preferences regarding target species, and c) the factors that define fisher's choices when choosing a particular target. The analysis showed heterogeneity among fishers both among and between the different communities. No evidence of specialization as claimed was confirmed, but preferences for certain species such as demersal fishes and octopus, as well as lobster, were observed in each community. Switching between fisheries appears to be related to different factors such as relative levels of profitability from alternative fisheries, resources availability, and experience in each fishery. In this paper, emphasis is placed on the importance of recognizing heterogeneity among individual fishers, which calls for the development of management schemes accounting for those differences. Equal emphasis is given to the evaluation of the impact that changes on one fishery can have on others. It would be expected that taking into consideration the dynamics of fishers can likely improve the management of coastal fisheries, as diverse responses can arise from individuals operating within similar environments.

70. Determination of biological reference points for Bering Sea and Aleutian Islands crab stocks, Shareef M. Siddeek

The US Magnuson-Stevens Fishery Conservation and Management Act mandates precautionary management to attain near Maximum Sustainable Yield (MSY) producing stock and exploitation levels on a long-term basis. Various biological reference points (BRP) have been suggested as surrogates for MSY producing instantaneous fishing mortality (*FMSY*) and stock biomass (*BMSY*) for poorly understood stocks, which are largely derived from finfish biological and fisheries characteristics. BRP estimation for crabs has been complicated by the fact that only males are harvested and that recruitment, in many instances, is largely driven by environmental factors rather than density-dependent responses. For managing Bering Sea and Aleutian Islands (BSAI) crab stocks, instantaneous natural mortality (*M*) is used for *FMSY* and mean mature biomass during 1983-1997 is used for *BMSY*. In this paper, spawning biomass-per-recruit were determined and used in conjunction with Beverton and Holt and Ricker stock-recruit (S-R) relationships for various parametric values to explore plausible *FMSY* and *BMSY* values for seven BSAI crab stocks: Bristol Bay and Pribilof Island red king crab (*Paralithodes camtschaticus*), St. Matthew Island and Pribilof Island blue king crab (*P. platypus*), eastern Bering Sea Tanner crab (*Chionoecetes bairdi*) and snow crab (*C. opilio*), and Aleutian Islands golden king crab (*Lithodes aequispinus*). The *FMSY* and *BMSY* depended on the type of S-R relationship and biomass growth.

71. The Efficacy of Releasing Caught Nephrops *as a Management Measure, Margarida Castro, Artur Araújo, Pedro Monteiro and William Silvert*

Survival of released lobsters (*Nephrops norvegicus*) was evaluated for the population from the South coast of Portugal. Individuals were caught on board crustacean trawlers during regular fishing operations and put into individual compartments in net cages that were placed on the bottom in conditions (especially temperature) similar to that of areas where they were caught. After a period of 6 to 7 days the cages were brought to the surface and the survival of the individuals recorded.

Exploratory data analysis showed that season and time of exposure on deck are key factors determining survival. Sex and carapace length did not affect survival. A log-linear model (main effects and interactions) was used to predict survival. The structure of the population by season was combined with these values and with the distribution of the catch in cold and warm months to produce an overall yearly survival rate of 31%.

Three management options were considered: a) release of lobsters during part of the year; b) minimum landing size greater than at present (release of small sizes), c) release of all lobsters caught year-round. Since the highest survival occurs when catches are low (cold months) returning lobsters to the sea during only this part of the year would have little impact on population recovery. For this reason only the option of returning lobsters to the sea year-round would result in effective population recovery (while allowing the fishery to continue targeting other crustacean species).

72. Shrimp population structure as an integral input to the resource management in Nigeria, Parcy O. Abohweyere

Population Structure of the penaeid shrimp resources in Nigeria was analyzed. There was a delineation of the population into two by it's amphibiotic life cycle. Juviniles totaling 20,888 were analyzed from the

Lagos lagoon while 1258 adults from the sea were also analyzed. Of the adults, 661 were males and 597 females. The lagoon and sea population exhibited a normal distribution in their structure. The lagoon sample size range was split into two, (1) Dry season:- 9 - 30mm C L, (2) Rainy season:- 8 - 24mm CL. Sea sample size range were 16 - 45mm and 4 - 50mm CL for male and female respectively. Samples were grouped into different sizes with a 5mm interval and period of prevalence of various sizes were estimated based on their abundance. For lagoon sample 16 - 25mm CL group constituted 80.19% in the dry season while for rainy season 11 - 20mm CL made up the bulk of the resource (87.29%). A preponderence of 16 - 20mm CL were observed in the sea sample in May / June. Length group 21 - 35mm CL had the highest percentage contribution in all the months of the year for male sea sample while for female it was 26 - 40mm CL. Shrimping in the lagoon is best in terms of size and abundance in the dry season when the greater percentage of the resource (80.19%) was between 16 - 25mm CL. This is an important input for the management of the resource. At sea, enforcement of correct shrimping mesh size (44mm) particularly in May / June with a prepondenrance of small size (16 - 20mm CL) shrimp is advocated.

73. Exploitation of crustacean stocks in the Russian Far East Seas, Boris G. Ivanov

Several dozens of shrimp and crab stock units are exploited in the Russian Far waters. The management of these units is rather variable. It is mainly based on the TAC determination for each unit. The TACs are determined by 7 fisheries research institutions using various methodologies. Regulation takes into account spatial structure of the crab metapopulation only for the red king crab off West Kamchatka and its nursery ground is protected as being a sanctuary for crabbing. Regulations based on mathematical models are used only for few stocks. Exploitation rates are frequently as low as 10% and the research institutes tend to overprotect the stocks. In spite of the low exploitation rate the stock abundance fluctuates greatly. Impact of fisheries and natural factors on the fluctuations is not very clear. Since the early 90s poaching has become a serious problem and crab and shrimp caught in the Russian waters are mostly landed in Japan ports.

Due to a wide geographic range commercial stocks can differ considerably in their size composition and other market parameters. Hence, for the same commercial species caught in various fishing areas, different legal sizes were adopted. The legal catch of crabs can be increased if the overprotection approach in the TACs determination is refused and the fishery regulations become more strict.

74. Analysis of the deep-sea shrimp fishery in the Mediterranean (including North Africa): efforts and economics, Evelina Sabatella

The main aim of the project was to know the situation on basic data of the catches, effort, evolution and economic implications of the fisheries of deep-sea shrimps (*Aristeus Antennatus* and *Aristeomorpha foliacea*) in the entire Mediterranean exploitation area (including North of Africa). In this paper, the results of the economic analysis are presented. This economic analysis of the red shrimp fishery is aimed: at analysing the actual fleet carrying out red shrimp fishery (number of units, territorial and administrative location, size, technical characteristics); at estimating the effort level, i.e. the average activity per vessel during the year (days of fishery, total hours aboard, days off, days of maintenance, days of bad weather, etc.) at estimating the most interesting economic variables for a correct evaluation of the profit levels of the operators (revenues, variable costs, fixed costs, social security contributions, profitability indicators, etc.); at analysing the social-economic aspects of the red shrimp fishery in the investigated area.
A cluster analysis has been applied in order to identify the groups of Mediterranean ports which exhibit a higher similarity with respect to some of the economic variables observed. The possibility to identify homogeneous groups is a valid management tool to evaluate the impact of Community policies on a very large geographical area.

Poster Presentations

75. A review of French crab fisheries, status and current management and perspectives, Daniel Latrouite

The French crab fisheries mainly concern edible crab *Cancer pagurus* and spider crab *Maja brachydactyla*. Those two species, which before 1960 were by-catch of lobsters *Homarus gammarus* and *Palinurus elephas* fisheries, have been targeted and fully exploited for three decades. Annual landings are about 6000 to 7000 tons for edible crab and 4000 to 5000 tons for spider crab and come from French/English Channel and Atlantic. Landings of velvet crab *Necora puber* and green shore crab *Carcinus maenas* are respectively around 300 to 400 tons and 500 tonnes. *Cancer bellianus*, *Paromola cuvieri* and *Chaceon affinis* are which are incidently caught are not commercialised.

The fleet is composed of twenty specialized offshore potters (20 m length) and a thousand of generally polyvalent coastal boats (6 to 16 m). Only pots (traps) and nets are allowed to fish for crabs but trawlers which have by-catch may land crabs up to 10% of their total "fish" catch.

An annual direct (dredging) stock assessment of spider crab was conducted for 10 years before being stopped and crabs stocks evolution is now estimated only through trends in catch rates. The often poor quality of catch and effort data (for coastal fisheries), the problem of splitting fishing effort into several species (crabs and clawed lobster) and catchability variability are limiting factors to the reliability of catch rates as abundance index in coastal fisheries.

Fisheries are managed through a series of technical measures and fishing effort limitation through legislation enacted at the European community, national or regional levels. Technical measures include minimal landing sizes, a ban on soft crab landings, a limitation of clawed landings and, for the spider crab, a closed season. Fishing effort is limited by a compulsory licencing scheme and by a pot limitation per boat linked to the crew number. A generalisation of those fishing effort limitations to the other fleets fishing for crabs and lobsters in the Channel and Atlantic is now the ambition of French fishermen.

The production potential of crabs has some negative interactions with coastal trawling which, in summer months, causes the destruction of several hundred tons of spider crabs, and with fish (sole and monkfish) netting which often destroys by-catch of edible crabs.

The evolution of crab fisheries management and thus their sustainability also goes through expected improvement in controls and decisions. A recent (April 2001) European which authorizes a daily landing of claws limited at 1% of edible crabs landings for potters and up to 75 kg for boats using any other gear than pots creates a risk to help the development of uncontrolled fisheries aimed at crab fishing.

76. The Crustacean Fisheries in Greece, Mytilineou, Ch., Politou, C.-Y., Kavadas, S., Fourtouni, A., Kapiris, K. & J. Dokos

The Crustacean Fishery does not consist a particular branch of the Greek Fishery, which is mainly multispecies. The following Crustacean species can be characterized as target: *Nephrops norvegicus*, *Penaeus kerathurus*, *Palinurus elephas*, *Hommarus gammarus*, *Parapenaeus longirostris* and *Palaemon adspersus*. From these, *N. norvegicus* consists the most important crustacean of the Greek Fishery presenting a high economic value and a high production (annual landings: 433 t). *P. kerathurus* has also a high commercial value, but its production is limited (annual landings: 195 t) and its fishing is locally exercised. *H. gammarus* and *P. elephas* despite their commercial importance display low landings (annual landings: 23 t), particularly the first species. *P. longirostris* presents the highest production (annual landings: 970 t), it is widely fished in all the country, however it is of moderate value. Some more crustaceans with lower commercial importance, such as *Liocarcinus depurator*, *Maja spp*, *Calappa granulata, Squilla mantis, Scyllarus spp, Munida spp* etc are caught as by-catches. Recently, considerable quantities of deep water shrimps, *Aristaeomorpha foliacea* and *Aristeus antennatus,* were found in the Greek Seas in the framework of experimental cruises. The presence of thes pristine resources may lead to the development of a Greek deep-water shrimp fishery. Fishing gears used for crustacean fisheries are the following: trawl (*N. norvegicus, P. longirostris, P. kerathurus, S. mantis, L. depurator, Munida spp*), gill and trammel nets (*P. elephas, H. gammarus, P. kerathurus, S. mantis, Maja spp, Scyllarus spp*), traps and other passive gears (*N. norvegicus, P. adspersus*). The assessment of commercial crustaceans is difficult and the national statistics do not provide accurate data. Only research data could be considered reliable; however, these are obtained from projects carried out for short time periods and in restricted geographical areas. Most management measures are not specialised for crustacean fisheries and apply mainly to the fishing gears.

77. Biological and socio-economic implications of gear-restriction fishery management regimes, Robert E. Blyth, Michel J. Kaiser, Paul J.B. Hart & Gareth Edwards-Jones

There have been few opportunities to study the potential of gear-restriction fishery management regimes in temperate waters as few exist in a form that would permit a rigorous analysis of the biological and socio-economic implications. However, the Inshore Potting Agreement, located off the south Devon coast (UK) is a voluntary management system operating to prevent conflict between fixed-gear (crab pot/fixed-net) and towed bottom-gear (trawl/scallop dredge) fishers. There is no legal recognition of the system, though it has been in operation for more than twenty years. While there may be potential fisheries and conservation benefits, the potential social and economic consequences of maintaining such systems may be more important in terms of arguing for their creation and continuation. The project examines the biological, social and economic implications of the IPA by:
Identifying the catch per unit effort for static gear and mobile gear fishers within and outside the IPA to investigate the potential importance of the habitat within the IPA for target species.
Identifying the costs and profits associated with both the static gear and mobile gear sectors of the industry.
Identifying economic links directly associated with both the static gear and mobile gear sectors.
Quantifying knock-on effects of altering the existing agreement.
Quantifying the value of the service functions and existence values of those species that are conserved by the operation of the closed areas.
Identifying reasons for the continued observance of the voluntary management agreement.

*78. An Assessment of a Red Shrimp (*Aristeus antennatus *Risso, 1816), Decapoda, Dendrobranchiata) Fishery off the Alicante Gulf (S.E. Spain), M. García-Rodriguez & A. Esteban*

This study presents data on the *Aristeus antennatus* fishery off the Alicante Gulf, obtained from sampling carried out on commercial monthly catches landed in the port of Santa Pola during 1995, 1996, 1997 and 1998. The total annual landings for the area fluctuated around an average of 100 t per year. The mean catch per unit of effort (CPUE), expressed in kilograms of shrimp by boat and fishing day, was 27.7 kg/boat/day. The values of biomass, yields and mortalities obtained by LCA, VPA and Y/R analysis on a pseudocohort, showed that the stock was slightly overexploited. The biomass caught by fishing was 71.8% and 75.5%, compared to a range of natural mortality between 28.2% and 24.5%, for males and females respectively. Biomass inputs were based on growth. A difference existed between sexes, with the biomass of the females being much greater than that of the males, showing a high rate of biomass production (Turnover). Female yields were, at least, double than that of the males, with values not far from the maximum sustainable yield (MSY), which was especially so in the case of the males. Although the MSY for females was located at half of the actual exploitation rate, despite the slope of the curve being very smooth in both sexes, similar yields were maintained with variations of the fishing effort. The mortality vector had a greater affect on the older age classes, especially in the females. This fact could be due to the whole resource not being equally accessible, since exploitation was based on the largest sizes in which the females predominated, leaving an important part of the population, mainly constituted by males, in deeper areas.

79. *Comparative analysis of biological parameters of the giant red shrimp,* Aristaeomorpha foliacea *(risso, 1827) in Mediterranean waters, Paolo Sartor, Chryssi Mytilineou & Paolo Belcari*

The giant red shrimp, *Aristaeomorpha foliacea* (Risso, 1827), is one of the most valuable deep-water resources in the Mediterranean. This species is mainly landed during summer, mostly due to the better weather conditions that allow the fishing vessels to operate far from the coast. In Mediterranean Sea the geographical distribution of *A. foliacea* shows a somewhat irregular pattern: the species is absent or has shown an important decrease in the last years in some areas (like the western Mediterranean, central and southern Adriatic), while it is currently exploited in other regions (e.g. central Mediterranean) or is almost unexploited in other zones (e.g eastern Mediterranean). For the Mediterranean sea, official statistical data about commercial landings of this species are somewhat scanty and available only for some areas. For example, in the Italian fishery statistics, information on the production of *A. foliacea* is available jointly with the other commercially important red shrimp species, *Aristaeus antennatus*; landings of the two species fluctuated from 2200 to 5000 yearly tons, in the period 1985-1996.

The aim of this work is to draw the "state of the art" on the biological information of this species. Such knowledge represents an important tool in order to assess and to predict the exploitation level. A review of all the available information on these topics for all the Mediterranean area coming from different sources (e.g. national or international research projects, independent researches, etc.) has been performed. Thus, a comparison of results on reproductive biology (spawning season, size of maturity), biological parameters (e.g. relative and absolute growth) coming from different areas has been included in this paper.

80. *On the applying of production models to estimate shrimp (*Pandalus borealis*) fishery in the Barents sea, V.A.Korzhev and B.I.Berenboim*

ICES recommended the following production models for the Barents Sea shrimp: stock production models, the time-dependent stock production model and biomass dynamics models. The paper is based on the international catch and Norwegian and Russian effort data on the Barents Sea shrimp for 1981-1999. The authors applied the Shaefer and Fox models which relate CPUE to fishing effort.

The correlation coefficient between fishing effort and CPUE for the Barents Sea shrimp derived using both models were significant at confidential probability $p<0.95$, therefore these models could be regarded as adequately fitting the fisheries data. The calculated values of maximum sustainable yield and the corresponding fishing effort are real made up 68800 tonnes and 379000 trawling hours from the Shaefer model and 75200 tonnes and 557000 trawling hours using the Fox model.

CPUE multiplied by 1/q (q-catchability coefficient) gave the mean commercial stock biomass at the selected exploitation rate. Therefore we calculated shrimp biomass for each year in the period from 1981 to 1999 by exploitation rate 0.1. The dynamics of the modelled shrimp biomass is found to be similar to the actual biomass assessed from the results of both Russian and Norwegian surveys. In conclusion the calculations by some production models indicate that the Barents Sea shrimp stock can vary from 0.4 to 1 million tonnes.

81. *Deep water shrimps on the continental slope of the SE Gulf of California, Mexico, Michel E. Hendrickx*

Deep water shrimps were collected with a benthic sledge in the southeastern Gulf of California, Mexico. One species of Dendrobranchiata (*Benthesicymus tanneri*) and three species of Caridea (*Acanthephyra brevicarinata, Heterocarpus affinis, Pandalus amplus*) are considered exploitable species for their maximum body size and distribution in the area. Samples of benthic fauna were obtained between 600 and 2250 m, and maximum abundance for these species was observed in the 800-1500 m depth range. All three species feature a high tolerance to hypoxic conditions (expressed in ml O_2/l) and were mostly sampled in environment with less than 1.0 ml O_2/l. Ranges of oxygen values were: *B. tanneri*, 0.38 to 1.88; *A. brevicarinata*, 0.25 to 1.98; *H. affinis*, 0.13 to 1.40; P. amplus, 0.38-0.86. Maximum body size and individual fresh weight obtained for these species were: *B. tanneri*, 120 mm, 18 g; *A. brevicarinata*, 105 mm, 9 g; *H. affinis*, 135 mm, 24 g; *P. amplus* 140 mm, 25 g. Highest catch during the survey was approximately 1 kg/ha, fresh weight, for *H. affinis*. This figure is obviously underestimated due to the sampling device used during the survey.

82. *Difficulties estimating mortality rates by capture-recapture, catch-effort and change-in-ratio models for a spring American lobster (*Homarus americanus*) fishery in Canada, Michel Comeau and Manon Mallet*

The major obstacle to a sound lobster management plan for the American lobster (*Homarus americanus*) in Canada is the lack of fishery independent surveys to verify mortality estimates produced by models. A direct method such as trawling to estimate mortality rates is not an acceptable tool to survey lobster in Canada as prime lobster habitat is usually associated with hard rocky bottom unsuitable for trawling. Thus, the estimation of mortality rates has to be generated from indirect methods relying on fishery based data models (catch-effort and change-in-ratio estimates) or tagging studies that rely on the fishery for recapturing tagged animals. In this study, mortality rates were estimated for a spring lobster fishery from a single port located in the Gulf of St. Lawrence. Simulations were also done to assess strengths and weaknesses of the various estimators. From our results, none of the proposed estimators can adequately estimate the natural mortality (*M*). The estimated exploitation rate (*u*) ranged between 32% and 83%. However, it is not possible to suggest the "best" value for *u* since estimators behaved differently under specific simulated conditions. Results from the simulations show that variation in catchability introduces a large bias for fishery based data estimators but not for tagging methods. Conversely, *M* does greatly influence *u* obtained from tagging methods but not the one estimated from fishery based data estimators. Furthermore, based on recapture rates from tagging experiments, lobsters demonstrated a trap-shy response. This bias could be avoided by using a method different from the fishery for initial capture.

83. *Fisheries and management perspectives of the goose barnacle* pollicipes pollicipes *of Galicia (nw Spain), J. Molares and J. Freire*

The goose barnacle, *Pollicipes pollicipes*, occurs in the Northeast Atlantic from around 48ºN at Britain (France) to 14ºN at Senegal. Commercial fisheries have been developed in several countries, but except for a short local consumption, most of the production goes to the Spanish market, where price can reach 90 ∈ per Kilogram.

Pollicipes pollicipes is an intertidal cirripede that lives attached to rocks in very exposed shores forming dense aggregations. This species has a metapopulation structure, with adult subpopulations sharing a common larval pool. The stock-recruitment relationship rarely holds in this kind of resource at the scale of subpopulations. Advection of larvae depends largely of oceanographic conditions that govern larval transport and survival.

Goose barnacle harvesting technique is simple but very risky, fishers, during low tide, separate animals from the rock surface with a scraper. Regional government regulations promote co-management between fishers' organisations ("cofradías") and the fisheries authority through territorial use rights (TURFs). Since 1992, TURFs are granted to "cofradías" after presentation of a management plan, where fishing (daily allocation of effort, maximum individual quotas and area of exploitation), surveillance and the marketing processes are established.

The main problems that "cofradías" are illegal fishing, excess of fishing force and price control by merchants. Estimation of the adequate fishing effort to be applied to each barnacle area is needed but information about their population dynamics is required in order to do this. We are developing new ways to improve the design and control of management plans using a combination of population models adequate to the characteristics of the resource (paying special attention to density-dependent processes) and the availability of data (constrained by the small-scale spatial structure of the resource and artisanal nature of the fishery) and computer-based methods (GIS).

84. Occurrence and possible implications of the lobster Homarus americanus *Norwegian waters, Gro I. van der Meeren, Kees O. Ekeli, Knut E. Jørstad & Stein Tveite*

In November 1999, two female lobsters, one with external egg batch, were captured in the common lobster fishery in the Oslo fjord, Norway and reported as possible American lobsters, *Homarus americanus,* to Bergen Aquarium and the Institute of Marine Research. More, but undersized specimens were said to be present in the fishery. Six more American lobster has since been captured several places along the Norwegian coast, both escapees from illegal import and some previously released on purpose. Some were banded, or showed sign of recent banding. Closer inspection confirmed that all eight showed a series of American characteristics, as a ventral tooth on the rostrums, longer and sharper teeth inside the cutter claw, and the typical greenish-brown colour common in American lobsters. Tissue samples were analysed by starch gel electrophoresis and all possessed new alleles, never reported in European lobster, *Homarus gammarus,* before, at several allozyme loci. These alleles correspond to common alleles in American lobsters as demonstrated in a reference sample. DNA analyses are under way. Possible ecological interactions and influence on the original lobster population when invaded by this possible competitor is currently being tested at the Bergen Aquarium, in cooperation with the Intistute of Marine Research. In each trial seven lobsters of each breed are to be stocked in a tank with five “good” shelters”, five suboptimal shelters and a feeding area with no shelter. Focus in these trials are: Competition for shelters of varying quality, competition for food, diurnal activity and social behaviour.

*85. The GEL project: Results of mtDNA RFLP analysis of the European lobster (*Homarus gammarus*) populations, Triantafyllidis, A. P. Apostolidis, V. Katsares, C.Triantaphyllidis, A-L Agnalt, E. Farestveit, A. Ferguson, P. Heath, K. Jorstad, M.Hughes, E. Kelly, J. Mercer, P. Prodohl, J. Taggart*

Despite the commercial importance of the European lobster (H. gammarus),little information exists on its genetic structure and diversity. MtDNAanalysis can contribute successfully to the estimation of the geneticdiversity and to the identification of different stocks. Several primerpairs have been designed in order to amplify the entity of the mtDNA, usingthe PCR technique, in four segments. After the initial screening using 24restriction enzymes for each segment, numerous enzymes have been found whichcan differentiate between the American and the European lobster species. Themost polymorphic mtDNA segment (which comprises part of the cytochromeoxidase I gene, cytochrome oxidase II and III genes, the genes of the 6thand 8th subunits of the ATPase, the gene of the 3rd subunit of thedehydrogenase of NAD and several tRNAs) has been selected for extensivescreening with the five most polymorphic enzymes. Samples from more than 30localities throughout H. gammarus distribution have been analysed. Theanalysis has revealed high values of haplotype diversity for mostpopulations. Evidence of differentiation has been found for one Norwegian,one Dutch and the Eastern Mediterranean (Greek) populations. The restpopulations form one cluster with little geographic structure. In order tofind the complete sequence of the whole mtDNA, almost 2000 bp have beensequenced. Comparing the homologous sequences between H. gammarus and H. americanus, a similarity above 90% has been found.

This study is partly funded by European Commission contract FAIR CT 98 4266.

86. The GEL project: Microsatellite genetic variation within and among populations of the European lobster, Homarus gammarus, *P. Prodöhl, M. Hughes, A-L Agnalt, A. P. Apostolidis, E. Farestveit, A. Ferguson, P. Heath, K. Jørstad, V. Katsares, E. Kelly, J. Mercer, J. Taggart, A. Triantafyllidis, C. Triantaphyllidis*

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As part of an EC project[6] on the genetics of the European lobster (GEL), genetic variation within and among populations is being examined by means of microsatellite markers. Following cloning of a *H. gammarus* genomic library enriched for tri- and tetranucleotides, 54 sets of primers were optimised for the Li-Cor™ automated genotyper system. 35 loci, which were found to be polymorphic and technically reliable, were chosen for initial screening in a test set consisting of 10 lobsters from each of 10 locations from throughout the European range of the species (northern Norway to Greece), and 10 individuals of *H. americanus*. These loci were found to be moderately variable, with 4 -17 alleles segregating per locus and expected per-locus heterozygosities from 12-92% in *H. gammarus*. *H. americanus* individuals were very distinct with many unique alleles and substantially higher variability. Screening of a subset of 20 microsatellite loci on 200 individuals from a single *H. gammarus* population sample indicated that a sample size of 85 individuals is optimal for population studies taking into account both the distribution of genetic variability and technical considerations. These initial analyses enabled subsets of microsatellite loci to be chosen either for routine population or individual/family identification based studies. Details of the inter- and intra-population sample genetic variability results obtained from ongoing survey of c100 individuals from more than 30 localities throughout the European range of the species will be presented.

This work is partly funded by European Commission contract FAIR CT98 4266.

[6]For further details of the European lobster genetics project see http://www.qub.ac.uk/bb/prodohl/GEL/gel.html

87. *The GEL project: Paternity assessment and Breeding Structure in the European Lobster* Homarus gammarus, *M. Hughes, P. Prodöhl, A. Apostolidis, E. Farestveit, A. Ferguson, P. Heath, K. Jørstad, V. Katsares, E. Kelly, J. Mercer, A. Triantafyllidis, C. Triantaphyllidis*

Knowledge of the breeding structure is fundamental to the rational management of a species and for understanding its population genetics. Current models used to determine effective population size are based on the assumption of monogamy with equal numbers of males and females having offspring. However, other reproductive strategies could exist involving multiple matings, i.e. polgyny, polyandry or polygynandry. Thus more individuals of one sex may contribute offspring and therefore genes to the next generation. Clearly, stocking activities could rapidly and substantially change the genetic composition of natural populations if such reproductive strategies exist. Further complications arise from the consequences of the reported ability that female lobsters have to store sperm. As part of an EC project[6] on the genetics of the European lobster (GEL), berried females of the European lobster were collected from 10 locations across the geographical range of the species. The paternity of egg masses from over 60 females was determined using 5 polymorphic microsatellite markers. Preliminary results suggest that, in the wild, eggs from a female lobster are fertilised by a single male. However, results obtained from breeding experiments in captivity, involving several males and females, indicate the potential for a more complex breeding structure involving both polygyny and polyandry. Further results and biological implications of these mating behaviours will be discussed.

88. *Quality of* Nephrops norvegicus *(L.) larvae from the Mediterranean and Irish sea, Guiomar Rotllant, Klaus Anger, Mercè Durfort and Francisco Sardà*

The Norway lobster, *Nephrops norvegicus*, is a commercially exploited decapod which is widely distributed throughout the north-eastern Atlantic and the Mediterranean Sea, where growth and reproduction are known to vary geographically. Ovigerous females from the Mediterranean and the Irish Sea were held at the Barcelona and Portaferry laboratories until larval hatching occurred. Changes in wet and dry weight (WW, DW), elemental composition (C, N, H), contents of ash, water, total lipids and proteins, and in digestive cell structure were examined in newly hatched larvae from both regions. Larvae from the Mediterranean population appeared to be larger than those from the Irish Sea, and their water (% WW) and ash (% DW) were higher. Elementary analysis showed that the absolute quantities of C, N and H per individual and the C/N ratios were higher in samples from the Mediterranean, while the relative CNH values (in % DW) were lower. The absolute level of protein was higher in larvae from the

Mediterranean, but no significant differences were observed in the individual lipid content; the relative protein and lipid values were higher in the Irish Sea population. The digestive cells were larger in larvae originating from the Irish Sea, suggesting a higher potential for food conversion. Intraspecific variability in size and biomass of newly hatched larvae from different regions may be related to different patterns of reproduction: In the Mediterranean Sea, larvae hatch in winter when planktonic food is scare; their survival should thus be favoured by enhanced initial energy reserves. This is in contrast to the Irish Sea, where hatching occurs in spring, i.e. during a period of high plankton production.

89. Gillnet by-catch of crab claws and it's impact on edible crab stocks in Scottish waters, Shelly ML Tallack

Vessels using gill-nets to target monkfish *Lophius piscatorius* operate in the vicinity of Shetland and also catch *Cancer pagurus* from which only the claws are landed. However, little is understood about the impact that such fishing methods are having on stocks of edible crab in Shetland or elsewhere in the UK. It is possible that on a small scale this lucrative bycatch claw fishery may have little impact on the overall quality and long-term sustainability of edible crab populations. However, large, though probably under-recorded, quantities of crab claws are being landed. In the current paper, an attempt has been made determine the size range and sex of crabs from the landings of claws, and to assess the impact of the gill-net fishery. Sampling access to claw catches is difficult owing to the controversial nature of this fishery. A total of 311 right chelae were examined in three samples seized by the Scottish Fishery Protection Agency. Measurements were made of chela length, height, weight, shell condition and incidence of black spot disease. Findings were compared with similar chelae measurements taken from samples of whole crab, from males (n=406) and females (n=397). Based on the whole crab data, an attempt was made to determine crab sex for the fished claw samples utilising the inter-relationships between the various chela parameters. Subsequently, sex-ratios and size-frequency distributions of the source crabs were extrapolated for each claw sample. The methods employed require further work in order to improve the accuracy of predictions. Nevertheless, the results in this paper represent a preliminary and novel attempt at assessing the impact on *Cancer pagurus* imposed by the gill-net monkfish fishing operations. Future investigations into the sustainability of *Cancer pagurus* resources would be justified in addressing this issue further.

90. An overview of the genus Plesionika *Bate, 1888 in European waters: Distribution, ecology, biology and fishing., Dimitris Yafidis, Chrissi-Yianna Politou, Aina Carbonell & Joan Company*

The genus *Plesionika* Bate, 1988 has a widespread occurrence all over the world and consists mainly deep water shrimps. *Plesionika* shrimps are nektobenthic species which feed on pelagic and benthic resources. Many studies have been done on the *Plesionika* shrimps of Mediterranean and European Atlantic regions. These studies have been concerned mainly with biogeography and ecology of the species and less on their biology. There are eight species in the genus; *Plesionika antigai* Zariquiey Alvarez, 1995; *P. giglioli* (Senna, 1902), *P. heterocarpus* (Costa 1871), *P. martia martia* A. Milne-Edwards 1883, *P. narval* (Fibricius 1787), *P. acanthonotus* (S.I. Smith 1882), *P. edswardsii* (Brandt 1851), *P. ensis* (A. Milne Edwards 1881).

In this paper an overview of the published and unpublished information on this genus in European waters is presented. This focuses on the distribution, biology, ecology and fisheries for these species.

91. The research plan and some preliminary results of the population structure of Edible Crab Cancer pagurus *along the Swedish West Coast, Anette Ungfors*

The fishery for the edible crab, Cancer pagurus, is underdeveloped in Sweden. The official commercial annual landing has been below 100 tonnes for three decades. Fishermen look upon this coastal fishery as highlydevelopable. A constellation of fishermen, fish auctions and fisheries biologists have, in a cooperative development project, identified critical tasks and research areas. This group identified processing industry and suitable logistics but not the resource as the missing link. In the project, the presumed future increase in fishing effort and fishing mortality on the crab stock are considered; the fishermen and industry want to know the harvest potential for a sustainable fishery. The project studies the resource (CPUE and quality) at different fishing grounds and seasons, as well as land based development of receiving stations and quality asssurance with light screening equipment. Local management is a trend in management of marine resources. In 2001 a PhD study started with the aim to investigate the biological background of the usefulness of local management in the crab fishery. The study focuses on population structure and life history parameters. Fisheries biological data are collected in three different ways; 1) log books from voluntary fishermen (long time series and a new started standardised voluntary programme), 2) regular visits onboard commercial vessels and 3) a combined commercial-research vessel. Mark-recapture data on migration and growth (1968-1973) are also considered. A population genetic investigation will be accomplished. If primers are available (now under development in an EU financed project in UK) the genetic cue will be microsatellites, otherwise the method is by RAPD.

92. Application of the Traffic Light Method to the Assessment of Decapod Crustacean Stocks in the Northwest Atlantic, D. G. Parsons, D. C. Orr, E. G. Dawe and G. Black

Development of assessment techniques for Crustacea, conceptually similar to the traffic light methodology described by Caddy in 1999, began in the late 1980’s in eastern Canada with a review of management alternatives for northern shrimp, *Pandalus borealis*. Since then, the use of multiple indicators to assess stock conditions with respect to factors such as abundance, mortality, production and the environment (physical and biological) has become widespread. Stock status reports for both northern shrimp and snow crab (*Chionoecetes opilio*) routinely display lists of performance indicators together with their interpretations and evaluations. The method has been received favorably by scientists, fisheries managers and the fishing industry. We offer a poster contribution designed to display recent developments in the application of the traffic light methodology to the assessments of selected crustacean stocks in eastern Canada.

93. Homarus gammarus *catch rates and environmental factors in Scottish waters, H.A. Lizárraga-Cubedo, I. Tuck, N. Bailey, G.J. Pierce and D. Bova*

European lobster is a highly valuable resource and its fishery represents the second biggest shellfish fishery in Scottish coasts. Recent modifications in minimum landing size (MLS) and a combination of other factors could have caused a steady increase in recruitment in the last five years. Fluctuations in lobster catch rates may reflect the variation of environmental parameters (Sea surface temperature, wind speed and direction), habitat composition, shelter and food availability, competitors and abundance. Well documented is the high correlation between SST and landings for the *H. americanus* fishery in American-Canadian waters and for *H. gammarus* in Welsh and Norwegian coasts. However, little is documented about the influence wind speed and direction has on the catch rates of *H. gammarus*. Moreover, analysing the structure of the catch rates may be a good approach to forecast future fluctuations in short-long term that allow fishery managers good decision taking in preserving the stocks.

Information on relative abundance indices (cpue) is obtained from log book forms on a monthly and annual basis for two main coasts of Scotland. Long time series of mean Sea surface temperature (SST), wind speed and wind direction will be analysed on an annual basis for the Southeast and Hebrides areas. Finally, comparisons on the structure of the relative abundance indices and environmental variables will be obtained by autocorrelation functions and cross correlation functions.

*94. Incorporating effects of error propagation in yield-per-recruit models for the common whelk (*Buccinum undatum*), Daniel Valentinsson*

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Fisheries stock assessment typically involves models that combine several estimates (e.g. stock size, body growth and mortality), each associated with some form of uncertainty. In order to fully acknowledge this uncertainty, it is necessary to determine how these uncertainties interact and propagate through calculations to produce uncertain final estimates. This paper evaluates a formal framework for error analysis, using a yield-per-recruit (dynamic pool) model on populations of the common whelk (*Buccinum undatum*) as an example. The framework is, however, applicable for any modelling procedure. Yield-per-recruit models are often used to seek fishing mortality rates that achieve the best trade-off between the sizes of animals caught, and the number of animals available for capture. As the data requirements are relatively modest, this family of models is often used in developing fisheries where little information on exploitation is available. In Sweden, a recent interest for the common whelk initiated a research programme in 1998. The results presented in the present paper are based on the initial exploratory fishery in the Skagerrak and the Kattegat. The results are discussed in the light of alternative approaches of addressing uncertainty and potential implications for sampling strategies.

95. Comparison of trawl survey and commercial fishery data to assess crustacean populations in the northern Tyrrhenian Sea (Western Mediterranean), Sbrana M., Belcari P., De Ranieri S., Reale B. and Sartor P.

Norway lobster, *Nephrops norvegicus* (Linnaeus, 1758), and deep-water rose shrimp, *Parapenaeus longirostris* (Lucas, 1846), are two economically important resources of the Mediterranean trawl fishery. In the northern Tyrrhenian Sea (Western Mediterranean) these species are exploited by otter trawling on muddy bottoms; *P. longirostris* is mostly caught from 200 to 300 m depth, while *N. norvegicus* on deeper bottoms (from 300 to 500 m). In this area, available data to assess these two species came from commercial fishery and from experimental campaigns. In order to evaluate if the information contained in these two sources of data allow to obtain the same picture, a comparison of abundance indices obtained in this area with the two sampling methods has been performed. Six years (from 1994 to 1999) of trawl landing data and trawl surveys data have been compared. Landing has been related with the corresponding fishing effort (fishing day per boat), in order to obtain landing per unit of effort (LPUE). The annual trends of LPUE are analysed applying a Generalised Linear Model (GLM) in order to derive standardised indices.

Annual abundance indices (catch per unit of effort, CPUE) of the two species, expressed as biomass per surface unit (km^2), are available from trawl surveys. Finally, the standardised LPUEs are compared with CPUEs to verify the existence of similar trends in the considered period.
At the same time, geo-referenced information coming from experimental trawl surveys and from commercial fishery are utilised to perform maps of distribution of these two species and to localise the most important fishing grounds, applying geographical information system (GIS) techniques.

96. How To Estimate Specific Fishing Effort In The South-Southwest Portuguese Multi-Species Crustacean Trawl Fishery, P. Sousa, M. Afonso-Dias, J. Simões and C. Pinto

Multivariate techniques were used to classify the 1998 and 1999 fishing trips of the South-Southwest Portuguese Crustacean Trawl Fishery. Hierarchical Cluster Analysis (HCA) was applied to log-transformed landings data to find groups of similar relative specific composition. Each hierarchical cluster must contain similar fishing trip types. The HCA was performed using the Euclidean Distance between observations and Ward's minimum variance method. The optimal number of clusters was found by analysing the fusion coefficients against the classification step, taking into consideration the loss of homogeneity within the clusters. The availability of GPS data (from the Portuguese Vessel Monitoring System) for the vessels with classified fishing trips, made it possible to quantify and map specific fishing effort for this fishery, within a Geographical Information System.

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97. Differential catchability of male and female European spiny lobster Palinurus elephas *(Fabricius, 1787), Raquel Goñi, Olga Reñones and Antoni Quetglas*

In contrast to better studied shallow water palinurids, partitioning the role of changes in abundance and of changes in catchability in stock assessment surveys of *Palinurus elephas* in the Mediterranean is not readily possible because its deep distribution hampers direct observation by divers. However, lobster survey catches may be influenced by behaviorally or environmentally driven changes in catchability and gear saturation. Catchability in traps may depend on biological and physiological factors, such as sex, size, molt or reproductive state, as well as on environmental factors such as temperature or moon phase. We conducted a study on the relative sex and size selectivity of traps and trammel nets to help the interpretation of the results of a series of experimental trap surveys conducted annually to assess the abundance of P. elephas in the Marine Reserve of Columbretes Islands. Our study reveals a discrepancy in the sex ratios of trap and trammel net catches that indicates reduced catchability in traps of male lobsters relative to females. This reduction in catchability appears to increase with lobster size and is more marked at certain times of the year. Since the largest lobsters in the population are males, it is difficult to ascertain whether the reduced catchability is sex- or size-related. We discuss the implications of these findings for the assessment of deep-water spiny lobster populations.

98. Seasonal variation in nutritional condition of Nephrops norvegicus *from the western Mediterranean Sea: an experimental approach, Joan B. Company, Guiomar Rotllant and José A. García*

Matter inputs to the benthic systems of continental slopes can be in seasonal pulses and the biological responses of the organism living at these depths could be linked to these pulses. Several studies have shown how populations are structured in relationship with the differential matter concentrations along their distribution ranges. Fewer studies have intended to find the relationship between seasonal fluxes of matter, mainly in form of organic matter, and some specific biological processes. With the objective to determine the effect of the seasonal fluxes of matter to the sea floor on the biological processes, concretely on the nutritional condition of *Nephrops norvegicus*, the biochemical composition (lipid, protein and carbohydrates) and oxygen consumption were conducted in individuals fresh-caught sampled seasonally and in individuals kept during 3 months in the laboratory under fed and food deprivation conditions. The preliminary results show an effect of the season on the carbohydrates and protein content, being significantly lower in the individuals sampled during winter and spring seasons. The individuals kept in the laboratory in food deprivation conditions also presented lower carbohydrates and protein content, and their oxygen consumption were significantly lower than the individuals kept in fed conditions. The results concerning lipid content and organic matter are still pending to be analyzed. *Nephrops norvegicus* adapts its metabolic condition to the surrounding environmental features. In order to understand the dynamics of the deep water environments, further studies needs to be undertaken concerning the links between specific environmental features (light, organic matter, depth, etc) and biological processes. This knowledge will surely help the management of these habitats.

99. A study of ovigerous Cancer pagurus *in situ, Astrid K. Woll*

Ovigerous *Cancer pagurus* in depths from 5-20 meters were observed during frequently diving from February 2001 until hatching. Ten of the crabs were tagged and their hiding place marked with the same number such as movements of the crabs could be noticed. Behaviour in the cold water in February – March were compared with behaviour from April until hatching.

100. Background, aim and method for a resource study of Cancer pagurus in commence in North-western Norway, Astrid K. Woll and G. van der Meeren

The Norwegian fishery for *Cancer pagurus* was in the 1940-50's a considerable industry in the coastal regions of Norway where 7-9000 tonnes were fished annually. After 1955 the fishery declined, the profit was low and in the early 90's the industry was heavily subsidized. A plan for the industry took action when the subsidizes were cut and the landings dropped. This, together with an increasing demand, has brought profitability into the trade again. The crab industry now wants to increase the catches.

Little is known about the crab-resources in Norway. Therefore a programme is to start this year where data will be recorded from voluntary logbooks maintained by commercial fishermen. Each fisherman will record the catches from 4 of his pots, selected in advanced. The data will form the basis for annual indexes. Catch per pot-lift, carapace with, sex and quality will be observed and used for comparison of the catches from different geographic areas from Møre to Lofoten. The method will be compared with more traditionally surveys.

101. Do continuing high catch rates for the European lobster, Homarus gammarus L., around Jersey, Channel Islands in an area of a large tidal gyre suggest that hydrographic mechanisms are at work in addition to the normal recruitment process ?, Simon F. Bossy and G.M. Morel

The relationship between commercial trap catches of decapods and their abundance is known to be complex. Catch per unit effort (CPUE) data may be useful to assess changes in stock abundance, if collection protocols are standarised. Data was collected in 2001, analysed and compared with historical data. It appears that the local lobster stock is very resilient despite escalating fishing effort in terms of pot number pot efficiency. There is a well documented tidal gyre around the Island that may assist in acting as a sink for lobster larvae. This may suggest that other mechanisms (e.g. hydrographic) are at work in maintaining high catch levels locally.

*102. Spatially based logbook system in Canadian Gulf of Maine lobster (*Homarus americanus*) fishery: Use in assessments and management, D.S. Pezzack, P. Lawton, M.B. Strong and C.M. Frail*

The lobster fishery in the Gulf of Maine extends from the subtidal zones to depths of over 700m along the upper slope and in the deep basins up to 200km from shore. Over 14,000 t are landed annually within this 50,000 km2 area which has a diversity of habitats, population densities and demographics and fishing practices and effort. The spatial complexity of the fishery and population requires spatially explicit data if assessments and management is to be effective. In 1998 biologists working with fishermen put in place a grid based log book system to be used by all 980 licensed fishermen in Canadian Lobster Fishing Area 34 in the eastern Gulf of Maine. Fishermen recorded daily catch and effort in 10X10 minute grids. This resolution provided the detail needed for biologist while addressing the concerns of fishermen over fishing location confidentiality. Data has been used to design at sea sampling programs, document seasonal and interannual changes in v-notching activity, effort, catch and catch rates and to respond to localized management issues. Used in combination with at-sea sampling size frequency data spatial distribution of sizes groups and egg bearing females have been mapped and provides the bases for development of a spatial fisheries model. Examples of the log information and its uses are presented.

103. Ecological Ramifications of Disease in the Caribbean Spiny Lobster, Panulirus argus, *Donald C. Behringer, Jr, Mark J. Butler, IV and Jeffery D. Shields*

Spiny lobsters have few reported diseases. The identification and prevalence of pathogenic diseases in wild populations of spiny lobsters are poorly known, and the effects of such diseases can only be guessed. We recently discovered the first viral disease known to infect lobsters, in this case the Caribbean spiny lobster (*Panulirus argus*). Our findings suggest that the disease alters the behavior and ecology of this species in fundamental ways, in part via remarkable changes in the social behavior of healthy individuals in response to diseased conspecifics. Both field and laboratory data show significant avoidance of infected lobsters by healthy conspecifics. We have identified infected juvenile lobsters at 75% - 100% of the 14 nursery habitat sites that we have surveyed twice a year (summer and winter) in the middle and lower Florida Keys, USA since 1999, with the disease prevalent in up to 40% of the juveniles at each site (mean = 8%). These estimates are based on late stage infections, and therefore conservative since we have not yet developed a diagnostic tool to assess infection at earlier stages. Our viral diagnosis was derived from negative Gram stains for bacteria on several individuals and histological examination showing alterations and nuclear inclusions in certain hemocytes. Subsequent transmission electron microscopy (TEM) confirmed the disease to be an enveloped, icosahedral, Herpes-like DNA virus (HLV-PA). Infected animals are often moribund, exhibit lethargy and have milky or chalky hemolymph. The virus appears to be highly pathogenic and lethal, with an infection rate of 90% (n=20, control n=10) in initial challenge trials using injected hemolymph from infected donors. We are awaiting histological diagnosis of infection from a recent oral-ingestion trial. We plan to incorporate all of this new knowledge into our existing spatially-explicit, individual-based simulation model describing lobster recruitment in the Florida Keys to assess the threat of the disease to the sustainability of this important fishery resource. An intriguing epidemiological twist is that commercial and recreational fishing activities for this economically valuable species potentially contribute to the spread of the pathogen.

104. Spatial Distribution Of The Portuguese Crustacean Trawl Fleet Fishing Effort In 1998-1999, M. Afonso-Dias, J. Simões and C. Pinto

The 1998 and 1999 GPS data transmitted by the South-Southwest Portuguese crustacean trawl fleet in 10 minutes interval and collected within the National Monitoring Vessel System was used to create a specific database (Access 2000). This relational database also incorporates landing data by vessel. Specific software was developed (in Visual Basic 6.0) to map, edit and analyse the data. An activeX control (MapObjects 2.0) was used to develop a Geographical Information System (GIS). This study includes the preparation of a geo-referred digital chart for the studied area and the identification of each fishing trip and trawl hauls. The geo-referred digital chart combines information from the three fishing charts available. The developed software allowed the identification of each fishing trip and the trawl hauls made within each fishing trip by vessel. A fishing trip was defined as a trip of one or more days with a consequent landing. The fishing effort was quantified and mapped by area and depth range. The fishing operation regime of this fleet, in 1998 and 1999 is also described.

105. Catch per unit effort and biological data of Nephrops norvegicus *from the SW Ireland Spanish trawl fishery, Fariña, A.C. & González, I.*

Norway lobster *Nephrops norvegicus* is a burrowing species inhabiting soft bottoms in the NE Atlantic and Mediterranean. In European western waters (SW Ireland) *Nephrops* is a commercial species of the bottom mixed fishery prosecuted by fleets from Ireland, France, UK and Spain. A comprehensive collection (1980-2000) of Spanish trawl fishery data and sampling of landings is available. Although *Nephrops* is a by-catch species for the Spanish trawl fleet, some vessels target it mainly during the spring and summer season. This study present a summarized description of that fishery and catch per unit effort trends. Annual *Nephrops* length composition by sex, length-weight relationship, sex-ratio and proportion of ovigerous females are given for the referenced period.

106. Sperm limitation and fertilization success of Caribbean spiny lobster in marine reserves and fished areas, Mark J. Butler, Alison B. MacDiarmid and Jamie Heisig

Fishing-induced changes in the size structure of spiny lobster populations may dramatically alter the reproductive success of individuals in unexpected ways. Because the reproductive output of females increases exponentially with female size, a shift toward smaller females in exploited populations has clear implications for reproductive success. Yet, under exploitation, male size often declines more precipitously than female size. The effect of reduced male size on sperm dynamics and fertilization success is not well known, but our earlier laboratory studies suggested that male size was surprisingly important to fecundity. In this study, we used laboratory experiments and field observations to compare sperm depletion, recharge rates, and fertilization success of Caribbean spiny lobster (*Panulirus argus*) from marine reserves and fished areas in south Florida. Our laboratory results show that sperm depletion, sperm recharge, and fertilization success differ with changes in male and female size that are indicative of populations in reserves and fished regions. Our field data indicate that sperm counts in spermatophores produced late in the mating season are indeed lower than those produced early in the season, and the decline differs between reserves and fished areas. We are now modeling this system to better understand these complicated dynamics and their consequences for the reproductive success of populations differing in size-structure, density, and sex ratios.

107. *Genetic differentiation of Norway lobster (*Nephrops norvegicus*) populations as revealed by mitochondrial DNA analysis, Costas Stamatis, Katerina A. Moutou, Alexander Triantafyllidis and Zissis Mamuris*

Nephrops norvegicus is a burrowing decapod crustacean whose area of distribution comprises the NE Atlantic and the Mediterranean and it is commercially exploited throughout its geographic range. Annual landings are around 60,000 tonnes making the species one of the most valuable lobster resources in the world. Although various aspects of its biology and fisheries have been studied, data on genetic population structure that could provide additional information for life history and proper fisheries management remain scarce throughout species' distribution.

In the present work, 231 specimens were studied from four areas of the North Sea, one of Portugal and five of the Aegean Sea, using mitochondrial DNA analysis. Two segments [Cytochrome b/D-loop, (2000 bp) and COI (1400 bp)] were digested by 20 restriction enzymes and gave 23 and 56 haplotypes, respectively. In a total of 94 haplotypes detected, 11 were common, while 42 were found only within the Aegean Sea and 41 only within the North Sea and Portugal. Thus, statistically significant difference ($P<0.005$) was found, concerning the distribution of haplotypes among these water bodies. On the contrary, there were no significant differences among populations within the Aegean and the North Seas. According to the N_{ST} value of 0.506, genetic differentiation was equally distributed among and within populations. High genetic polymorphism might be indicative of large population sizes with lack of bottleneck phenomena (e.g. fishing pressure). Inter-population nucleotide divergence was low, ranging from 0.000% to 0.045%, and it was not correlated with populations' geographical distances, suggesting an increased gene flow even between very distant populations.

European Decapod Fisheries: Assessment and Management (EDFAM)

Concerted Action Project number QLK5 1999 01272

Workpackage 4: Draft Final Report

I. Sampling design in European Crustacean Fisheries
II. Database template for European Crustacean fisheries

Main Contributors

Ch. Mytilineou, K. Kapiris, A. Conides, S. Kavadas, C.Y. Politou, J. Dokos, O. Tully

Contents

I. Sampling design in European Crustacean Fisheries

Introduction
Careful planning of the sampling design is essential to achieve maximum efficiency, accuracy and precision in results and advice to fisheries managers. It is necessary to consider the following questions prior to detailed planning

- How much work can be expected from available vessels, gear and staff?
- What is the variability in results from the sampling technique to be used, e.g., trawl-nets, static nets, traps, etc?
- What data are to be collected and which design is most suitable for recording them?
- How much money is available?

Various works in the literature deal with the planning of the sampling design (e.g. Bazigos, 1974; Cochran, 1977; Garcia & Le Reste, 1981; Nielsen & Johnson, 1983; Fogarty, 1985; Caddy, 1989; Do Chi, 1993; Sparre & Venema, 1998).

Taking into account the available up to date information for European decapods concerning their sampling, assessment, management and fisheries (as included in the metadata database of the EDFAM project and as described in the report of WP1) some general sampling design recommendations are outlined below. Special attention is given to the metapopulation concept and required data, since it is an approach that will need greater attention in the future assessment and management of these fisheries (see report of WP3).

Search for Historical Data
Existing data from research studies or the commercial fishery (biological information, distribution, landings, effort, fisheries related data) should be sourced and reviewed prior to planning any new program. As far as European decapod fisheries is concerned the majority of the information is available from research projects. Relatively less information has been derived from the commercial fishery although in northern Europe this imbalance is not so apparent.

In all countries more effort should be given to the collection of time series of data from the commercial fishery (catch, effort) and on suitable spatial and temporal scales. Long term scientific studies on recruitment, spawning and juvenile indices should also be increased. The majority of scientific studies on these fisheries are short term and discontinuous over time.

Sampling Design
Attention should be given to the following

- *Accuracy* or consideration of how well the samples represent the population. Design should ensure representative samples, especially when the sampling method (e.g. gear) in use collects only a part of the population. Distribution and burrowing behavior, daily migrations in the water column, seasonal migrations in various depths etc could affect the accuracy of the samples.
- *Precision* refers to repeatability and requires careful design, extensive sampling effort and large samples. Statistics for an estimate made from a sample (e.g. standard deviation, confidence limits) are measures of precision.
- *Cost-benefit gains* should be considered in relation to the quality of the collected data and the use to which the data can be put.

Sampling
Sampling could be random, stratified, stratified two-stage probability, clustered, systematic or permanent depending on the objectives. Environmental characteristics and time of day, season related to growth, spawning and migration of the target species should be taken into consideration in the sampling design.

Sampling location-period:
The location and period sampling should be chosen on the basis of the objectives. Survey could be carried out a single time or several times. For exploratory purposes the area to be explored should be selected so that it can be sampled adequately with the survey equipment available, thus ensuring that meaningful results are obtained and that sampling over a large range of habitat types can be carried out. Attention should be given to the distribution of the population because in many cases the sampling area does not include the whole population.

Choice of Gear:
The choice of gear depends on the stocks that will be surveyed and the objectives of the study. Gear for exploratory fishing should be selected to make the most efficient use of sampling time rather than to take high catches. Attention should be paid to all factors affecting the construction of the gear (e.g. material, size, auxiliary elements) as well as its operation (e.g. trawling speed, trawling direction, strength and direction of currents in the area, depth, sampling time). The same gear should be used in all samplings over time. Different gears should be used only when one gear is not adequate to catch accurate samples of the whole population. The various phases in the life-history of a species may require several sampling gears. Trawling is generally the least selective type of gear but when appropriate a 10 to 20 mm mesh size should be used in the codend or a small mesh cod end cover should be used to catch specimens which normally escape. More selective gears (e.g. gill nets, trammel nets) influence the estimates of several biological parameters (e.g. growth rate, mortality, length-weight relationship).

Choice of vessel
The choice of vessel could be commercial or research. Commercial vessels are more efficient at fishing, but research vessels offer more facilities and permit the use of more sophisticated equipment and methods.

Number and size of samples
The desired accuracy and precision in the target data will determine the balance between number and size of samples. Generally, many small size sampling sites in relation to the available budget improve the data accuracy and precision.

Sample size
The sample should be representative and where large a sub-sample should be taken using specific rules that preserve the integrity of the sample.

For decapods, samples should be separated by sex. Samples for biological studies (e.g. reproduction, fecundity, relative growth, moult, gastroliths, stomach analysis etc) should cover all the size range according to a predetermined rate (e.g. 10 specimens per 5 mm interval). Samples for length-based analyses should be composed at least of 200 individuals per each stratum, where stratum is the gear, the season, the month, the depth, the location (Gulland and Rosenberg, 1992) or 1500 individuals annually (Hoenig et al., 1987 cited in Pauly & Morgan, 1987). Other researchers suggest that the sample size should consist of at least 50 specimens for each age group composing the length frequency histogram (MacDonald and Pitcher, 1979). Since length based analyses are frequently used in decapods, attention should be paid by the researchers to obtain large and representative samples of the whole population.

Measurements:
- They should be precise when they are related to the main objectives of the work.
- They should be in metric units, because they can be easily converted to larger or smaller units since the entire system is based on units of 10.
- The digits reported in means should be of the same significance as that taken during measurement.

- Attention should be given by the data collector to not exhibit a preference for certain numbers thereby introducing bias into the data

Research Data

A study of a stock of decapods where the objective is to develop sustainable management of the resources, requires a good knowledge of the life-cycle as well as the relationship between the different stages of the cycle. Indeed because of the lack of a method of direct determination of age in decapods only a detailed analysis of the different stages can establish the chronology of the main phases (spawning, larval migration, juvenile migration, recruitment, etc.). The study of the different phases of the life cycle of decapods (larvae, juveniles, adults) requires different approaches in the sampling design.

Fisheries Surveys data

Sampling should take into account possible seasonal changes in the distribution of the species, as well as the bathymetric distribution of densities and sexes. The work will be facilitated by the knowledge of the principal axes along which the variation occurs. The difficulties caused by diel variations in yield or by changes in vertical distribution are for the most part impossible to resolve satisfactorily. On the other hand, seasonal changes in nycthemeral rhythm could be taken into account by changing the sampling hours. The duration of the fishing time is also an important factor that affect catches and consequently catch per unit effort. One hour is generally recommended for hauling during trawl surveys. The effects of the immersion time for traps on the catch is reported by various authors (e.g. Skud, 1979, Auster, 1986; Krouse, 1989).

<u>Data to be recorded during survey</u>

The following data should be recorded during survey

- Project
- Country
- Institute
- Scientist responsible for the project
- Chief scientist on board
- Scientists on board
- Sampling area
- Date and time of sampling
- Code number, coordinates, orientation and depth of the sampling station
- Time and Duration of the sampling in each station
- Gear information (type, characteristics, tack, gear behavior data)
- Vessel information (name, type, characteristics)
- Abiotic environmental data (depth, temperature, salinity, other oceanographic data, tide, currents, turbidity, bottom type, weather data, waves, daylight/darkness, moonlight etc)
- Biological data depending on the objectives of the work (benthos data, plankton data)
- Biological data for the target species and the community structure related to the species, abundance, biomass, population dynamics, by-catch species, discards, tagging experiments, geostatistics, biometrics and genetic studies.

Tagging studies

Attention should be paid to the mark that will be used and the duration of time the mark must remain on the organism, how easy it is to used, tag induced stress, the method of capturing the organism. The major problem in all crustacean tagging programs is moulting. Any tag must (a) survive the moulting process, and (b) not interfere with moulting itself. Many researchers have attempted to overcome this problem by anchoring the tag through the exoskeleton into muscle. These tags are associated with problems including high mortality, failed molting, excessive tag loss and attraction of predators (Anon., 1999a). The marking of crustaceans by branding the exoskeleton has been reasonably successful with the adult stage (Anon., 1999a). The use of streamer tags to identify small crustaceans was first tested on shrimp (*Penaeus* sp.). Tagged animals showed high survival, and did not appear to have any difficulty in swimming and borrowing (Marullo et al., 1976). In lobster (*Homarus sp*.) coded microwire tags have been successfully implanted in the base of the pereiopods in juvenile *H. gammarus* (Wickins & Beard, 1984; Uglem & Grimsen, 1995). A problem with microtags is that they are impossible to detect in live lobsters without a special magnetic sensing device (Uglem et al., 1996). Based on their findings, Linnane & Mercer (1998) proposed that elastomer be implanted into juvenile *H. gammarus* less than 10 mm CL and branding of individuals less than 15 mm CL is not advised. Branding and ablation are not recommended for long term tagging studies. The internally placed tags, i.e., visible implant elastomer and microtags would appear to be more suitable options. A variety of methods for marking juvenile crustaceans have been reported in the literature (Farmer, 1981). Tattoos (Ra'anan et al., 1991) and nylon filament tags (Schmalbach et al., 1994) have been used effectively to mark juvenile *Macrobrachium rosenbergii* from a size of about 10 g and 46 mm total length. Effective use of coded wire tags to mark small individuals (6 mm CL) has been reported for several species of crustaceans (e.g. *Homarus gammarus*: Uglem & Grimsen, 1995; Linnane & Mercer, 1998, *Panulirus argus*: Sharp et al., 2000 and *Scylla paramamosain*: LeVay et al., 1999). Successful tagging experiments have been carried out also for the deep-water red shrimp *Aristeus antennatus* (Relini et al., 2000). Particular attention should be given to the V-notched tagging method for female lobsters, already used in some of the northern seas of Europe (Ireland, Scotland, England).

Given that important information on growth, migrations, reproductive patterns and population estimates can potentially be obtained from tagging studies more effort should be put into tag studies. Increased cooperation between professional and sport fishermen is necessary in tagging studies.

<u>Data to be recorded</u>

- Project
- Country
- Institute
- Scientific responsible of the project
- Person applying the tag
- Species
- Type of tag
- Gear used to catch specimens
- Gear which recaptured the tagged specimen
- Area of capture of the specimens (coordinates)
- Date of capture of the specimens
- Number of tagged specimens
- Date of recapture
- Number of recaptured specimens
- Tag ID
- Time
- Damage from tag
- Size and weight of specimen before tagging
- Size and weight of specimen when recaptured

Ageing with lipofuscin

Lipofuscin, which is a fluorescent pigment detectable in crustacean neural tissue, is correlated with age in laboratory populations of decapods. In natural populations where age is unknown it is correlated with body size. In lipofuscin frequency distributions, modes are present in some instances and may indicate the age structure of these populations. Lipofuscin accumulation is affected by temperature acting through its effect on metabolic rate. Data produced to date showed that lipofuscin can be quantified in all species concerned and that it is correlated with age, in species for which the age is known, or body size, in species where the age is unknown. Different rates of accumulation of lipofuscin in males and females may be detected, indicating sex-specific differences in metabolic and growth rates and susceptibility to oxidative stress. Various laboratory and field based experiments are conducted to assess the role of temperature and population density on organism metabolic rate and lipofuscin accumulation.

Lipofuscin studies have been conducted for various European decapods such as *Homarus gammarus, Nephrops norvegicus, Penaeus japonicus, Parapenaeus longirostris, Aristeus antennatus* (Tully et al., 1995, Anon., 1999b).

<u>Data to be recorded in lipofuscin studies</u>
Species
Environment (natural, tank)
Environmental conditions (e.g. temperature)
Individual length
Sex
Age
Lipofuscin accumulation : % area occupied by lipofuscin granules, number of granules per unit area, average size of granules

Geostatistical studies
Geostatistics is an approach of combining advanced spatial statistics and GIS using software packages, which integrates both modern visualisation techniques and geostatistical methods for spatial data. The main reason to apply geostatistical techniques on fisheries data is that these techniques can be used to estimate values at unsampled locations i.e. interpolation. The accuracy of the estimation and by extension the quality of the produced maps depends of the following parameters: (a) the morphology of the survey areas, (b) the sampling grid and (c) the quality of the data and the calculated variance. The method is more appropriate for species which are not highly mobile relative to the time it takes to conduct the survey.

Few geostatistical approaches have been carried out for decapods in the Mediterranean Sea (e.g. *Nephrops norvegicus, Aristeus antennatus, Aristaeomorpha foliacea, Plesionika martia* etc)

<u>Data to be recorded</u>
- Coordinates of the sampling stations
- Depth
- Abundance or biomass of the target species

Biometric studies
Biometric data are used for stock separation and for phylogenetic studies. They are also necessary for management purposes by establishing mathematical expressions which define particular morphometric relationships.

Many morphometric studies have been carried out for the European decapods (e.g. *Nephrops norvegicus, Aristeus antennatus, Aristaeomorpha foliacea, Penaeus kerathurus, Maya sp., Homarus gammarus*)

<u>Data to be recorded:</u>
- Carapace length
- Total length

- Abdomen length
- Telson length
- Rostrum length
- Pereiopods Length
- Uropods Length
- Carapace height
- Abdomen height
- Scaphocerite (in shrimps, lobsters)
- Carapace width (in crabs)
- Tail length (in shrimps, lobsters)
- Claw length, height, circumference (in lobsters, crabs).

Genetic studies

The genetic substructure of a species is an important component for the management of harvested species, particularly in metapopulation studies (e.g. it might be used to predict whether immigrants will successfully repopulate a locally depleted population) (de la Rosa-Velez, 2000). r-RNA analyses are useful in phylogenetic studies (Kim & Abele, 1990). Decapods generally have very low levels of genetic variation as measured by electrophoretic techniques, the only exceptions seeming to be species occurring over broad areas and in widely different environments (Felgenhauer &Abele, 1983). DNA-based markers are newly developed methods and are still under development. Although they are more efficient, allozyme methods are still more accessible in gene flow studies. In the framework of the project GEL, it was found that a minimum sample size of 80 individuals should be used in microsatellite population studies. They recommend that for all future studies minimum sample size should be determined empirically, and that two persons should independently verify genotyping Triantafilidis et al. (2002).

Generally, few genetic studies have been carried out for European decapod species. Most of them are based on electrophoretic analyses (e.g. *Nephrops norvegicus, Penaeus kerathurus*) whereas DNA, allozyme and paternity analyses were carried out recently for *Homarus gammarus*.

<u>Data to be recorded</u>

- Electrophoretic (allozyme) analyses data
- DNA analyses data
- r-RNA analyses data

Metapopulation studies

An introduction to metapopulation concepts and how they may be appropriate to marine crustacean fisheries is presented in the report of WP3 (Part I).

<u>Data to be recorded:</u>

Determination of locally distinct subpopulations

- Determination of Spatial distribution of subpopulations
- Determination of Spawning grounds
- Determination of Nursery grounds
- Determination of Feeding grounds
- Genetic evidence of subpopulation
- Mark-recapture studies

Number of local subpopulations

- Source subpopulation-limited size subpopulations
- Equal subpopulations

Distance between subpopulations

Size of each patch occupied by each subpopulation

Isolated subpopulations
Population dynamics of each subpopulation
- Age distribution
- Mortality
- Life tables
- Sex ratio
- Fecundity
- Max age of males-females
- Reproductive age of males-females

Dispersal ability of specimens of each subpopulation
- Moving activity and ability
- Movements for spawning
- Movements for feeding
- Day-night migrations
- Larval stage dispersal ability

Environmental data for each patch occupied by a subpopulation
- Temperature
- Salinity
- Oxygen
- Light
- Substrate
- Currents
- Turbidity
- Geomorphology
- Barriers

Intra- and Inter-specific relationships
- Predator – prey relationship
- Intra-specific competition
- Interaction between species sharing localities and resources

Subpopulation growth rate
Subpopulation size
Carring capacity of local patches
Empty patches
Variables of emigration from each subpopulation
- First-last age of emigration
- Time interval between consecutive emigrations
- Male-female emigrations per age class

Variables of immigration from each subpopulation
- First-last age of immigration
- Time interval between consecutive immigrations
- Male-female immigrations per age class

Extinction factors
- Deterministic factors (e.g. habitat destruction, loss of refuges, food supply, competition)
- Stochastic factors (demographic stochasticity, environmental stochasticity, catastrophic events, genetic deviations)

Selectivity surveys data

These are studies for the study of gear selection. They are usually referred to as trawl codend selection and to gill net selection. The most commonly applied method for trawl selection studies is that of the covered codend. Trap selection is more complicated (Murno, 1974, 1983; Krouse, 1989), although Pope et al. (1975) suggested that trap selection is like the trawl type. Selection is usually related to length of individuals, however, it could also be a function of age, shape and other morphological factors.

According to Gulland (1972), the selectivity curves for shrimps are not sufficiently defined to justify regulations using mesh size. Mistakidis (1958) also points out that selectivity is not "perfect for prawns and that the trawls always retain, independent of mesh size, a proportion of juveniles. Sarda et al. (1993) and Mytilineou et al. (1998) for *Nephrops norvegicus*, and Ragonese et al. (1994, 2002) for *Aristaeomorpha foliacea* and *Aristeus antennatus* found that even larger mesh sizes in the trawl codend were little more selective than the one in use and certainly were not adequate to protect specimens around the size at first maturity.

Many selectivity studies have been carried out for several decapods in various European areas (*Nephrops norvegicus, Parapenaeus longirostris, Aristeus antennatus, Aristaeomoprha foliacea, Plesionika martia, Crangon crangon*). However, the objective was mainly the trawl codend selection.

Data to be recorded

- Project
- Country
- Institute
- Scientific responsible of the project
- On board responsible
- On board group
- Sampling area
- Date and time of sampling
- Code number, coordinates, orientation and depth of the sampling station
- Time and Duration of the sampling in each station
- Gear information (type, characteristics)
- Vessel information (name, type, characteristics)
- Biological data for the target species caught by the gear (length, weight) and the community structure related with the species, by-catch species, abundance.
- *In the case of trawl*
- Codend mesh size
- Cover mesh size
- Biological data for the target species in the cover of the codend (length, weight) and the community structure related with the species, by-catch species, abundance.
- Damaged specimens in the cover
- Mortality of specimens in the cover
- *In the case of nets*
- Net mesh size
- Hanging ratio
- Mortality of specimens caught
- Part of the body being selected (tail, cephalothorax, abdomen)

Direct Underwater surveys

These data can be collected directly by divers or by video camera or by bottom glass boat or submersible. They are useful, when other methods are inappropriate (e.g. in macrophyte beds, holes, coral rocks) or to combine information particularly for species behavior, habitat description, activity patterns and home range determination.

Underwater television and direct scuba diving observations have been carried out to study the behaviour, ecology and density estimates for Norway lobster in various areas of Europe as well as for *Squilla mantis*. Also scuba diving techniques have been carried out in for many macrobenthic species, among them many decapods.

Data to be recorded

- Project
- Country

- Institute
- Scientific responsible of the project
- Persons who did the observations
- Sampling area
- Method used
- Date
- Environmental conditions
- Species
- Enumeration of the population
- Behavior
- Home range
- Habitat description
- Activity patterns
- Size of specimens

Indirect Underwater surveys-Telemetry
Data can be collected by attaching to an organism a device that transmits biological or other information. Radio or ultrasonic or electromagnetic energy is used for the emissions. The tag can be external, stomach inserted or surgically implanted. Information on migrations, habitat and physiology (e.g. swimming velocity, activity, direction, heart beat, electrocardiogram) can be provided as well as abiotic information (temperature, salinity, light, depth). The method is expensive. Alternatives may be for laboratory studies or using other methods (e.g. tagging). The number of tagged individuals depends on the objectives, cost, labor, availability of animals, type of data desired and methods of statistical analysis. Generally, for widely distributed species 20-40 individuals should be tagged, whereas a smaller number for physiological or behavioral studies is required. The area of searching, the day-time and the time interval to record data and the number of data points depend on the nature of the target species, the objectives of the study and the available funds. Movements of semi-terrestrial and freshwater decapods have been studied by radio-tracking, but radio energy is severely attenuated by seawater (Smith et al., 2000). The most commonly used systems of telemetry in decapods (for crabs and lobsters) have been the ultrasonic ones, except in specific cases such as in intertidal areas or structurally complex habitats, where, on occasion, radiotelemetry or electromagnetic systems have been used respectively. Some studies have been carried out for European decapods using this method.

Ultrasonic tracking have been used to study various species of crabs and lobsters and, in some species, environmental, physiological, or behavioural data have been telemetered (Freire & Gonzalez Gurriaran, 1998). Ultrasonic tracking with a fixed hydrophone array is unsuitable for decapods inhabiting uneven rocky seabed, particularly when they spend a large proportion of their time within shelters or among dense vegetation (Freire & Gonzalez Gurriaran, 1998). Electromagnetic tracking has previously been used to study movements of spiny and clawed lobsters, initially using portable aerials carried by a boat or diver (Ramm, 1980) and later using a grid of loop aerials laid on the seabed (Collins et al., 1994). Smith et al. (2000) described a telemetry system based on digital encoding of electromagnetic signals, which permitted to track many more than one individuals simultaneously and additional behavioral, physiological or environmental data to be conveyed in the tag signals.

<u>Data to be recorded</u>

- Project
- Country
- Institute
- Scientific responsible of the project
- Survey responsible person
- Telemetry system (radio, ultrasonic, electromagnetic)
- Type of tag (external, stomach inserted, surgical implanted)

- Tracking method (boat, airplane, triangulation, fixed stations, diving etc)
- Species tagged
- Number of tagged individuals
- Date of tagging
- Area to set the tagged individuals
- Area from which data are recorded
- Time interval to record data
- Coordinates of each record
- Temperature
- Salinity
- Light
- Depth
- Swimming speed of animal
- Swi``mming activity of muscles
- Swimming direction
- Heart beat
- Electrocardiogram

Larval and settlement phase surveys
These are used to study the early life history stages, to identify spawning grounds and seasons and nursery areas, to evaluate the current status, seasonal or interannual fluctuations or long-term trends of community, stocks or populations and to differentiate stocks or subpopulations. The larvae are normally planktonic while the later stages may be either nektonic or benthic. Larvae of many marine invertebrates disperse far from their origin during the larval phase, but must return to specific areas, usually near shore, for successful settlement. In some cases the larvae have different temperature and salinity requirements from the later stages, and in all cases they have different food requirements. Moreover, in some cases, juveniles have a burrowing behaviour. All these factors should be taken into consideration in the sampling design. The number of the larval stages, the factors affecting their pelagic distribution, the exact time of settlement. Details on metamorphosis are not clear for many species. Additionally, the specific habitat requirements of juveniles are not known for many species. In many cases it is difficult to locate very small early pelagic or benthic stages of decapods and it may be difficult to taxonomically resolve some species. In same cases, rearing experiments are also required in order to obtain information about larval behaviour, such as orientation, swimming speed, etc.

The number and type of samples, number and distribution of sampling stations, frequency of sampling and the choice of the sampling gear should be related to the distribution, the nature and the behavior of the target species. It is also necessary to determine spawning grounds and nursery areas as well as settlement grounds. The location of sampling points must take into account the distribution of the adults. It is preferable to increase the number of sampling points in zones of greatest abundance of the adults. Distribution of larvae, limited sampling effort, inefficiencies of the sampling gear and techniques used increase variability. Replicate samples are needed to measure and limit this variability. Depending on the objectives, a twice a week to twice a month sampling frequency is required during the spawning period of the species except in for exploratory surveys. Time of day is also an important factor influencing the catchability of larvae that should be considered in the sampling design; many of the larvae reach the surface during night, whereas they move to the deeper during day. The gear selection should be done with care depending on the objectives. Plankton nets of large mesh size are commonly used. Sub-sampling prior to sorting is not recommended for most studies unless the abundance of the target species is very high.

The burrowing behavior of many decapod species makes the sampling of juveniles difficult because they are often buried for extended periods and are also able to avoid capture by rapidly burying when disturbed. In an effort to overcome these difficulties, a number of sampling devices have been developed. The majority of these devices rely on some mechanical means of scraping the bottom, thus a proportion of decapods may be disturbed, probably dependent on the sediment type and on the time of day or night, making the resulting catch data highly variable.

Data to be recorded
- Project
- Country
- Institute
- Scientific responsible of the project
- On board responsible
- On boardgroup
- Sampling area
- Date
- Gear type
- Type of draw
- Gear speed
- Shooting time
- Rope length
- Draw depth
- Draw time
- Water volume
- Plankton biomass
- No of larvae
- Oceanographic data
- Weather condition
- Sea `condition
- Number of larvae per species
- Length of larvae per species
- Larval stages per species

Hydroacoustic surveys

This method is not commonly used. Hydroacoustic studies for shrimps have been carried out in Japan but none is known from Europe. High frequency sounding seems to be more effective for small organisms such as shrimps.

Data to be recorded
- Project
- Country
- Institute
- Scientific responsible of the project
- On board responsible
- On boardgroup
- Sampling area
- Date- Time
- Nautical mile – Ping
- Coordinates
- Depth
- Frequency
- Layer
- Target strength (TS)
- Area back scattering coefficient (Sa)
- Weather condition
- Sea condition

Commercial Catch, landings and discards

Catch is defined as the total removal from the stock by the fishing effort. It could be landed and/or discarded. Attention should be paid to the estimation of the total catch since landings as well as discards should be considered. The discarded catch, includes non commercial species, the under-sized individuals of commercial species, the commercial species with market restrictions and the portions of commercial species with little or no value (e.g. heads). In order to sample the catch of exploited stocks the total area of distribution of the stock should be taken into account as well as all the fishing activities taking place in the area, which catch that particular stock (different vessels, different gears). In the case of shared stocks data from other countries should be taken into consideration.

Discards studies are not very common for European decapods. Furthermore, landings estimated from national statistics are not very reliable in many of the European countries and particularly the Mediterranean ones.

<u>Data to be recorded</u>

- Project
- Country
- Institute
- Scientific responsible
- Vessel data
- Gear type
- Gear data
- Date to record the data
- Number of hauls or length of nets or number of traps
- Fishing duration
- Day-time for fishing
- Area of fishing
- Port, Date and Time to leave from
- Port, Date and Time to return to
- Total Catch data (commercial, discarded catch)
- Landings data per species
- Discards data per species
- Biological data from the target species (landings and discards)
- Merchant buying the landings
- Data from the fisheries fleet (e.g. number of vessels, vessels data per gear, fuel)

Effort data

Effort could be estimated as gear (HP, vessel length etc) or be time (hours, days on trips) related. Effective effort could be affected by factors such as trip limits (e.g. maximum catch imposed), new technology and experience of fishers. Effort data could be obtained by the logbooks of fishers or by interviews of the fishers or by field work (onboard observation). If a certain quantity of a species is obtained in a certain fishing time or vessel-gear unit, then an effort estimation could be calculated. Stratified random sampling is necessary taking into account strata such as the fishing ground, the season, the landing port, the vessel type, the gear etc. Attention should be paid to species which are target in some areas whereas in others are incidental to the catch of other species.

In many Mediterranean countries logbooks do not exist. Effort data for decapods are not available from some European and particularly Mediterranean countries.

<u>Data to be recorded</u>

- Project
- Country

- Institute
- Scientific responsible
- Production, biological and economic Data
- Vessel data
- Gear type
- Gear data
- Date
- Area of fishing
- Number of hauls or length of nets or number of traps
- Fishing duration
- Total time in the sea
- Fuel consumption
- Total Catch data (commercial, discarded catch)
- Landings data per species
- Discards data per species
- Fishing fleet data

Socioeconomic data
The application of economic models in management is determined by two concepts, a) the production concepts, expressed by the industry production functions (bioeconomic models) and the firm production models, and b) the demand – consumption concepts. Three types of data could be collected: (1) the primary data which refer to data collected from the basic producer to the final consumer, (2) the secondary data which refer to the statistics published in a continuous basis by management agencies and (3) the experimental data which are generally of limited use in economic studies.

Many decapod fisheries consist of an inshore and an offshore segment. The inshore segment involves the use of different types of fishing gear- e.g. fixed nets, small boats with nets-. The offshore segment is more often the industrial fleet of trawl vessels. It is of increasing importance to have a sound understanding of the effective fishing effort, preferably of both segments of the fishing industry but at least of the industrial fleet.

<u>Data to be recorded:</u>
Project
Country
Institute
Scientific responsible
I. Economic data

(a) Production statistics:
- Landings, Weight (Kg), Value, Effort
- Boats and Vessels (number, size, motor size, age, equipment)
- Fishers (full-time, part-time, fishing rate)
- Gear units by specific type

(b) Market statistics
- Employment
- Number of wholesalers, Processors, Middlemen, Importers, Exporters
- Employment in marketing sector
- Prices
- Fishers (Prices received from wholesalers, Prices received from retailers Prices received from consumers,
- Wholesale level (Prices received from retailers, Prices received from consumers, Retail price received from consumer)
- Import and Export prices
- Processed Product prices
- Volume of sales

-Fishers level (Volume of sales to wholesalers, Volume of sales to retailers, Volume of sales to consumers)
- Wholesale level (Volume of sales to retailers, Volume of sales to consumers, Retail volume of sales to consumers, Volume of Imports and Exports, Volume of Processed Product)

Research data
(a) Production
- Costs & Returns Budget by Gear type and Size of Operation
- Industry and Firm production and Cost Functions

(a) Consumption and Demand Equations
(b) Marketing
- Description of product flows
- Descriptive Study of Marketing and Processing activities
- Feasibility of new methods

(c) Social and economic profile of fishers

Recreational fishery data
These data can be obtained using direct interview, on-site and survey sampling techniques. Sampling could be simple random, stratified random or stratified two-stage Probability sampling. The collection of data could be off-site (telephone, mail, logbooks) or in-site (aerial survey, roving survey, access point survey, complemented survey (Malvestuto, 1983). Attention should be given to the method by which contact is made, in order to gain their confidence.

<u>Data to be recorded:</u>
- Project
- Country
- Institute
- Scientific responsible

Recreational fisher data
- Fisher personal data
- Vessel data (if in use)
- Date of data collection
- Fishing area
- Departure port
- Departure data and time
- Arrival port
- Arrival date and time
- Fishing way (by boat, from land)
- Fishing gear data
- Fishing duration
- License
- Costs of the day trip
- Costs for the conservation of the boat, equipment and gear
- Weather condition
- Sea condition
- Target species
- Harvested species
- Released species
- Discarded species
- Total catch
- Catch per species
- Measurements of the harvest specimens

Recreational fishery data

- Number of recreational fishers in the area (per sampling unit, per surface area)
- Number of licenses in the area
- Area surface
- Cost of license
- Renewal of license
- Cost of the state for the recreational activities
- On site fees
- Economic data from the recreational fishery (number of sport fishermen from several origins, total population in each origin, average trip costs)

Future research
In order to conserve the stocks of decapods, special attention must be given to the following areas of research:

(i) Natural mortality

- Comparative studies using data already available to obtain a greater understanding of the natural mortality of the different decapod types.
- Studies of the underlying causes of mortality-predation, physiological death, diseases.
- Further tagging studies with particular attention being given to the degree of tagging mortality.

(ii) Stock and recruitment relationship

- Definition of index of breeding stock abundance
- Fecundity, with a review to estimating an index of egg production
- Definition of index of recruitment
- Recruitment variability due to environmental factors

Emphasis should be placed on establishing causal mechanisms that could affect recruitment, and, where feasible, identifying density-dependent effects which could generate a stock-recruitment curve.

(iii) Identification and standardization of effective fishing effort

Many decapod fisheries consist of an inshore and an offshore segment. The inshore segment involves the use of different types of fishing gear- e.g. fixed nets, small boats with nets-. The offshore segment concerns the industrial fleet of multi-rigged trawl vessels. It is of increasing importance to have a sound understanding of the effective fishing effort, preferably of both segments of the fishing fleet, but at least of the industrial part.

The nature of the inshore fishery may make it difficult to calculate effort. It is also important to establish the unit of effective fishing effort of the industrial fleet when the data are first being collected from the fishery. It is important therefore to attempt to assign a fishing effort figure to all segments of the fishery to aid the decision making process.

Areas of research, which should be considered in the future, include

- Independent estimates of the stock, eg. by fish locating pattern of the fleet
- Catchability studies-behavior of the animals and fishing pattern of the fleet
- Gear research to estimate amount of fishing mortality generated by a particular gear type and to establish the selectivity of nets of different meshes for decapod and bycatch.
- Methods of analyzing length-frequency data, including adaptations of cohort analysis.

(iv) The habitat

As changes in the habitat are likely to have a major influence on decapods recruitment, it is important to pursue studies on the nursery habitat so that causes in recruitment variation can be better understood. Information on habitat changes is not only important in analyzing the stock production data and stock-recruitment data, but also in providing the fishery manager with information about the likely effect of proposed man-made changes to the nursery habitat. A valuable contribution to the development of future research programs would be a global view of types and areas of inshore habitat in relation to shrimp abundance, and including information on habitat changes which have occurred.

(v) Database

The database should be a historical description on an annual basis of the decapods fishery and science. Continued updating and efficient administration is important.

It is recognized that the amount and sophistication of data collection will vary from country to country. However, whatever data are available should be properly identified so that they are in a form capable of being used by those providing advice as well as to fishery managers and administrators.

(vi) Data integration

Fisheries scientists collect an array of data on decapod stocks, and some of these data are essential for other studies, such as those undertaken by economists. It is important, therefore, that fisheries scientists understand the requirements of economists, and the sociologists too, so that the database is capable of being used by all personnel with a responsibility to provide advice to management. Furthermore, the advice of the fishery scientist will be more meaningful if the scientist has a basic understanding of the work being undertaken by the economist and sociologist.

(vii) Ecological interactions

In many studies, the capture of decapods is accompanied by considerable quantities of fish, much of which is discarded; while in others again the fishery is directed at both decapod and fish. Research is required on the ecological interactions of the fauna on the decapod species grounds to provide information on the likely consequences in terms of total yield of introducing gear changes such as a shrimp separator trawl.

In relation to this subject, studies are required on the selectivity in feeding habits of the fish, measurement of the relative biomass of the various prey in the stomach of fish, and a comparison with the relative biomass of these prey items in the decapod environment.

(viii) Socio-economics

Future work should include greater emphasis on the role of the socio-economist in providing advice to management. Areas of work needing particular attention are those which:

- Clarify management objectives for any particular fishery taking into account the existence of an inshore and an offshore fishery. In considering this subject consideration will need to be given to such matters as quantifying trade-offs between net revenue, employment and individual income

- Determine costs and how these might be lowered by variations in the balance of elements of capital, manpower, energy and in cost structure
- Determine the multiplier effect under various management options
- Provide information on the mobility in and out of the fishery of labor (especially in rural areas where there are cultural barriers) and of capital
- Provide information on fishermen's earnings
- Add to an understanding of the benefits of management options; this should include the collection of information on management schemes used in some traditional fisheries, such as property rights.

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II. Database template for European Crustacean fisheries

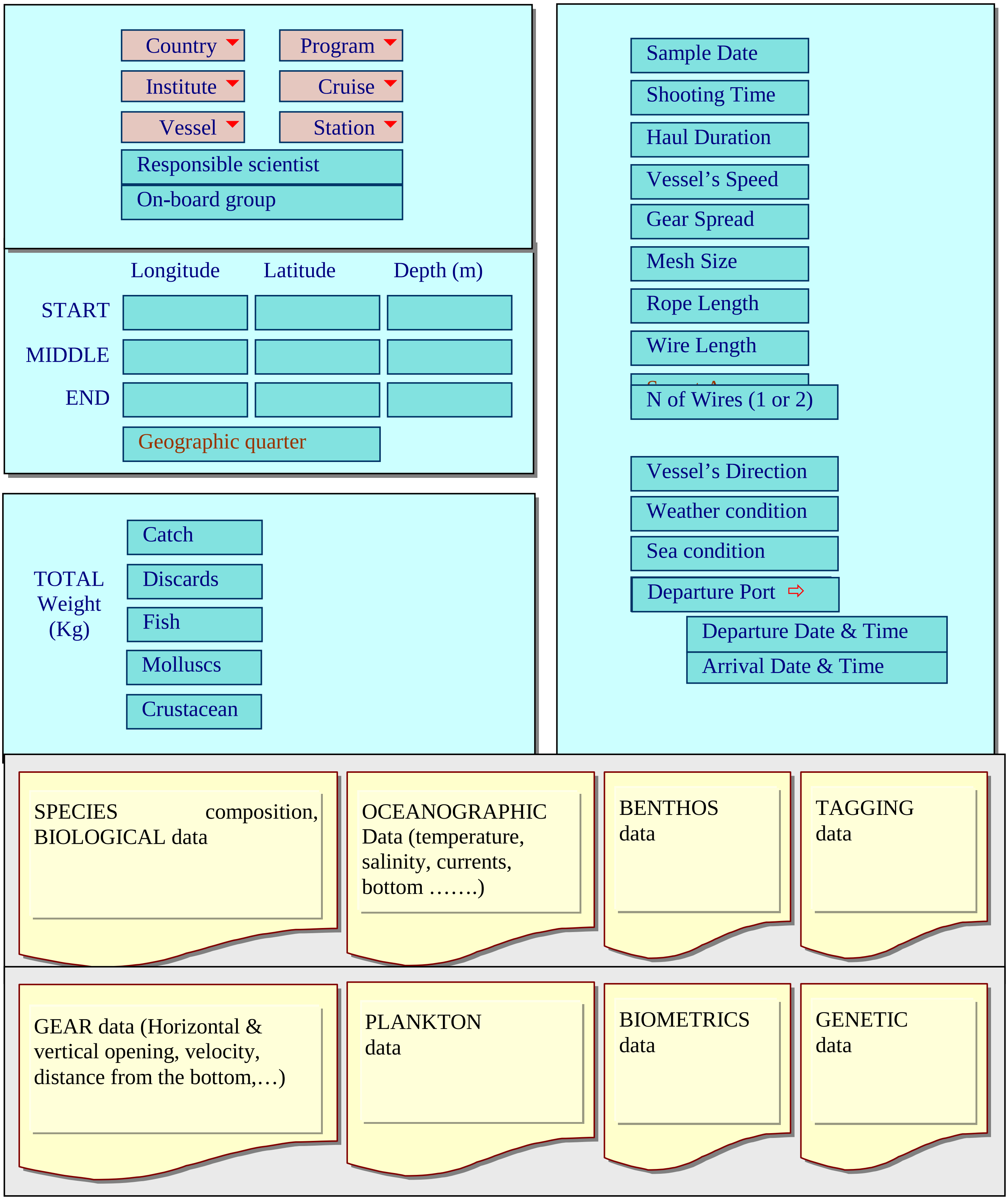
Introduction

WP1 of EDFAM describes an operational metadatabase for data relevant to the biology, assessment and management of European crustacean fisheries. This database is designed around existing data types commonly collected in European research and monitoring programmes and the contents are expressed as metadata under specific datathemes. The EDFAM proposal at the outset recognized that there were many gaps in the existing programs and that various types of data very relevant to the management of crustacean fisheries would not be included in the WP1 database which resulted from a review of existing data. One of the objectives of WP4 was to establish a template for research and monitoring data which included all information relevant whether it currently existed or not. This together with the recommendations on sampling and future research (part I of the report of WP4, this document) would help to focus future programs of data collection and provide some guidelines on research programs that may be relevant to future management of crustacean resources and the specific data which should be collected to facilitate this management. Important gap areas such as metapopulation dynamics, recruitment and larval ecology are but three areas that need additional work. This section of the report of WP4 provides an outline template for a database on crustacean fisheries biology, assessment and management. The main components included in this template are

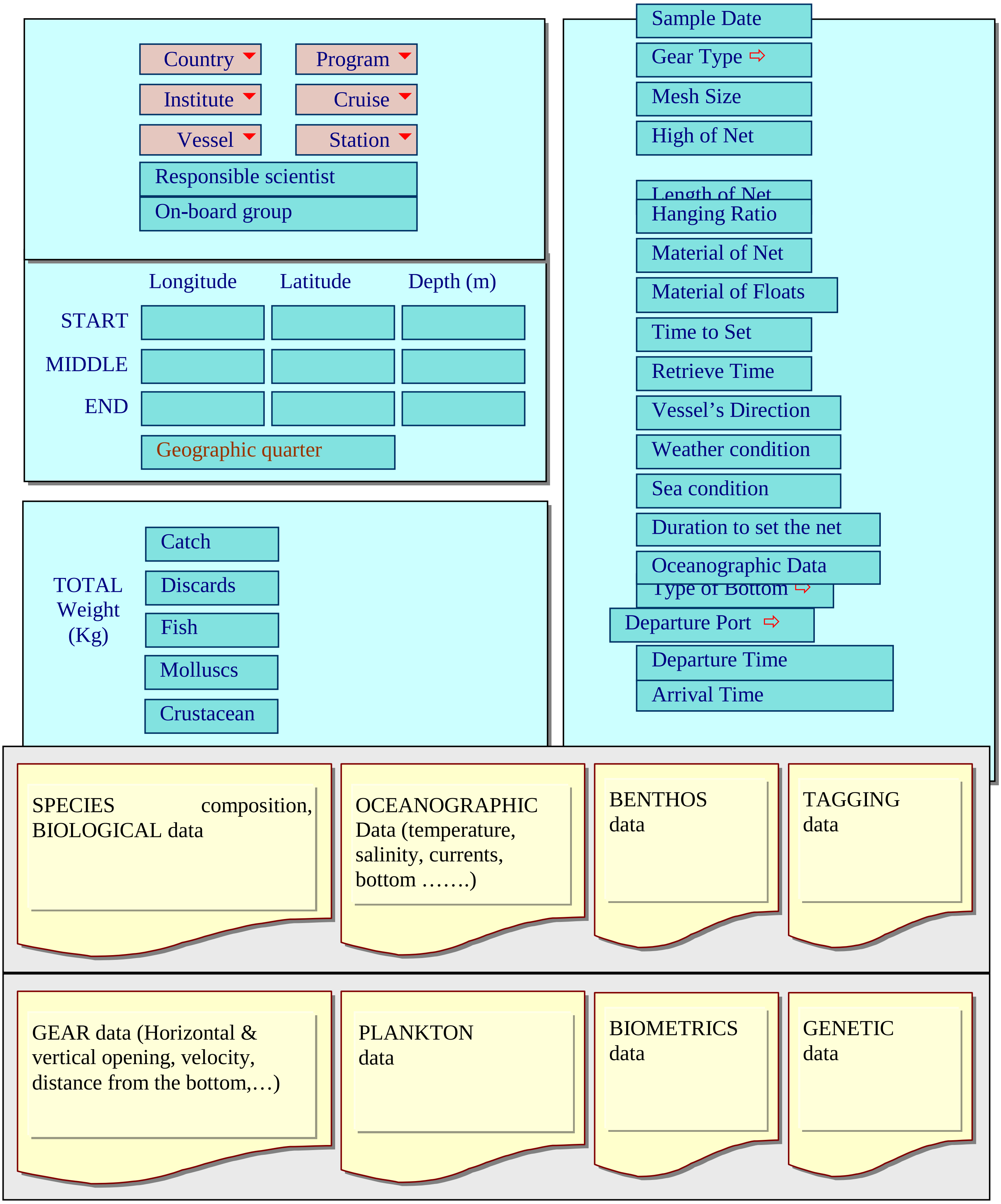
1. Research data : trawl surveys
2. Research data : static net surveys
3. Research data : trap and pot surveys
4. Research data : species composition
5. Research data : tagging studies
6. Research data : Ageing methods
7. Research data : Biometric studies
8. Research data : Genetic studies
9. Research data : Metapopulation data
10. Research data : Selectivity
11. Research data : Underwater observations
12. Research data : Indirect underwater observations and telemetry
13. Research data : Larval phase surveys
14. Research data : Hydroacoustic surveys
15. Research data : Onboard commercial sampling
16. Commercial sampling : logbook and interview
17. Commercial catch : national statistics component
18. Commercial effort
19. Socio-economic data
20. Recreational fishery
21. Stock assessment component

This database is not operational but provides a template for the collection and management of data on crustacean fisheries and their management.

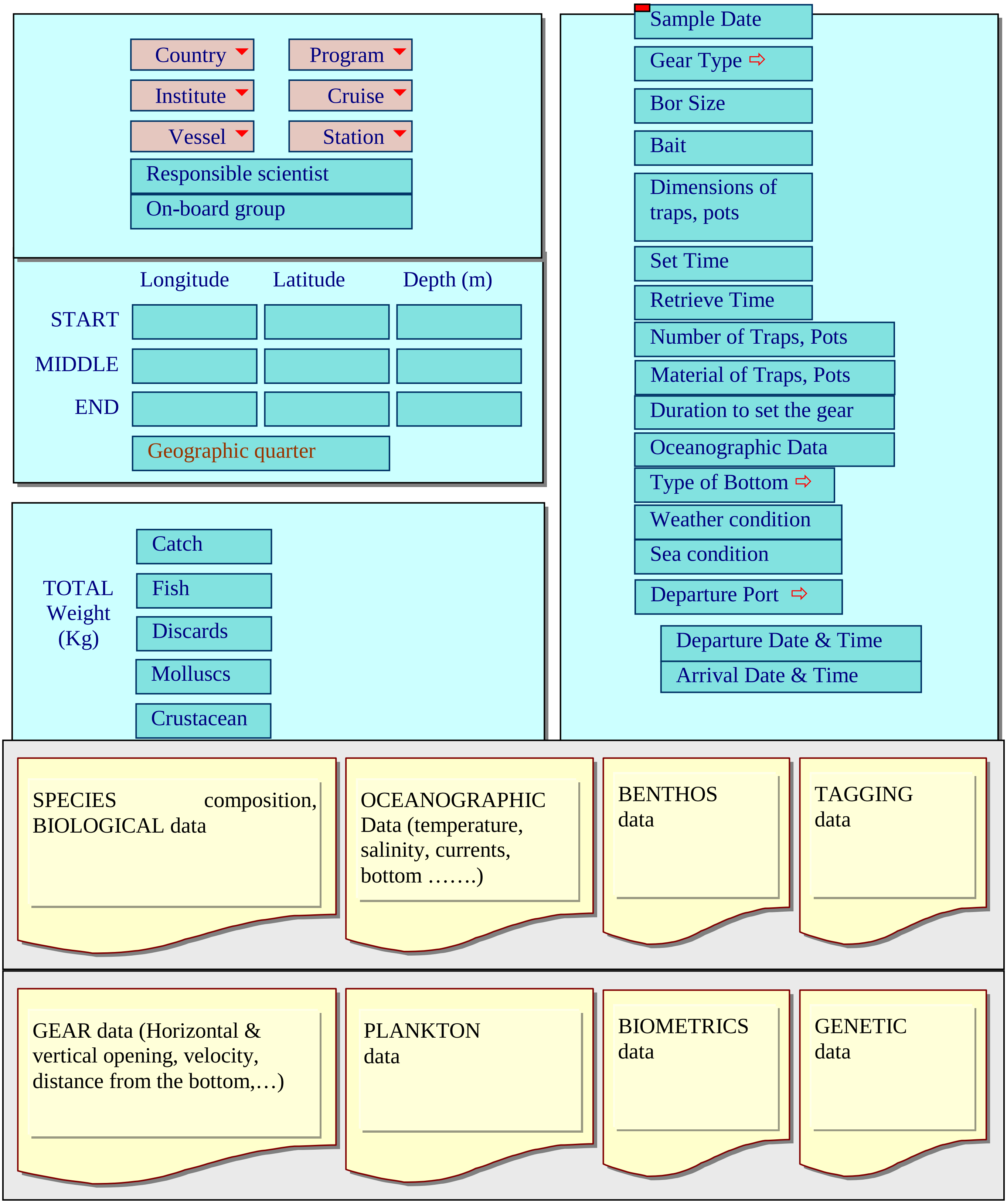
RESEARCH DATA: TRAWL SURVEYS Component



RESEARCH DATA: STATIC NETS SURVEYS Component



RESEARCH DATA: TRAPS & POTS SURVEYS Component



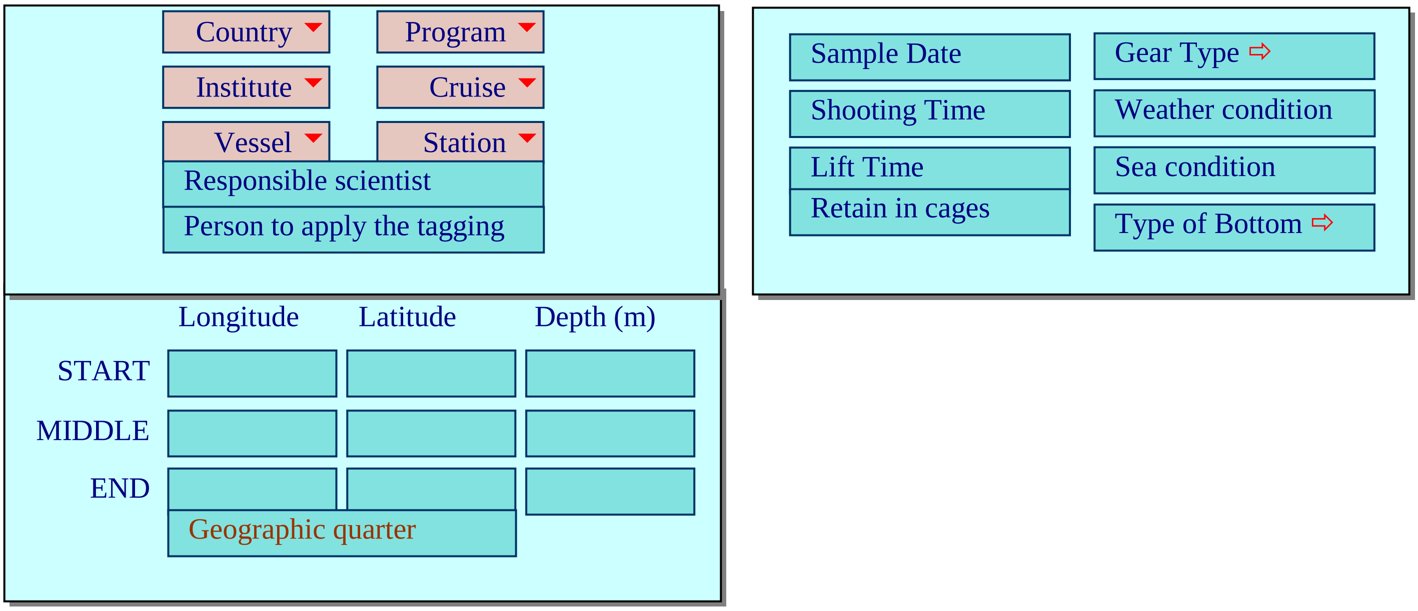
RESEARCH DATA: SPECIES COMPOSITION Component

Species Code ⇨	Sex	Quality	Total Catch Number	Total Catch Weight	Sample Size	Calculated Total Catch Weight

RESEARCH DATA: BIOLOGICAL DATA Component

Length (carapace)	Length (total)	Sex	Total W	Net W	Hepato-pancreas W	Maturity stage	Age	GSI	Sperma-tophore	Ampula Sperm	Abdomen Eggs Presence	Fecundity	Moult Stage

RESEARCH DATA: TAGGING STUDIES Component

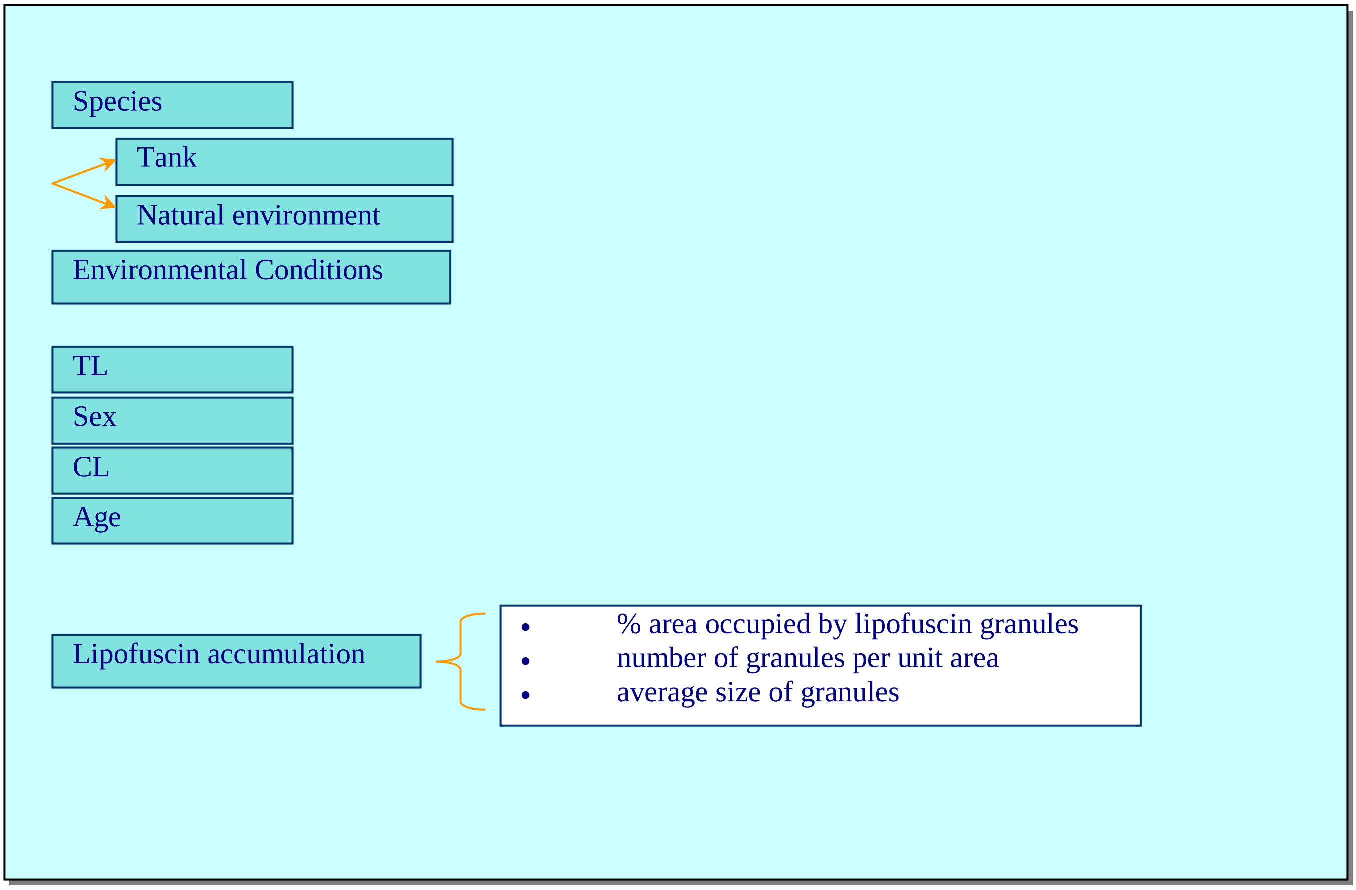


RESEARCH DATA: TAGGING detailed Component

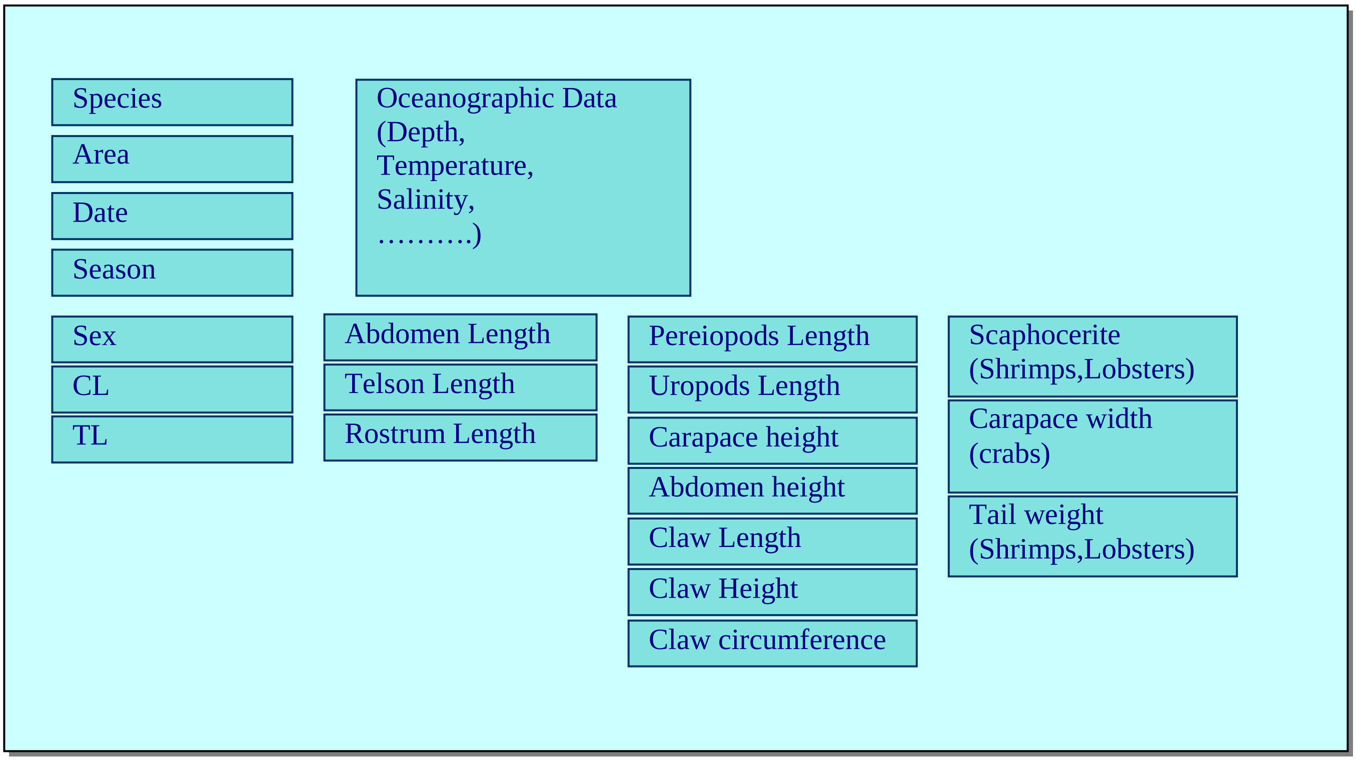
Species Code ⇨	**Type of tag ▼**	**Marked Number**	**Recaptured Number**

Tag ID	**Set/Recapture ▼**	**Length**	**Weight**	**Damage from tag**	**Recaptured Times**

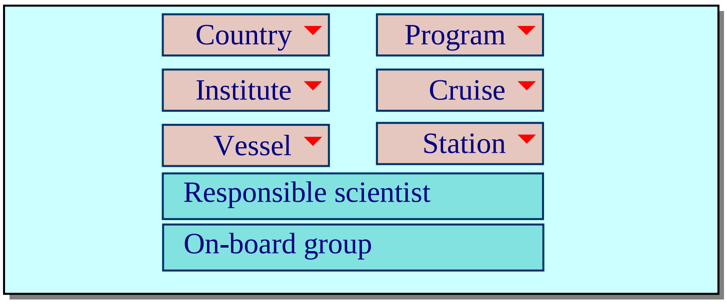
BIOCHEMICAL STUDIES FOR AGEING (LIPOFUSCIN) Component

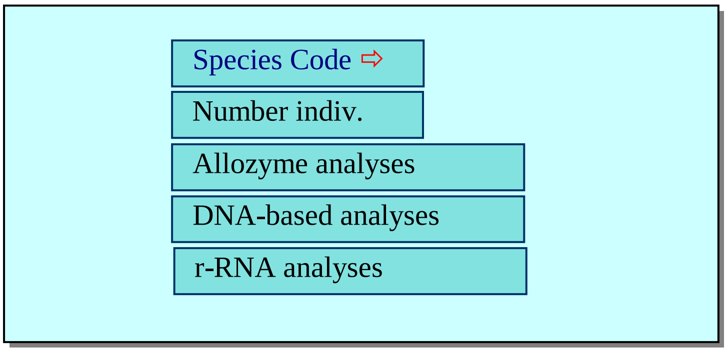


BIOMETRIC STUDIES Component



RESEARCH DATA: GENETIC STUDIES Component





RESEARCH DATA: METAPOPULATION STUDIES data Component

Determination of locally distinct subpopulations in a metapopulation network

- Spatial distribution of subpopulation
- Spawning grounds of subpopulation
- Nursery grounds of subpopulation
- Feeding grounds of subpopulation

Number of local subpopulations

- Source subpopulation – limited size subpopul.
- Equal subpopulation

Distance between subpopulations

Size of each patch (area) occupied by each subpopulation

Isolated subpopulations

Population dynamics of each subpopulation

- Age distribution
- Mortality
- Life tables
- Sex ratio
- Fecundity
- Max age of males-females
- Reproductive age of males-females

Dispersive ability of specimens of each subpopulation

- Moving activity and ability
- Movements for spawning
- Movements for feeding
- Day-night movements
- Larval stage dispersal ability

Environmental characteristics for each subpopulation

- Salinity
- Temperature
- Oxygen
- Substrate
- Currents
- Turbidity
- Geomorphology
- Barriers

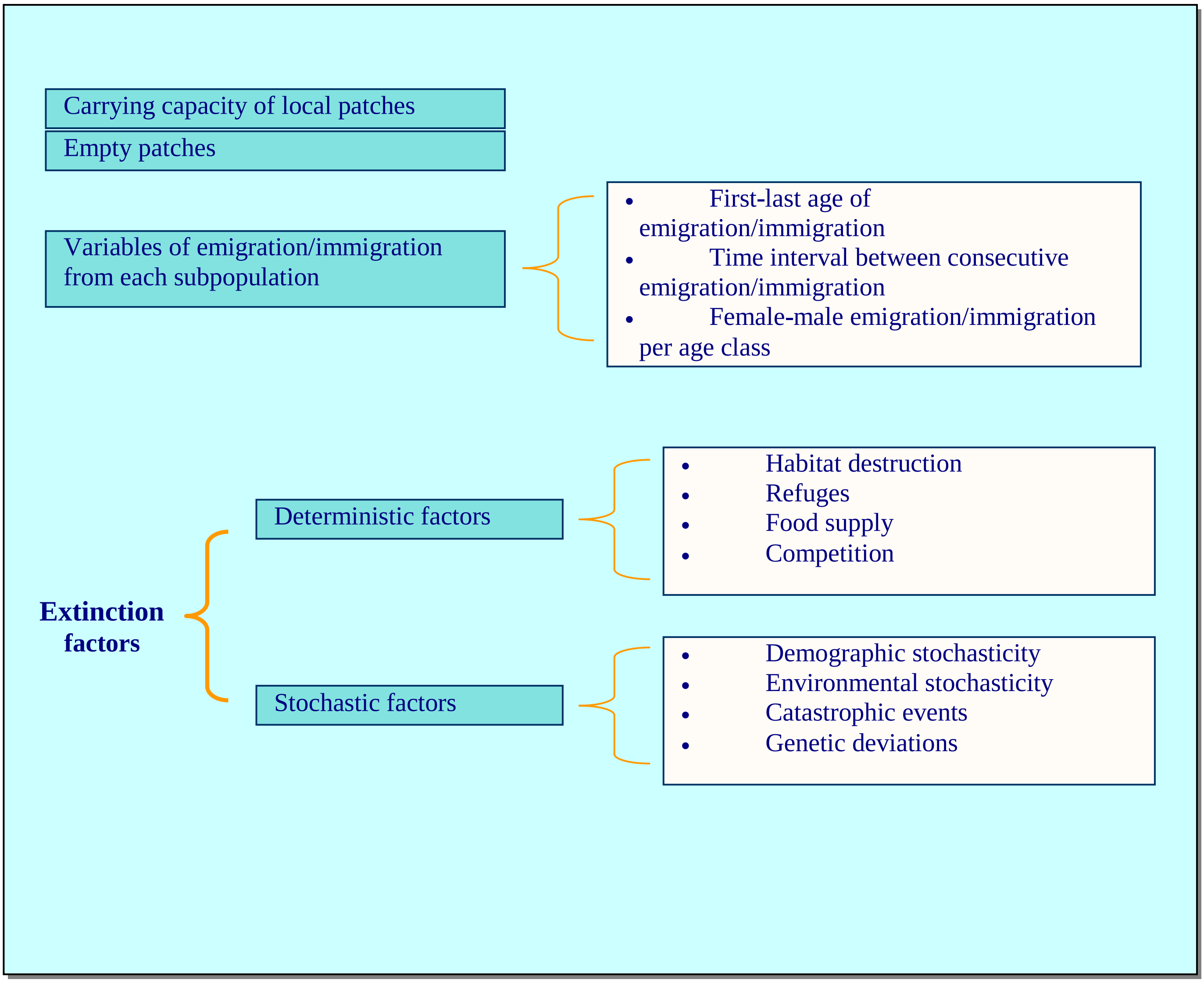
Population dynamics of each subpopulation

- Predator prey relationship
- Intraspecific competition within the subpopulation
- Interaction between species sharing localities and resources

Subpopulation growth rates

Subpopulation size

RESEARCH DATA: METAPOPULATION STUDIES data Component



RESEARCH DATA: SELECTIVITY SURVEYS Component

Country | Program
Institute | Cruise
Vessel | Station
Responsible scientist
On-board group

	Longitude	Latitude	Depth (m)
START			
MIDDLE			
END			

Sampling Area

Sample Date | Gear Type ⇨

For Trawlers	For nets
Codend Mesh Size	Net Mesh Size
Cover Mesh Size	Hanging Ratio
Shooting Time	Haul Duration
Vessel's Direction	Sea condition
Weather condition	Departure Port ⇨
Oceanographic Data	Departure Time
Type of Bottom ⇨	Arrival Time

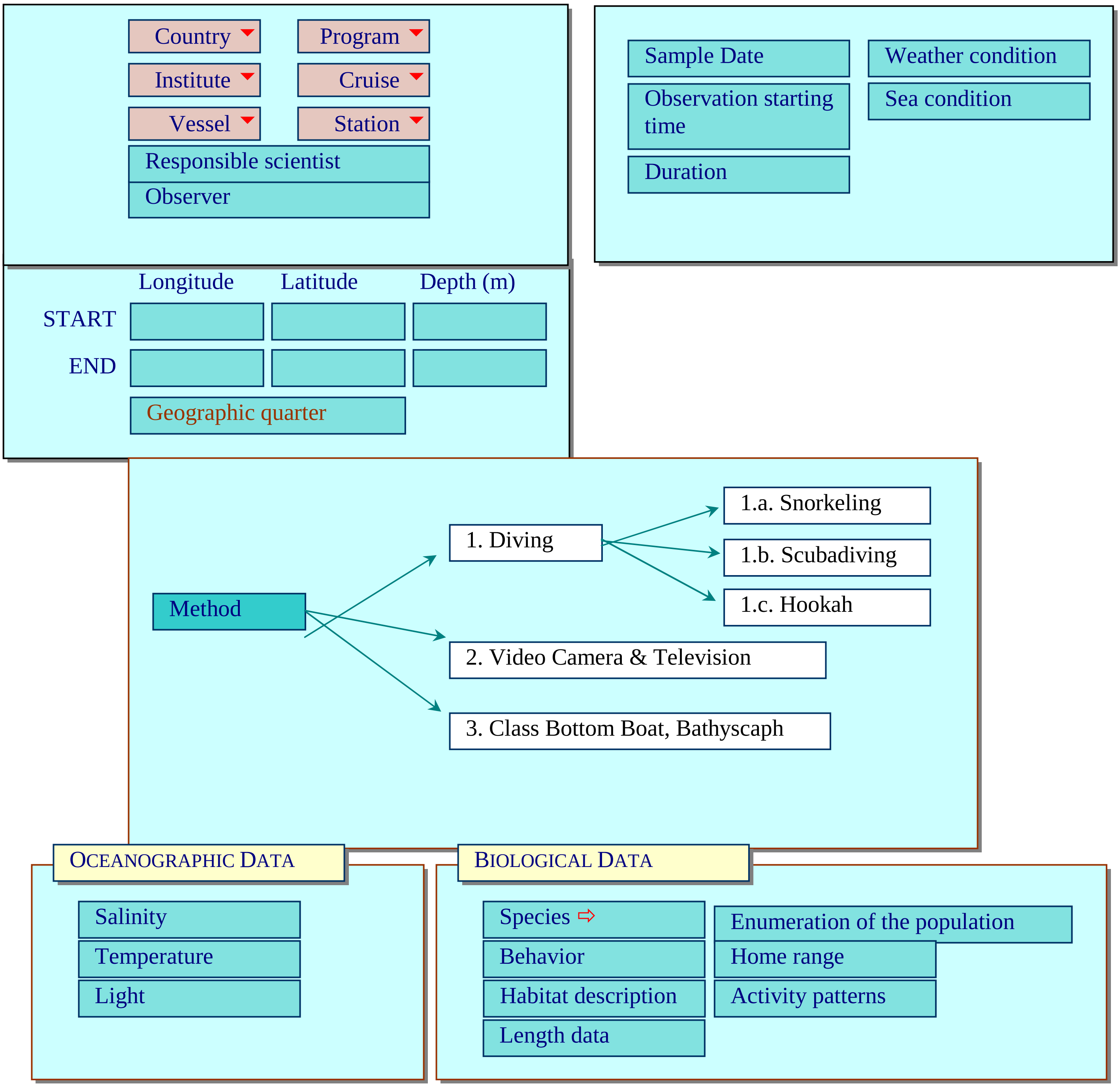
TOTAL Weight (Kg): Catch | Fish | Discards | Molluscs | Crustacean

Gear or Cover	Species Code ⇨	Sex	Quality	Total Catch Number	Total Catch Weight	Sample Size	Calculated Total Catch Weight	Damaged specimens in the cover	Survival specimens in the cover

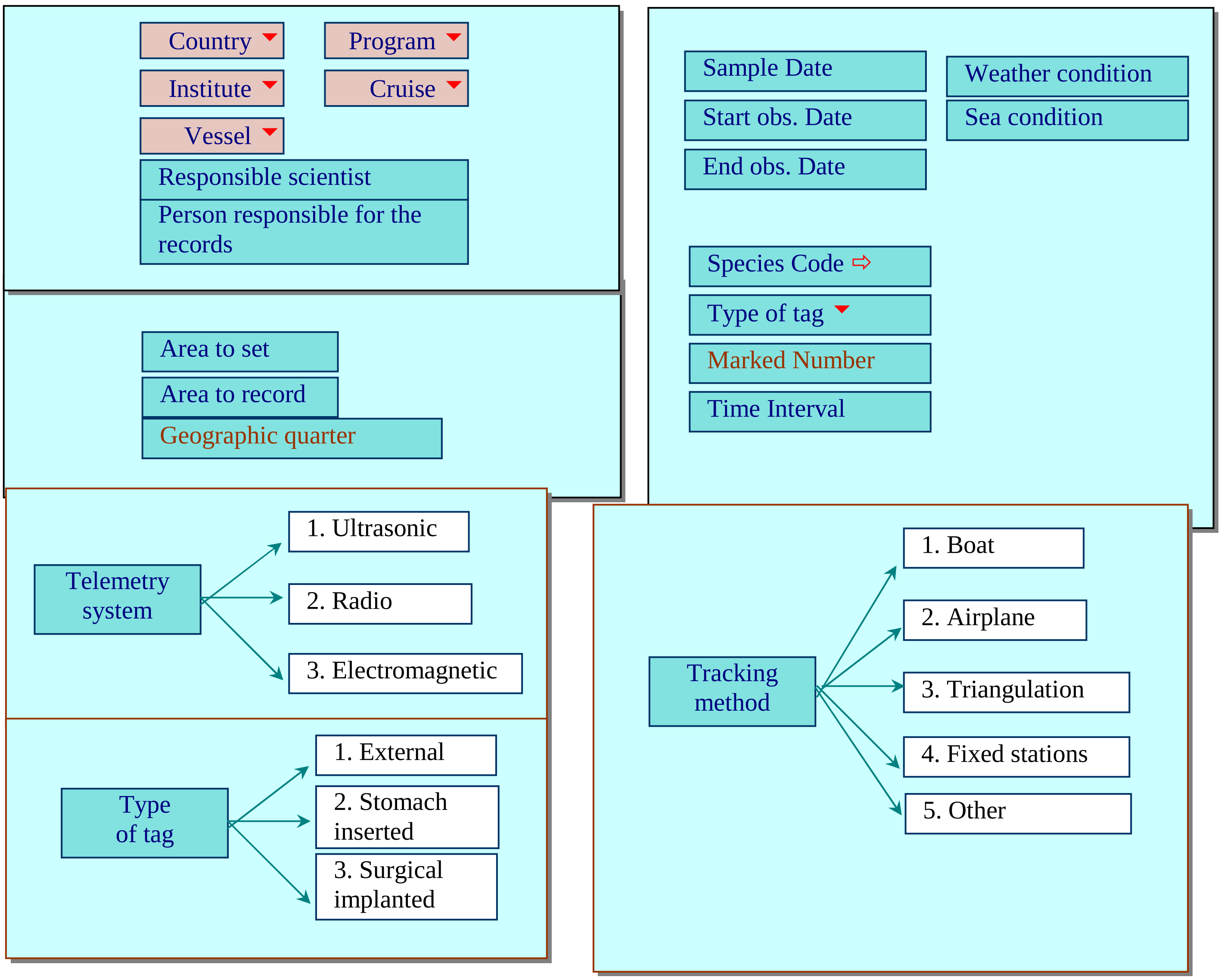
Length (carapace)	Length (total)	Sex	Total W	Net W	Maturity stage	Type of getting caught

GEAR data (Horizontal & vertical opening, velocity, distance from the bottom,…)

RESEARCH DATA: DIRECT UNDERWATER OBSERVATIONS Component



RESEARCH DATA: INDIRECT UNDERWATER OBSERVATIONS- TELEMETRY Component



Ind. ID	Coordinates	Depth	Swimming speed	Swimming direction	Swimming activity	Heart beat, electrocardiogram	Salinity	Temp.	Light

RESEARCH DATA: LARVAL PHASE SURVEYS Component

Country ▾ Program ▾
Institute ▾ Cruise ▾
Vessel ▾ Station ▾
Responsible scientist
On-board group

	Longitude	Latitude	Depth (m)
START			
MIDDLE			
END			

Geographic quarter

Sample Date
Gear Type ⇨
Type of draw
Shooting Time
Gear speed
Rope Length
Draw Depth
Draw Time
Water volume
Plankton biomass (ml)
No of Larvae
Oceanographic Data
Weather condition
Sea condition

Species Code ⇨	**Scientific Name**	**Family**	**Larvae Number**

Length of Larvae	***Larval Stage***

RESEARCH DATA: HYDROACOUSTIC SURVEYS Component

Country	Program
Institute	Cruise
Vessel	
Responsible scientist	
On-board group	

Nautical mile / Ping	Longitude	***Latitude***	***Depth (m)***	***Frequency***

Layer	**TS**	*Sa*

Date/Time	**Weather condition**	*Sea condition*

RESEARCH DATA: ONBOARD COMMERCIAL CATCH Component

Country | Program
Institute | Cruise
Vessel | Station
Responsible scientist
On-board group

	Longitude	Latitude	Depth (m)
START			
MIDDLE			
END			

Geographic quarter
Max Depth
Min Depth
Stratum

TOTAL Weight (Kg)

Catch	Commercial	Discarded	Total
Fish			
Molluscs			
Crustacean			

Sample Date
Gear Type ⇨
Vessel's Direction
Weather condition
Oceanographic Data
Departure Port ⇨ | Arrival Port ⇨
Departure Time | Arrival Time

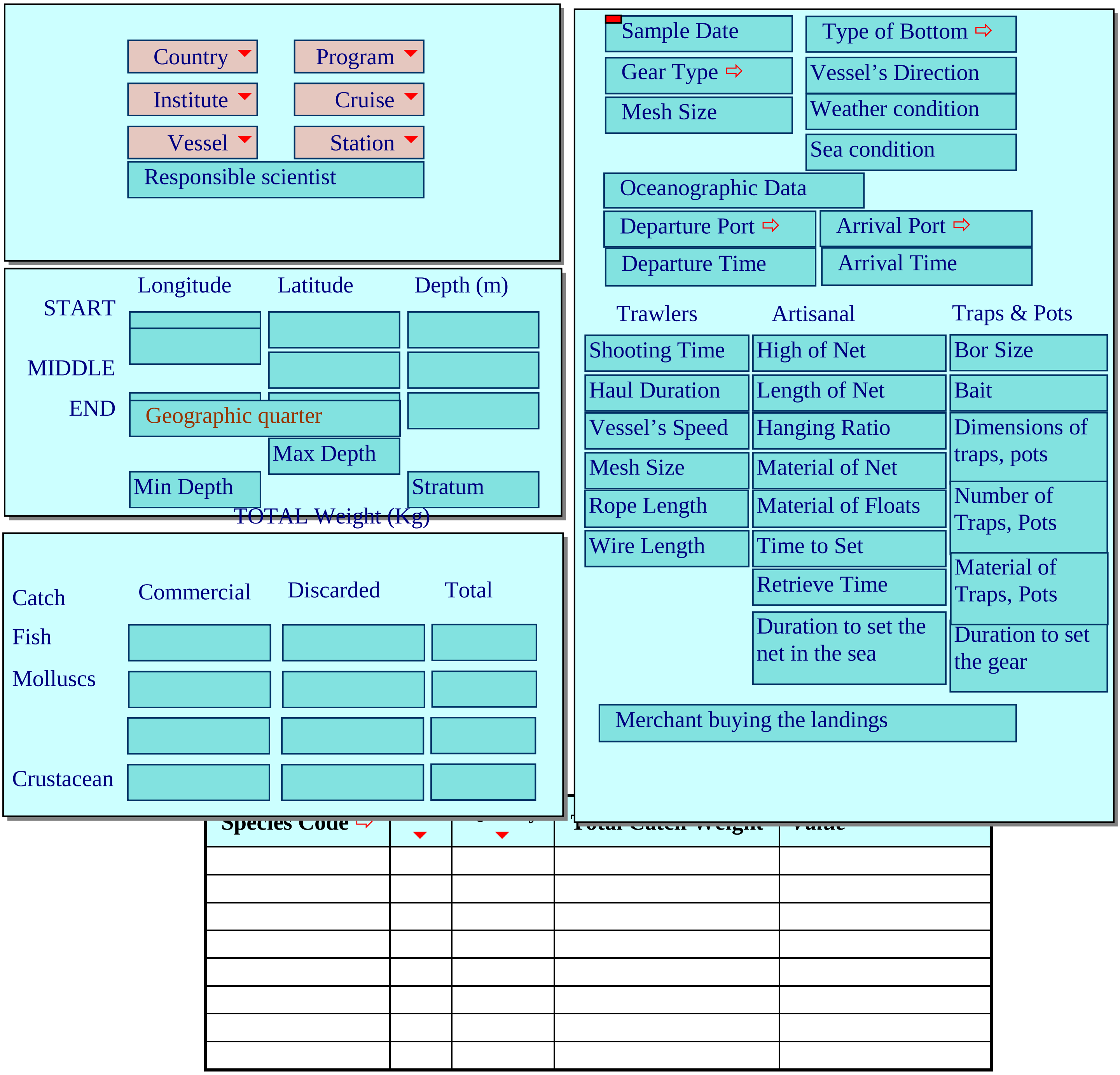
Trawlers	Artisanal	Traps & Pots
Shooting Time	High of Net	Bor Size
Haul Duration	Length of Net	Bait
Vessel's Speed	Hanging Ratio	Dimensions of traps, pots
Mesh Size	Material of Net	Number of Traps, Pots
Rope Length	Material of Floats	Material of Traps, Pots
Wire Length	Time to Set	Duration to set the gear
	Retrieve Time	
	Duration to set the net in the sea	

Merchant buying the landings

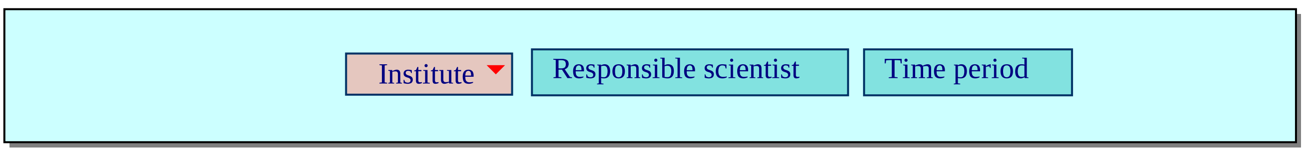
Code ⇨			Number	Weight	Number	Weight	Number	Value

Length (carapace)	Length (total)	Sex	Total W	Net W	Hepato-pancreas W	Maturity	GSI	Sperma-tophore	Ampula Sperm	Abdomen Eggs Presence	Fecundity	Moult Stage

COMMERCIAL CATCH from LOGBOOK & INTERVIEW Component



NATIONAL STATISTICS COMMERCIAL CATCH Component



Quantity of catch, by principal species & by month (monthly or yearly)

Species ⇨	**Date (yy/mm)**	**Frozen**	**Fresh**

Quantity of catch, by principal species & type of fishing tools (monthly or yearly)

Species ⇨	**Date (yy/mm)**	**Overseas fishery**	**Trawl nets**	**Ring nets**	**Seine nets**	**Trammel nets**	**Longlines**	**Other**

Quantity of catch, by fishing area & type of fishing tools (monthly or yearly)

Fishing area ⇨	**Date (yy/mm)**	**Overseas fishery**	**Trawl nets**	**Ring nets**	**Seine nets**	**Trammel nets**	**Longlines**	**Other**

Quantity and value of catch, by categories & type of fishing tools (monthly or yearly)

Fishing tools ⇨	**Date (yy/mm)**	**Category (A, B, C)**	**Quantity**	***Value***

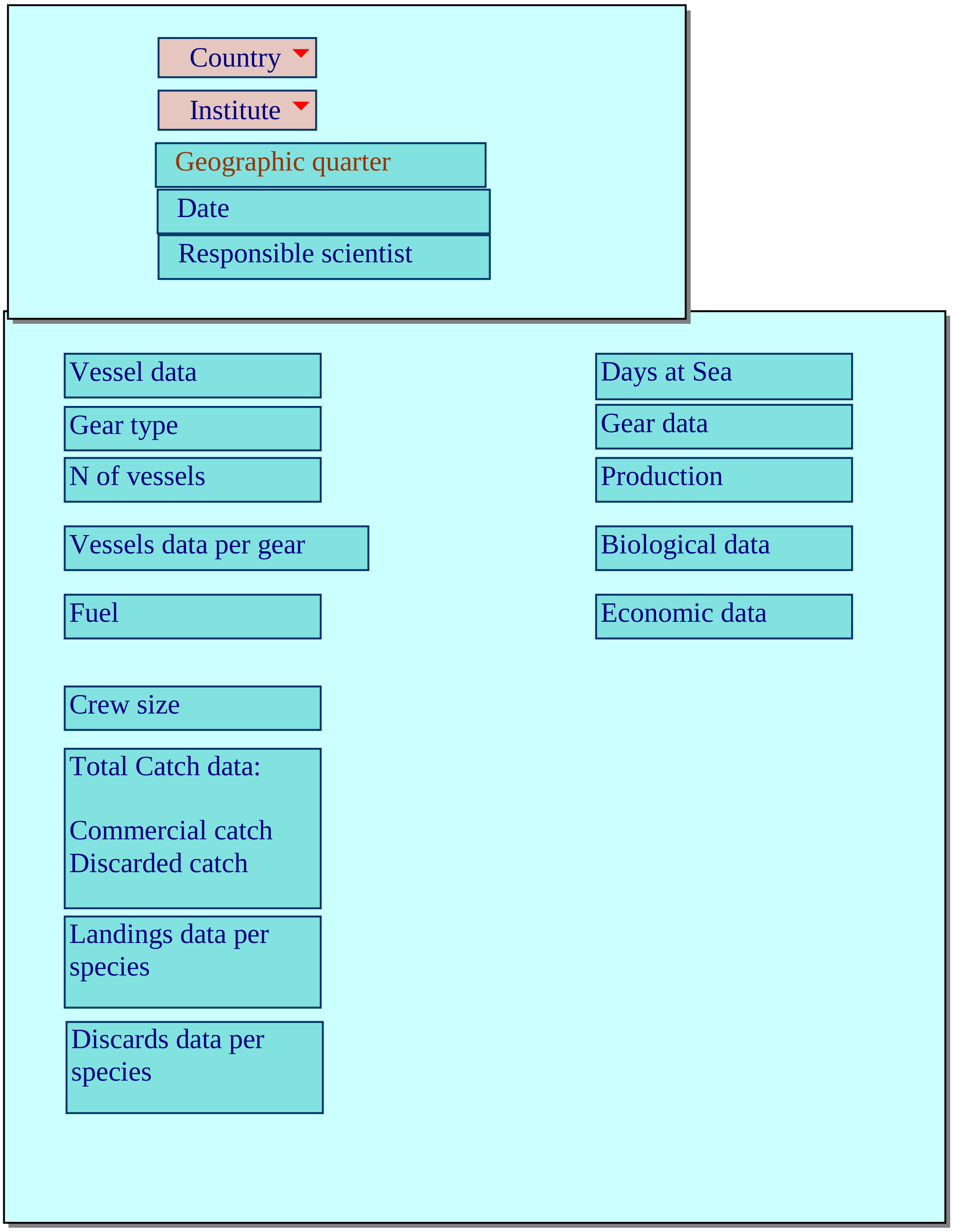
Number, HP & tonnage of fishing vessels, by categories

Fishing vessels category⇨	**Date (yy/mm)**	**Number**	**HP**	***GRT***

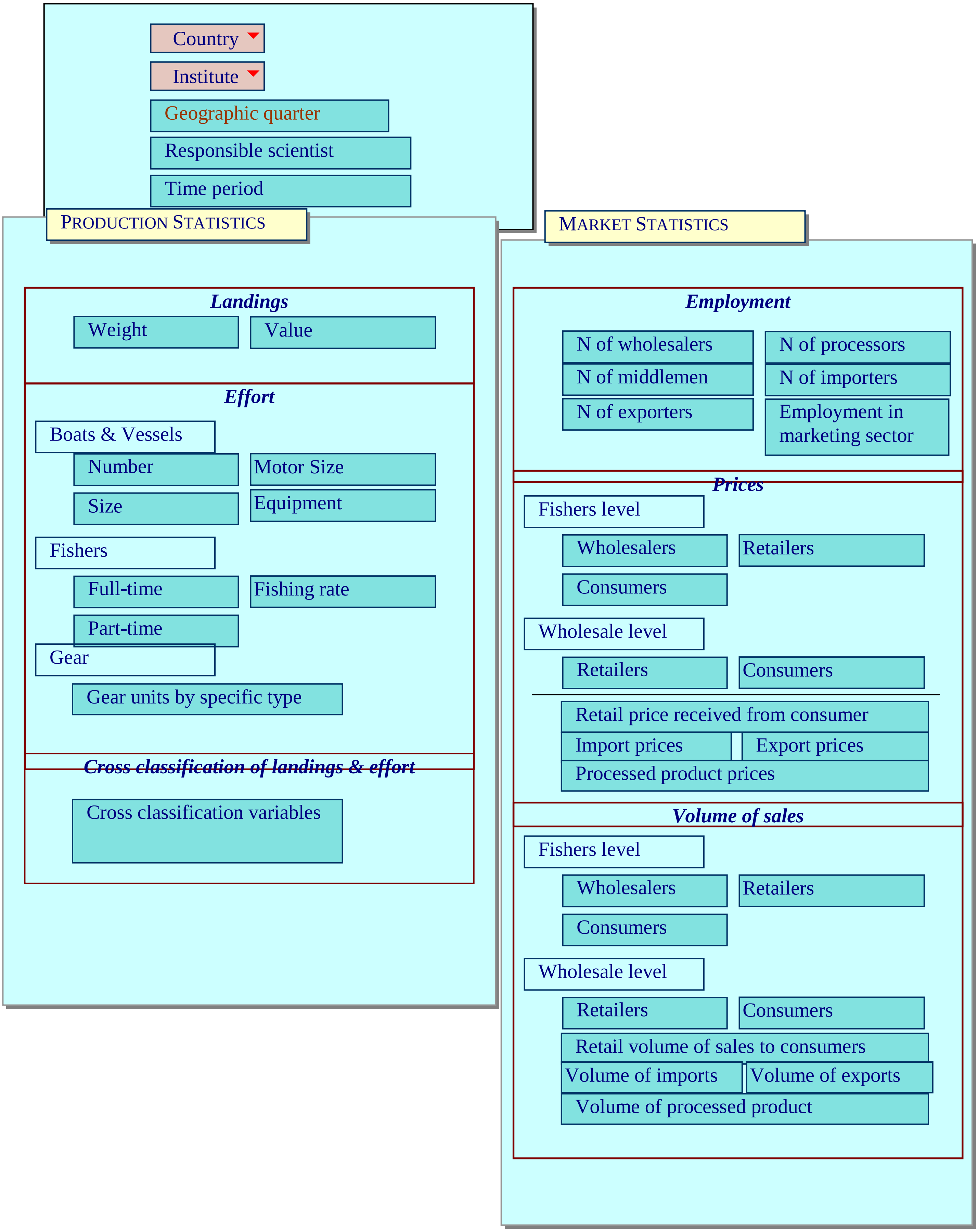
Annual average employment, quantity landed and value of catch, by type of fishing tools

Fishing tools ⇨	**Date (yy/mm)**	**Number of persons employed**	**Quantity landed**	***Value***

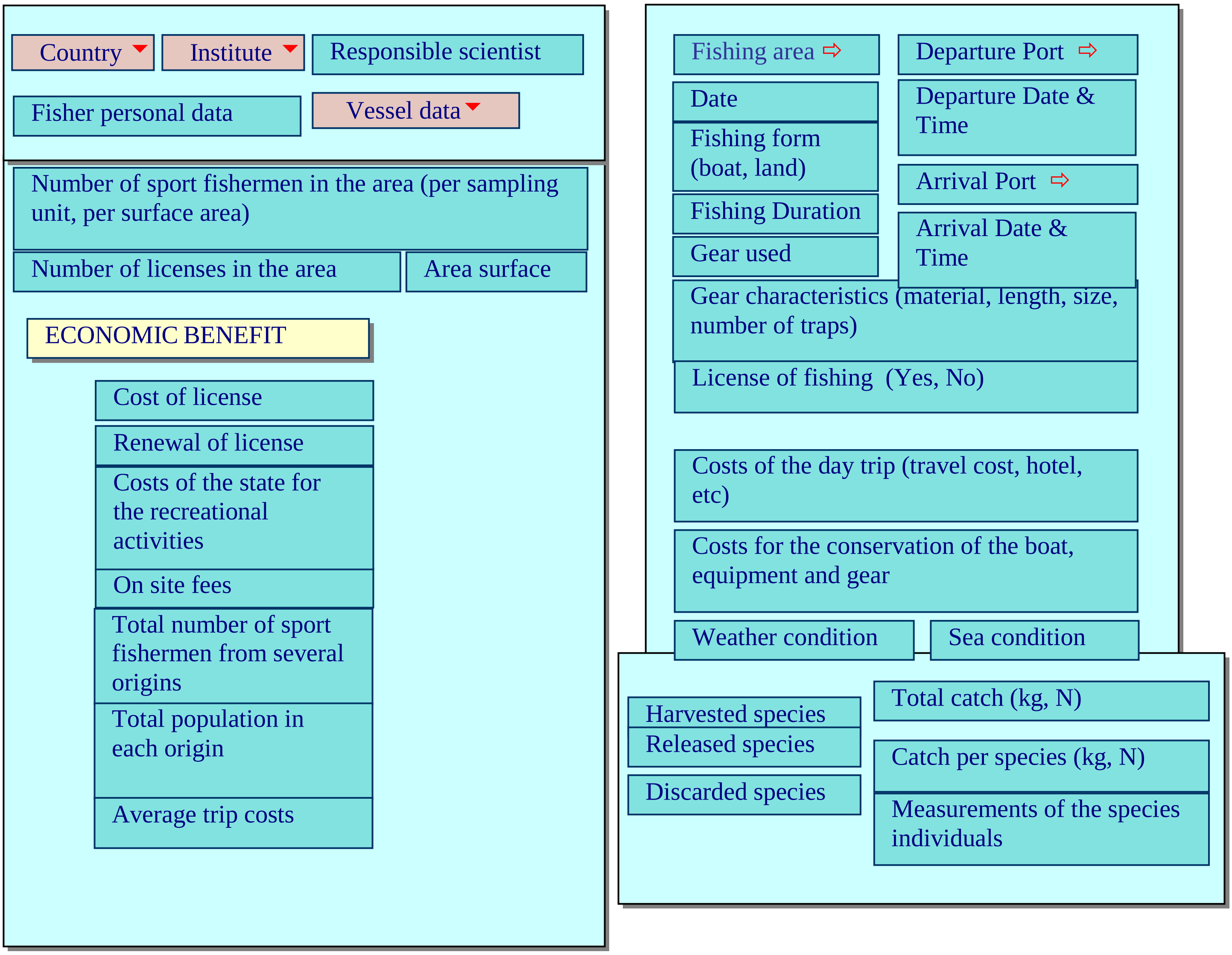
EFFORT DATA Component



SOCIO-ECONOMIC DATA Component



RECREATIONAL FISHERY Component



STOCK ASSESSMENT

CPUE & BIOMASS

INPUT:

Program,
Cruise(s),
Region casting,
Species (one/selected),
Weight/Number
Catch/Fish/Discards/Molluscs/Crustacean

→

OUTPUT:

CPUE and Biomass per Cruise, Region and Stratum

LENGTH DISTRIBUTION

INPUT:

Program,
Cruise(s),
Station(s),
Species,
Male/Female/All,
Minimum Length,
Maximum Length,
Length Class

→

OUTPUT:

Length Distribution

AGEING

INPUT:

Program,
Cruise(s),
Station(s)
Species (one/selected),
Male/Female/All

→

OUTPUT:

Length-based Age Determination

STOCK ASSESSMENT

BIOCHEMICAL METHOD OF LIPOFUSCIN FOR AGEING

INPUT:

Species
Tank / natural environment
Environmental conditions
CL
TL
Sex
Age
Lipofuscin accumulation

→

OUTPUT:

Lipofuscin – age temperature models
Lipofuscin-based age classes

REPRODUCTION, SEX RATIO

INPUT:

Program,
Cruise(s),
Station(s),
Species

→

OUTPUT:

Sex Ratio Graphs & Table

REPRODUCTION, MATURITY

INPUT:

Program,
Cruise(s),
Station(s),
Species,
Male/Female,
Minimum Length,
Stages

→

OUTPUT:

Maturity per Season Graphs & Table
Maturity related to length Graphs & Table

STOCK ASSESSMENT

REPRODUCTION, SIZE-AT-MATURITY

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
Length-frequency key at max GIS month, all females
Length-frequency key at max GIS of all gravid females

→

OUTPUT:

Age-at-maturity (size/age at 50%)
Relationship between size and percentage of maturity sigmoidal curve
Table and graphic

REPRODUCTION, FECUNDITY

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
Length key of females
Gonad weight key

→

OUTPUT:

a
b
R
Table & Graph

MORPHOMETRY

INPUT:

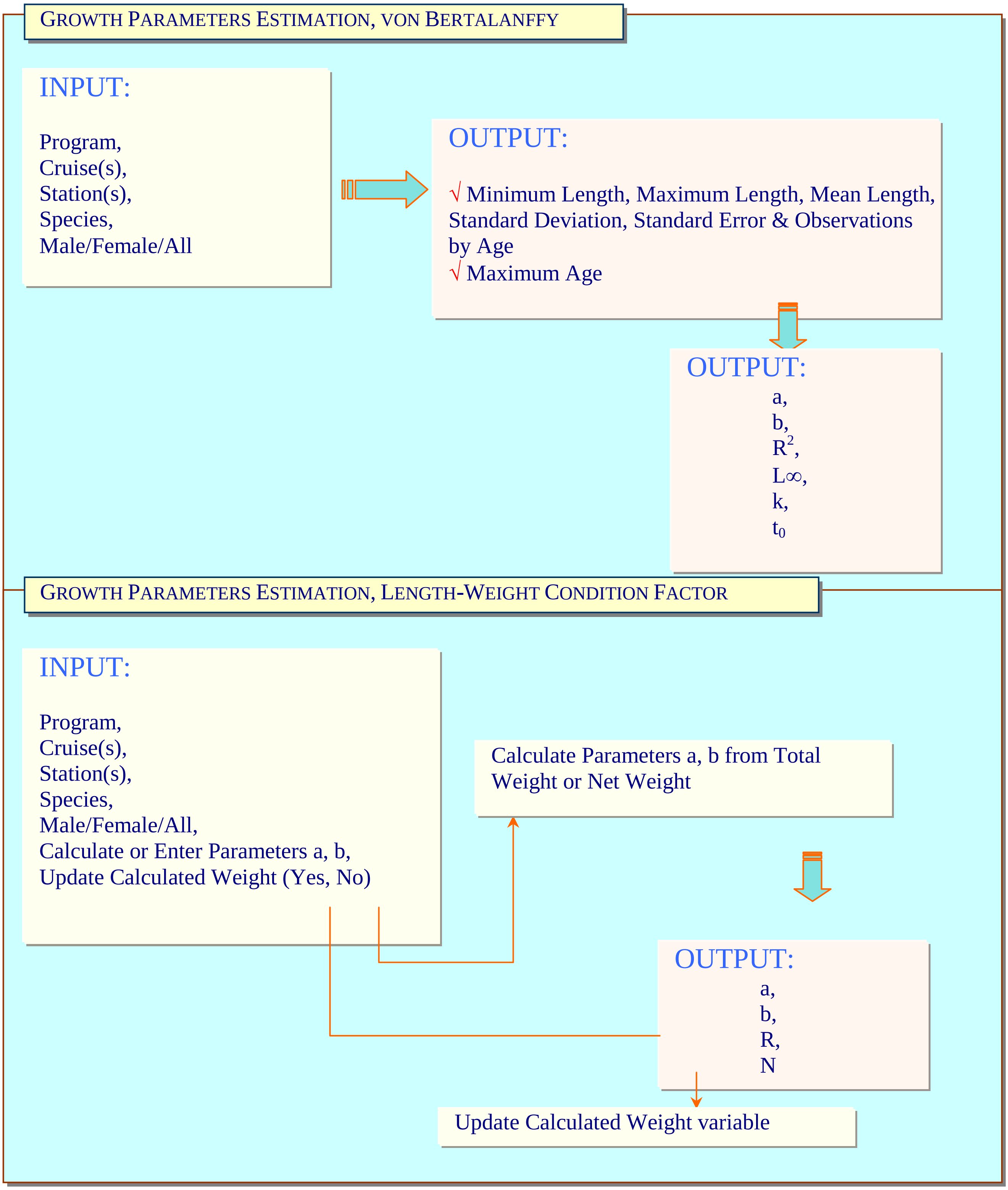
Program
Cruise
Station(s)
Season(s)
Species
Speed standardize
Time standardize
Length and weight keys

→

OUTPUT:

a
b
R
Tables & Graphs
Outliers
ANCOVA results among stations, seasons etc.

STOCK ASSESSMENT



STOCK ASSESSMENT

Population Dynamics Parameters, Total Mortality (Hoenig Empirical Model)

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
Longevity
Mean age at first capture
Sample size

→

OUTPUT:

Z

Population Dynamics Parameters, Total Mortality (Beverton-Holt Empirical Model)

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
$L\infty$
K
Cut off length
Mean length above cut off length

→

OUTPUT:

Z

STOCK ASSESSMENT

POPULATION DYNAMICS PARAMETERS, TOTAL MORTALITY (AULT-EHRHARDT EMPIRICAL MODEL)

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
L∞
K
Cut off length
Mean length
Maximum length in sample

OUTPUT:

Z

POPULATION DYNAMICS PARAMETERS, TOTAL MORTALITY (HEINCKE EMPIRICAL MODEL)

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
Number of individuals in each cohort

OUTPUT:

Z

STOCK ASSESSMENT

POPULATION DYNAMICS PARAMETERS, NATURAL MORTALITY (RICHKTER-EFANOV EMPIRICAL MODEL)

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
Age at first maturity

→

OUTPUT:

M

POPULATION DYNAMICS PARAMETERS, NATURAL MORTALITY (GUNDERSON EMPIRICAL MODEL)

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
Mean length of mature females
Gonadosomatic index
K
Several constants

→

OUTPUT:

M

POPULATION DYNAMICS PARAMETERS, EXPLOITATION RATIO

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
F
Z

→

OUTPUT:

E=F/Z*100

STOCK ASSESSMENT

POPULATION DYNAMICS PARAMETERS, JONES AND VAN ZALINGE CUMULATIVE LENGTH-CONVERTED CATCH CURVE

INPUT:

Program
Cruise
Station
Species
Speed standardize
Time standardize
L∞
K
Length frequency key

OUTPUT:

Z
Z/K

POPULATION DYNAMICS PARAMETERS, MORTALITY (CATCH CURVE)

INPUT:

Program,
Cruise(s),
Station(s),
Species,
Male/Female/All,
Speed Standardize,
Time Standardize,
L∞,
k,
Temperature

OUTPUT:

√ Catch Curve Table & Graphs
√ Minimum Age
√ Maximum Age

OUTPUT:
Total Mortality,
R,
Observations

STOCK ASSESSMENT

POPULATION DYNAMICS PARAMETERS, MORTALITY (PAULY 1984)

INPUT:

Program,
Cruise(s),
Station(s),
Species,
Male/Female/All,
Speed Standardize,
Time Standardize,
L∞,
k,
Temperature

OUTPUT:

√ Mortality according Pauly 1984 Table & Graph
(Class, Xvalue, N, Lower, Upper, t_1, t, t_2, D_t, ln(N/D_t))
√ Class interval

OUTPUT:

Natural Mortality,
R,
Observations

POPULATION DYNAMICS PARAMETERS, YIELD PER RECRUIT

INPUT:

Program,
Cruise(s),
Station(s),
Species,
Male/Female/All,
Speed Standardize,
Time Standardize,
Natural Mortality,
Age at recruitment,
Age at length 0 ($-t_0$),
Growth parameter k,
Weight infinity(W∞)

OUTPUT:

√ Fishing Mortality (from, to)
√ Age at first capture (from, to)

OUTPUT:

Y/R against TC
Y/R against F

STOCK ASSESSMENT

JONES LCA

INPUT:

Program
Cruise
Station(s)
Season(s)
Species
Speed standardize
Time standardize
Length key
Catch at length class
M
K
Loo
E terminal = F terminal/Z
a,b

OUTPUT:

Survivors at length class
FZ
E
Weighted annual numbers
F per year
Biomass per year
Yields

XSA

INPUT:

Program
Cruise
Station(s)
Season(s)
Species
Speed standardize
Time standardize
Catch at age matrix
M
K
Start of fishing period index
End of fishing period index
Fleet CPUE per year matrix

OUTPUT:

F at age matrix
N at age matrix
N per fleet matrix

STOCK ASSESSMENT

VPA & Cohort Analysis models

INPUT:

Program
Cruise
Station(s)
Season(s)
Species
Speed standardize
Time standardize
Catch at age matrix
Number at age matrix
F terminal to F terminal-1 ratio
Maximum age in sample
M

→

OUTPUT:

F at age matrix
N at age matrix
N per fleet matrix

Separable VPA

INPUT:

Program
Cruise
Station(s)
Season(s)
Species
Speed standardize
Time standardize
Catch at age matrix
Final F
Selectivity of older age
Reference age
Selectivity of reference age
M

→

OUTPUT:

F at age matrix
N at age matrix
N per fleet matrix

STOCK ASSESSMENT

SURPLUS MODELS

Selection
(a) Fox model
(b) Pella-Tomlison model
(c) Schaefer model

INPUT:

Program
Cruise
Station(s)
Season(s)
Species
Speed standardize
Time standardize
Catch time series
Fleet effort time series
Fleet catches time series
Initial population estimate

OUTPUT:

Biomass time series
Expected catches time series
Carrying capacity, K
Intrinsic rate of growth, r
Fleet catchability, q

THOMSON-BELL MODEL

INPUT:

Program
Cruise
Station(s)
Season(s)
Species
Speed standardize
Time standardize
LFD
F maximum
M
Loo
k
a,b
Catch time series per fleet per species
Probability of selection per fleet per species
Selection ogives per gear per fleet per species

OUTPUT:

Yields plot & matrix per species and fleet
Biomass plot & matrix per species and fleet
F matrix per species and fleet
Cumulative F functions

STOCK ASSESSMENT

MONTE CARLO SIMULATIONS

INPUT:

Program
Cruise
Station(s)
Season(s)
Species
Speed standardize
Time standardize
Age groups
Year class strengths
Montlhy recruitment
Loo
k
t0
M
F maximum
Probability of capture
Selectivity

OUTPUT:

Simulated LFD
Kolmogorov-Smirnov between actual LFD and simulated LFD

STOCK ASSESSMENT

GEOSTATISTICS

INPUT:

Longitude,
Latitude,
Regionalized Variable
Duplicate Data (To Keep,
X Tolerance, Y Tolerance)
Maximum Lag Distance,
Angular Divisions,
Radial Divisions,
Detrend (None, Linear,
Quadratic)

→

OUTPUT:

√ Variogram Graph

Experimental Variogram

Direction,
Tolerance,
Step amount,
} Lag Direction

Estimator Type (Variogram, Standardized Variogram, Autocovariance, Autocorrelation),
Maximum Lag Distance,
Number of Lags,
Lag Width,
Vertical Scale

Model

Variogram Model (Exponential, Spherical, Linear, Gaussian, Logarithmic, Nugget effect, Quadratic,
Cubic, Wave, Power, Pentaspherical),
Scale,
Length (A),
Anisotropy (Ration & Angle)

↓

II. √ Kriging Gridding Method

Kriging Type (Point or Block)
Drift Type (None, Linear, Quadratic)
Search criteria (Number of sectors to search, Maximum number of data to use from all sectors, Maximum number of data to use from each sector, Minimum number of data in all sectors),
Search Ellipse options (Radius 1, Radius 2, Angle),
Breaklines

↓

OUTPUT:
Contour Maps

STOCK ASSESSMENT

GENETICS' DATA

INPUT:

Species,
Number indiv.,
Allozyme analyses,
DNA-based analyses,
r-RNA analyses

OUTPUT:

Genetic structure,
Genetic homogeneity,
Genetic variation,
Geographical variation,
Identification of different populations or sub-populations

METAPOPULATION STUDIES DATA

INPUT:

Determination of locally distinct subpopulations in a metapopulation network.
Number of local subpopulations.
Distance between subpopulations.
Size of each patch (area) occupied by each subpopulation.
Isolated subpopulations.
Population dynamics of each subpopulation.
Dispersive ability of specimens of each subpopulation.
Environmental characteristics for each subpopulation.
Population dynamics of each subpopulation.
Subpopulation growth rates.
Subpopulation size.
Carrying capacity of local patches.
Empty patches.
Variables of emigration/immigration from each subpopulation.

OUTPUT:

Immigration probability
Extinction probability

models:

Production-extinction models
Migration-colonization models (source-sink model, dispersion models)

OUTPUT:

Identification of metapopulation
Analysis of population viability

STOCK ASSESSMENT

HYDROACOUSTIC

INPUT:

Nautical mile or Ping,
Longitude,
Latitude,
Bottom Depth,
Frequency,
Layer,
TS,
Sa

OUTPUT:

Biomass (Kg) per nautical mile per layer

RECREATIONAL FISHERY

INPUT:

Fishing duration,
Gear characteristics,
Cost of the day trip,
Total catch,
Catch per species,
Measurements of species ind.,
Total number of sport fishermen from several origins,
Total population in each origin,
Average trip costs

OUTPUT:

CPUE

Catch/fishing time
Catch/gear
Catch/surface area
Catch/sampling area
Catch/trip
Catch/day
Estimation of catch (kg, N)
Estimation of catch per species (kg, N)
Measurements of the species individuals
Total Catch/Total effort (mean of the total period)
$Catch_i/effort_i$ (mean daily value)
Catch/Sport fisherman/day (average for all days of sampling)

ECONOMIC BENEFITS

Consumers' surplus (estimated from trip demand curve and site demand curve

PRODUCTION

Costs & Returns Budget by Gear type and Size of Operation

Industry and Firm production and Cost Functions

MARKETING

Description of product flows

Descriptive Study of Marketing and Processing activities

Feasibility of new methods

CONSUMPTION & DEMAND EQUATIONS

Variable 1
……
Variable n

SOCIAL & ECONOMIC PROFILE OF FISHERS

Variable 1
……
Variable n

European Decapod Fisheries: Assessment and Management (EDFAM)

Concerted Action Project number QLK5 1999 01272

Workpackage 5: Draft Final Report

I. Management of European Crustacean Fisheries

(Papers from meetings in Pisa, Italy, September 2002 and Dublin, Ireland, May 2003**)**

Main Contributors (in alphabetical order)

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Contents

Workpackage 5 of EDFAM

The draft final report of work package 5 of EDFAM is comprised of two main deliverables

1. A series of papers (this document) on the management of crustacean fisheries. The international legal context, institutional arrangements, property rights, delegation from central government, integrating biology and management and bio-economics are discussed in some detail.

2. In a separate second report of WP5 a detailed discussion on the assessment and mangement of the European lobster is presented. This resulted from a meeting with the Irish industry and lead to discussions on the feasibility of a fundamental change from open access to limited entry to these fisheries. Interestingly the workshop subsequently lead to a submission to the Irish authorities from industry arguing for the introduction of limited entry complete with documentary evidence of support from industry groups. It remains a useful example of the feasibility and importance of integrating stakeholders in the development of policy for management of crustacean fisheries.

1. The Management of Crustacean Fisheries in Europe: Introduction to Work Package 5 of EDFAM

David Symes, University of Hull, Hull, UK
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Introduction

Work Package 5 (WP5) of EDFAM is required to review existing management systems, structures and practices for crustacean fisheries and, in so far as is possible, recommend new approaches to management of these resources. There are many complex issues involved. The review of existing systems needs to take account of the scientific data, regulatory measures, which will both, safeguard the sustainability of the resource and maximise its economic and social utility and the institutional arrangements that will best deliver integrated management. To do this will require; the extrapolation of sound management guidelines from a limited but growing understanding of the population dynamics of decapod species; some understanding of socio-economic circumstances within which the fisheries take place; an awareness of existing legal and regulatory frameworks; and an appreciation of the institutional frameworks which can best facilitate positive interactions between science, management and industry.

The review should also reflect something of the debate currently taking place worldwide on the institutional arrangements for fisheries management, including the need to improve integration of fisheries management and marine environmental management together with the evolving concepts of an ecosystem based approach (EBA) and 'responsible fisheries', and, of course, the reformed Common Fisheries Policy (CFP).

This introduction poses some of the key questions which must be addressed in management of crustacean fisheries. It begins with a brief appraisal of the ways in which our scientific understanding of the behavioural characteristics of decapod populations should inform their management and how the management regimes need to respect the very diverse economic and social conditions under which the fisheries are conducted. Key issues concerning the choice of regulatory systems are then outlined both in terms of the selection of regulatory measures available to managers and the broader socio-political choices confronting the administration in relation to 'open' access, territorial or individual property rights regimes. This is followed by an exploration of questions concerning institutional arrangements by which key partners in the management process - scientists, administrators and fishermen - are brought together to create a basis of good governance, and the crucial issues of scale of management are addressed.

Science and management

One of the assumptions underlying the EDFAM project is that the general neglect of crustacean fisheries in management terms, alluded to above, and the consequent absence of comprehensive management strategies to cope with their evident overexploitation in European waters, is largely a function of inadequate scientific data and an insufficient understanding of the dynamics of decapod populations. This in turn has meant an inability to provide robust stock assessments. Under such circumstances it is scarcely surprising that fishermen are critical of attempts to impose more rigorous management regimes. Improvements to crustacean management thus rest on the ability to develop appropriate assessment models rather than continuing to rely on models borrowed from finfish populations which customarily assume self -contained populations closed to recruitment through migrations from other areas (Orensanz and Jamieson, 1998).

Basic management issues are posed by the life cycle characteristics of decapod populations. Although there are common features there is also great diversity in distribution and structure of populations and mobility of adults. In particular the source-sink dynamics affecting large scale metapopulations, on the one hand, and the local, density dependent dynamics of small geographical areas containing sub-populations, on the other, raise questions of scale and structure of management organisations and the need for coordination of local management schemes applied to sub-populations with broader management strategies at the metapopulation level. Many of these issues are dealt with in papers published from the conference on Life history, Assessment and Management of Crustacean Fisheries held at La Coruna, Spain in 2001 and which form the output of WP3 of EDFAM. They are also discussed in part 2 of the report of WP5 for European clawed lobster.

The Social and economic contexts

A good deal less is known about the economic and social conditions under which crustacean fisheries are conducted compared to the biological behaviour and population dynamics of the stocks themselves. Yet this knowledge is also vital for the development of sound management practice. Fishing activity for crustaceans is diverse in type and scale, from coastal to deep sea.

While some species have been exploited for many decades or even centuries by local inshore fisheries - and often subject to quite precise informally enforced norms of fishing behaviour - others have evolved much more recently from the status of by-catch species to become the target for new, largely unregulated commercial fisheries. They now attract elements of the large scale fleet segments and in some instances fishing has moved progressively offshore, generating very different fishing strategies and demanding a rather different management approach.

If we are to be able to recommend appropriate and effective management systems, we first need rather more than the bare statistical parameters of numbers and size of vessels, levels of employment and earnings - important though these basic indicators may be. Such information may suffice for simple, 'universal ' regulation at a central level; it will be insufficient to help sort out optimal management arrangements at the regional or local levels. Just as important is an awareness of how far participation in the fisheries involves specialised, all year round engagement or seasonal activity combined with other fisheries. Also needed is some understanding of the adaptive strategies of the fishermen involved (ie how they would be likely to respond to management decisions to limit participation in particular fisheries). Crustacean fisheries have themselves been the victims of redeployed fishing effort consequent upon the tightening of controls on fishing for other more effectively regulated species.

In contrast to fish species, where significant differences in life cycle characteristics are taken for granted, there is a disturbing tendency to ascribe a single set of economically rational behavioural characteristics to all fishermen. This may prove profoundly misguided and contribute to the apparent 'failure' of some management regimes. In particular management tends to discount the particularities of small boat fishermen, many of whom are engaged only part time or seasonally in fishing activities. The behavioural responses and coping strategies of some small boat fishermen cannot logically be explained by neo-liberal economic analysis. They do not necessarily respond to conventional economic signals in expected ways and their coping strategies may be very different to those more closely governed by profit and loss accounting and returns on capital.

At the same time, we do need to understand the true economic status of crustacean fisheries particularly at regional and local levels. Despite the fact that the absolute and relative value of shellfish landings has increased in recent years throughout much of the EU, there is still a tendency to treat certain decapod species as ' second class citizens' in management terms. Consider, for example, the current situation in the Irish Sea. Here in pursuit of the cod recovery programme the Commission recently argued for a significant reduction in the TAC for *Nephrops* on the basis of the bycatch of cod, haddock and whiting rather than concern for the state of *Nephrops* stocks, *per se.* At present, *Nephrops* accounts for half of the value of landings from the Irish Sea, while together cod, haddock and whiting account for only 17.5%.

Regulatory frameworks

Good management presumes a minimal level of interference with established patterns of fishing activity, sufficient to protect stocks from overexploitation and to maximise economic and social utility of the resource. The rules and regulations imposed on the fishing industry must be consonant with the legal frameworks (international, European, national and local) and with the prevailing social and economic conditions. And, of course, to have any real chance of success, the rules and regulations must be fully appreciated by, and acceptable to, the fishing industry .

The current regulatory system is not a blank sheet of paper. There is complex mosaic of local regulations found within inshore waters (0-6 nm) of certain European countries, where EU member states are allowed considerable discretion to develop their own systems of management for stocks confined within these limits.

Regulatory frameworks usually combine two quite distinct functions: conservation of resources and allocation of access rights. Most traditional systems put the emphasis on the latter. Ensuring equity in the allocation of fishing rights assumed priority at a time of relative resource abundance. Measures to protect resources only took precedence once resources came under threat from overexploitation triggered in many cases by differentiation in fishing methods and improved fishing technology. The task is to select the combination of measures most relevant to the biological and population characteristics of the species concerned and to the normal conduct of the fishery. Just as one may be critical of the lack of regulation in some crustacean fisheries, so too one may question whether in other cases the fisheries are subject to over regulation. The real test is whether the fishermen are willing to submit to a complex set of rules to protect their long term interests and, ultimately, whether the system succeeds in maintaining healthy stocks and good commercial yields (sustainability and viability).

The selection of an appropriate regulatory regime may also involve social or political choices. Implicit in the construction of almost any regulatory system is the prior need to adjudicate between the competing economic and social objectives of the fishery - whether to optimise economic returns on capital or maximise social value in terms of employment. Currently there is a major debate over the introduction of *rights based management,* involving privatisation of fishing rights through the implementation of individually transferable quotas (ITQs). The issue is whether to expose industry to free market forces rather than attempting to control fishing effort through input regulation.

There can be no doubting the potential benefits of ITQs in terms of the rationalisation of fleet structures in reducing the number of participants in a fishery and improving the economic performance of the surviving units. But the price may be too high not only in the loss of employment especially in the small boat sector but also in the risks that effective ownership of the quota - and therefore a significant element of the industry's capital - may pass into the hands of non-fishing interests. Property rights management is on the increase but as yet not very widespread. In Iceland and New Zealand (and to a lesser extent in the Netherlands), ITQs have been established as a basic feature of fisheries management, while in Australia they have been introduced only for a limited number of species.

For our purposes, the question of property rights is a technical rather than political one: are freely tradable individual vessel quotas appropriate to crustacean fisheries?

Institutional arrangements

Although the regulatory framework is a central feature of any management system, it certainly does not describe the whole picture. Until quite recently the overall architecture of the management system has been largely ignored, with serious consequences for the efficacy of policy decisions. Today, by contrast, a good deal of emphasis is placed upon the structures and processes through which policy decisions are made, including the communication networks linking scientists, administrators and the fishing industry; stakeholder involvement in decision making; and the relationship between international, national and local decision making.

The reform of the CFP explicitly recognizes the importance of appropriate institutional arrangements and scale in the mangement of fisheries through it's proposals to introduce Regional Advisory Councils (RACs) which will allow more inclusive decision making given the reduction in geographic scale within the remit of each RAC compared to the European common pond.

A number of key issues help to define some of the central features of the institutional arrangements *viz.*

How to facilitate meaningful communication and exchange of information, experience and ideas between science, industry and administration, especially the melding of research based scientific findings and the evidence from practical knowledge of working fishermen. Orensanz and Jamieson (1998) give three main reasons for encouraging such a dialogue: first, the value to be gained from the input of empirical knowledge into stock assessments; second, the sharing of costs of assessment and management in face of declining public investment in fisheries science; and third, the need to win the trust, commitment and compliance of fishermen in the management process. As a corollary , there is a further issue of *how to develop a fu//er understanding by the industry of the principles and practice of stock conservation.* Fishermen must be provided with timely information that allows them to appreciate the reasons why particular management measures need to be introduced.

How to involve the fishing industry more effectively in the formulation and implementation of management decisions . The debate on institutional arrangements in recent years has been dominated by two interrelated themes: co-management (or 'participative governance') and decentralised decision making (or regional management). The first of these concerns the direct involvement of the fishing industry in the system of management, whereby the industry shares with the state ownership of the decisions and assumes co-responsibility for their outcomes. Fishermen's organisations have been used quite widely in the implementation of regulations but much less commonly in their formulation. Timing of the stakeholders' entry into the process is crucial: the industry frequently complains that they are consulted far too late to have any real chance of influencing the decisions. Key questions are therefore: at what point in the decision making to involve the industry and whether the involvement should be part of the advisory process or as full members of the policy making community.

How to ensure integration of decision making throughout a hierarchy of geographica/ scales. Orensanz and Jamieson (1998) identify what they describe as meaningful scales for analysis of the spatial dimension of population processes (p 443) in the context of invertebrate stocks, namely: *megasca/e* or the zoogeographic range of closely related species and genetically distinct stocks; *macroscale* correlating with metapopulations; *mesoscale* for sub-populations; and *microscale* or 'neighbourhoods' describing the interactive space of individual animals. In practical terms, the critical relationship is that between the macro- and meso- scales where management must respect the dynamics of both the metapopulation and its sub-populations. Arguments in favour of decentralised management, predicated on the reasonable assumption that stakeholder involvement will be most effective at the regional and local levels, carry with them certain risks. Decentralised management can become too localised and introverted in its perspective so that it loses sight of the whole picture. Institutional arrangements must therefore be capable of ensuring effective coordination between macro- and meso- level management strategies.

How to minimise unconformities of management practice between different policy regimes. Most though not all crustacean fisheries occur within inshore waters and are therefore subject to national (and local) management. But the scaling up of these fisheries in recent years has led to an increasing spatial range of fishing operations. Problems may occur where the distribution of harvestable stocks straddles the boundaries of national and EU jurisdiction and where part of the stock can be fished in offshore waters free from the much tighter controls applied within inshore waters.

Is a dedicated institutional framework required to to serve the interests of crustacean fisheries or is it more likely that responsibility for management of crustacean fisheries will be vested in organisational structures designed to deal with the full range of marine fisheries? The essential task is to ensure that the distinctive needs of crustacean fisheries are not lost from view in whatever structures are established.

Content of the report

Many of the issues outlined above are dealt with in the papers in this report or in the second report of WP5 which reviews the management of clawed lobster fisheries. All of the information and original research required to comprehensively deal with the issues raised are not available however. For instance social and economic data, which could lead to an analysis of the contexts in which crustaceans fisheries are exploited, are generally absent. For other issues such as rights based fisheries much debate has occurred and recommendations can be and are made. The background and raw material for the review of the management systems for crustacean fisheries in Europe are provided in papers 2 and 3 of the report. In paper 2 the regulatory measures used to control the exploitation of each of the commercially important species of crustacean in each country in Europe are tabulated. This paper shows that there is an overwhelming reliance on minimum landing sizes to regulate exploitation of crustaceans and that the majority of these fisheries are effectively in open access. This situation reflects a number of important issues and deficiencies in the management of crustacean fisheries in Europe. Firstly management has not given due attention on a species basis to crustacean fisheries or considered adequately their probable fate if they remain in open access. Of the 20 or so commercially exploited crustacean species in Europe only *Nephrops*, *Pandalus* and *Crangon* are assessed and managed through the ICES and ACFM system. Secondly many of the species have coastal distributions and come under the aegis of national legislation through derogation in the CFP allowing national control over the exploitation of fisheries within 12 miles of the coast. The weak regulatory system also signifies that national authorities have not yet designed appropriate management measures for these coastal fisheries. Thirdly deeper water crustacean fisheries in the Mediterranean are relatively new and as a result the scientific information relevant to their assessment is only now becoming available. These fisheries are also the subject of multi-species trawl fisheries which makes a species based approach to management more difficult to implement. This is not as significant a problem for national authorities in northern Europe where the important crustacean fisheries (other than *Nephrops*) are primarily trap based.

The lack of specific and well designed management systems for crustacean fisheries in Europe, signaled in the weakly designed regime regulating their exploitation, is confirmed in Papers 2 and 3 which briefly describes the regulations and institutional arrangements for the management of these fisheries. The majority of crustacean management in Europe is centralized and top down but with notable exceptions. The *ad hoc* nature of management arrangements in many cases points to weak development of policy and planning. This is reflected in a general lack of multi-annual plans for stock management and absence of any proactive development of regulatory measures to achieve particular management objectives. Management is not dynamic, remains centralized and is generally non consultative.

Prior to pointing to possible new approaches that deal with the issues outlined above Paper 4 provides detail of the legal framework within which the management of decapod fisheries sits. It sets out the international and European legislation that impinge on the exploitation of crustacean fisheries and within which existing or proposed management systems must operate. These vary from international conventions on biodiversity, to transposition of these conventions to EU Directives and to species specific measures introduced at EU and national level. Much of the legal framework points to the responsibility of management systems to develop sustainable fisheries that protect biodiversity and the ecosystem and that take account of the social and cultural heritage of coastal communities relying on these resources.

Papers 5-9 analyse particular issues that need to be considered in re-thinking crustacean fisheries management in Europe. Paper 5 provides a necessary theoretical backdrop for the design of new approaches to management. Questions of *scale* and *integration of scales* are seen as paramount. Many crustaceans stocks are structured as metapopulations with local sub-populations requiring vertical and horizontal integration of scales in the assessment process and in the institutional arrangements for the management of these fisheries. *Vertical integration* is the communication between industry and regional to national to EU authority. *Horizontal integration* of locally delegated authorities and industry managing the constituent populations of the more widely distributed metapopulation or exploiting the same stock is obviously important for effective management.

The importance of scale is also exemplified in Paper 6, which identifies some important issues and comparisons for the management of shrimp, crabs and lobsters in northern Europe. The biology, population structure, recruitment, fisheries, economic value and management requirements for these species are different in form and scale. This paper shows the need for management to be species and location specific in order that it can deal with the broad range of issues that affect development of *sustainable* and *viable* fisheries.

A critical issue in management, and one, which has received a deal of attention in recent years in the fisheries management literature, is the issue of *property rights*. Papers 7-9 in various ways demonstrate that management needs to have very clear and explicit policy on property rights that is dovetailed with overall national social and economic policy. In the examples given ambiguities and lack of policy in relation to property right has directly imposed very significant additional costs of fishing and seriously affected the viability of fishing. The costs are imposed because the management authorities have allowed the trading of limited fishing capacity on the private market. The resultant artificially high costs have increased pressure on operators to increase fishing effort. The social cost in particular of the development of individual and transferable quotas (ITQs) is very clear. Tasmania has had a 30-year history of management using ITQs and their social impacts now seem apparent. Clear recommendations come from Paper 8 on the issue of property rights. This paper uses a case study in Ireland to demonstrate, with the help of a report from a consultation with the Irish lobster industry in 2000, to argue for public rather than private transferability of fishing licences. Security of tenure for licence holders that adequately promotes long term investment horizons and stewardship of fisheries can be developed while retaining the public interest in common pool fisheries resources and in parallel avoiding the imposition of entry costs to subsequent generations of fishers. Paper 9 describes two examples of delegated systems for management of crustacean fisheries in England and France and compares the relative merits of these systems with central management and the use of species-specific management advisory committees in Tasmania. Delegation or devolution is not seen as an answer in itself and there are clear problems of poor integration in these examples. A new focus on species as the fundamental units of biological production is required in the institutional management of crustacean fisheries albeit there is a need to consider and manage interactions in these fisheries. This is not contradictory to more recent emphasis on multi-species assessment and ecosystem based management but re-emphasises the need to consider the basic units prior to considering the interactions. This is not currently the case either in the multi-species trawl fisheries in southern Europe where interactions are intense or in northern European trap fisheries where interactions are sometimes unimportant. The report ends with 2 papers on the socio-economics of crustacean fisheries. Paper 10 describes the interactions between fisheries in northern France and models the socio-economic implications of different management strategies in this complex ecosystem. Paper 11 presents a case study of the socio-economics of shrimp fisheries in Greece.

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2. Regulations used in the management of crustacean fisheries in Europe

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Measures to control fishing mortality in crustacean fisheries in Europe are outlined in Tables 1 (Minimum Landing Sizes), Table 2 (Effort Limitation) and Table 3 (Quota Control). Minimum landing sizes are by far the most common form of regulation. Relatively few fisheries are effort limited. Quotas are used to manage *Nephrops* and *Pandalus*.

The reliance on Technical Conservation Measures (TCMs) such as minimum landing sizes is insufficient to protect stocks from recruitment overfishing. The protective effect offered by TCMs to spawning potential can be nullified by increase in fishing effort. As very few of the fisheries are effort or quota controlled they have to be regarded as vulnerable to over fishing. They are not in this sense being managed sustainably.

Many of the fisheries, in particular trap fisheries in northern Europe which target single species (*Cancer, Homarus, Maja, Palinurus, Palaemon*) are amenable to effort limitation or quota control. Effort is easily quantifiable in trap fisheries. Trap fisheries for lobster and crab in northern France are now effort regulated through limited entry and by restricting the quantity of fishing gear per vessel. The UK proposes to introduce restrictive licencing for crab and lobster in 2004. Limited entry has also been discussed for a number of years in Ireland and indeed the lobser industry submitted a request to Governement for its introduction in 2001. The UK also uses Regulatory Orders to regulate effort and entry in crustacean fisheries on a local or regional basis. Shetland is the only current example however.

A number of fisheries use additional measures to protect stocks. Closed seasons and areas (temporary closures or Marine Protected Areas) are commonly used although their effect on annual fishing mortality or spawning potential is unknown. Additional measures such as v-notching of lobsters is common in Ireland and UK.

Minimum sizes are usually set by the European Commission and are directly transposed to national legislation. These limits can be made more stringent but not diluted by national governments. In many cases the minimum sizes are not necessarily based on estimates of size at maturity particularly where size at maturity may be regionally if not locally variable. Generally insufficient biological information is available to set regional or local specific minimum sizes. Minimum size regulations in trawl fisheries are less effective than in trap fisheries because discard mortality is probably high.

Table 1. Minimum landing sizes for crustacean species by countr. Blank indicates no limit.CW=carapace width, CL=carapace length

Species	Norway	Ireland	England Wales	Scotland	France (Atlantic)	France (Med)	Portugal	Spain (Atlantic)	Spain (Med)	Italy	Greece
Nephrops norvegicus	Yes	25 mm CL, 20 in VIa,VIIa	25mm, 20mm in VIIa	25, 20 in VIIa	Yes	Yes	Yes	Yes	20mm	20mm	20mm (70 TL)
Pandalus borealis	15mm CL										
Homarus gammarus	85-88mm CL	87 mm	87-90mm	87	87			Yes	Yes	Yes	85 (240 TL)
Palinurus elephas		110 mm CL	110mm	110mm	95mm	Yes		Yes	80mm	80mm	85mm
Palinurus mauritanicus					Yes	Yes			Yes	?	
Cancer pagurus	110-130 mm CW	130 mm CW, 140 mm north of 56°	115-160 depending on area	140 mm north of 56°	140 N of 48, 130 S 48			Yes			
Maja squinado		130 mm CL male, 125 mm female	130 male 120 female		120	120		Yes			
Necora puber			65 mm CW		Yes	Yes					
Paralithodes camtschatica											
Liocarcinus depurator											
Carcinus meanas											
Crangon crangon											
Palaemon spp.											
Parapenaeus longirostris											
Aristeus antennatus											
Aristeomorpha foliacea											
Penaeus kerathurus											
Scyllarides latus									?		
Scyllarus arctus									?	Yes	
Squilla mantis											
Plesionika spp.											

Table 2 Effort limited fisheries for crustaceans in Europe. Y = yes, blank = none. RO = regulatory order which has the power to limit effort

Species	**Norway**	**Ireland**	**England Wales**	**Scotland**	**France (Atlantic)**	**France (Med)**	**Portugal**	**Spain (Atlantic)**	**Spain (Med)**	**Italy**	**Greece**
Nephrops norvegicus							Y				
Pandalus borealis	Licences										
Homarus gammarus			In 2004 ?	Shetland RO	Y		Y				
Palinurus elephas			In 2004 ?				Y				
Palinurus mauritanicus											
Cancer pagurus			In 2004 ?	Shetland RO	Y						
Maja squinado			In 2004 ?		Y						
Necora puber			In 2004 ?	Shetland RO	Y		Y				
Paralithodes *camtschatica*	Y										
Carcinus meanas											
Crangon crangon											
Palaemon spp.			In 2004 ?				Y				
Parapenaeus longirostris							Y				
Aristeus antennatus							Y				
Aristeomorpha foliacea											
Penaeus kerathurus											
Scyllarides latus											
Scyllarus arctus											
Squilla mantis											
Plesionika spp.											

Table 3. Crustacean fisheries in Europe controlled by quota. Blank = no quota

Species	**Norway**	**Scotland**	**England & Wales**	**Ireland**	**France (Atlantic)**	**France (Med)**	**Portugal**	**Spain (Atlantic)**	**Spain (Med)**	**Italy**	**Greece**
Nephrops norvegicus	TAC	TAC	TAC	TAC	TAC		TAC	TAC			
Pandalus borealis	TAC										
Homarus gammarus											
Palinurus elephas											
Palinurus mauritanicus											
Cancer pagurus											
Maja squinado											
Necora puber											
Paralithodes camtschatica	TAC										
Liocarcinus depurator											
Carcinus meanas											
Crangon crangon											
Palaemon spp.											
Parapenaeus longirostris											
Aristeus antennatus											
Aristeomorpha foliacea											
Penaeus kerathurus											
Scyllarides latus											
Scyllarus arctus											
Squilla mantis											
Plesionika spp.											

3. Management of crustacean fisheries : the process in European Countries

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Mediterranean – summary comments:

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Management of fisheries in the Mediterranean is not specifically designed or targeted at crustaceans . Only some species of crustaceans have minimum landing sizes (*Penaeus kerathurus, Nephrops norvegicus, Homarus gammarus* and *Palinurus* spp.), as per EU legislation (Directive 1626/1994, 27 of June 1994). Most of the legislation regarding crustacean fisheries is legislation relating to trawl design, not only because it is the main gear used, but also because it has poor selectivity in comparison with artisanal gears (nets and traps). Other management measures based on close seasons, protected areas and various methods of effort control vary from country to country and within countries. On the other hand, while policies are in place to limit the nominal fishing effort (i.e., maximum engine power of 500 HP, or limiting the number of boats or the time at sea) the fishing mortality applied to many crustacean stocks continues to increase, probably because technological progress (and fishing efficiency) has not been properly taken into account and because these fisheries are mixed-species and limiting fishing effort on a species basis is difficult. A major problem concerning management is the low level of enforcement of the legislation, especially when legislation is enacted at the supra-local level. The experience with local management at the level of *cofradías* indicates that the self-regulation of fishermen is a feasible, and cheap, way to manage fisheries.

A sound management regime for Mediterranean crustacean fisheries should take into account the following issues:

-the local socio-economic nature and value of crustacean fisheries,
-the small scale variability (biological, environmental) inherent to these fisheries
-the collection of biological, environmental and economic data on a continuous basis, not only related to ongoing scientific projects (long term monitoring programs)
-the practicalities of enforcing management measures

In order for management to be effective, there must be a clear management policy and the means to enforce this policy must be in place. If management by government (or international) agencies is deemed prohibitively expensive for small scale coastal fisheries, local or community-based initiatives should be encouraged.

Greece

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The most important crustaceans species fished in Greece are *Nephrops norvegicus, Parapenaeus longirostris, Penaeus kerathurus* and *Palinurus elephas*. The legislative and the management measures are not specifically designed for crustacean fisheries. The measures are mostly technical and directed to the protection of juveniles by the imposition of closed seasons, closed areas and minimum landing sizes. The management measures are summarized in Table 1.

Table 1. Management measures relevant to crustacean fisheries in Greece.

General Technical Measures	
Trawl	- Codend minimum mesh size 40 mm (stretched) - 3 miles from the coast or in depths >50m - Closed season of 4-6months - Closed areas in coastal areas - Maximum engine power, 500HP
Fixed nets	No restrictions, except closed areas in National Parks
Measures for some species	
N. norvegicus	Minimum landing size: 20 mm CL or 70 mm TL Fishing with traps is not allowed
P. kerathurus	Closed season in Amvrakikos Gulf: one month (July)
P. elephas	- Min landing size: 85 mm CL or 240 mm TL or 420 ± 10g - Closed season: 4 months generally (September - December), 7 months in Alonissos National Park (September - March) - Prohibition to fish berried females
H. gammarus	- Min landing size: 85 mm CL or 240 mm TL - Closed season: 4 months generally (September - December), 7 months in Alonissos National Park (September - March) - Prohibition to fish berried females

According to the EC recommendations and in common with other EU countries (E (87/2371/11-12-87, E(92) 1071/9/29-4-92, E(92) 3319/9/21-12-92) fishing capacity (GRT and engine power) of the Greek fishing fleet is restricted since 1991 (P.D. 261/91). No new fishing licenses, except in the case of the replacement of a vessel by a new one, were subsequently issued. In addition various vessel decommissioning schemes were launched in order to reduce the fishing effort and to renew the fishing fleet.

The fisheries management in Greece is centralized. Devolved legislative power is exercised by the Districts and the Port Police office (Ministry of Merchant Marine) of each region.

The input of information from the fishers to the management system is as follows. The inspectors of fisheries (in the Prefectures) collect information on local issues or problems that arise for fishers. They then inform the Fisheries Department of the Ministry of Agriculture. These problems are presented to the Fisheries Council. The Council consists of the General Secretariat of the Ministry of Agriculture, the Director of Fisheries Department of the Ministry of Agriculture, a representative of NCMR, a representative of Ichthyologists of the Ministry of Agriculture, a representative of the Ministry of the Merchant Marine and a representative of the Hellenic Confederation of Unions of Fisheries Cooperatives.

The Fisheries Council can decide on penalties to be used for breaches of legislation. The Fisheries Council submits proposals on legislation to the Minister, which may accept or reject them. The Minister has the authority to pass legislation concerning measures for individual fisheries. General laws or policies concerning fisheries are decided by the Parliament.

Except for the participation of NCMR (National Centre for Marine Research) on the Fisheries Council, the various research organisations must submit reports of results of their research to the Ministry of Agriculture so that they can be taken into account in the planning of fisheries policy.

The Ministry of Agriculture may fund various organisations to carry out fisheries research projects in order assist the development of sustainable management.

Meetings are also organised between the representatives of the Ministry of Agriculture, the fishers and their representatives and the representatives of the various research organisations in order to present scientific results or discuss new regulations and the problems of fishers.

France

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The important crustacean fisheries in France are for *Cancer, Maja, Homarus, Palinurus* and *Palaemon*. All except *Maja* are trap fisheries.

Management of trap fisheries
All species are regulated by minimum landing sizes. In addition it is compulsory for all French boats fishing for crabs and lobsters to have a “grands crustaces” licence. Only potters and netters can be issued such a licence. Licences are issued using pre-defined allocation rules on a regional basis by industry. It is issued to the skipper/boat and must be renewed annually. Effort is therefore limited at the generic “grands crustaces” but not at the species level. The cost of the licence is €50-100 (a fixed part of the fee is shared between each of the 3 levels of industry organisation; local, regional and national). Decision rules (a priority order) have been put in place to deal with new demand for licences. In effect only the Basse Normandie region applies these decision rules (as of 2001) and there is still a risk of legal challenge from applicants that are excluded. To improve knowledge of the fishery the licence holders are asked to produce a logbook for the previous years fishing.

In addition to the licencing scheme there is also a limit on the number of pots each boat can fish. The number of pots per boat is related to the number of crew. In most fisheries it is 200 pots (locally 250-300) per crew member with a maximum of 1000 pots per boat but in the future this may be related to Vessel Capacity Units (VCUs). All traps must be tagged to identify the year of issue and the licencee.

The industry plays a proactive role in management and is organised at local, regional and national level (see Tully *et al*. ‘European fisheries inside 12 nm: the role of delegation in effective management’ of this report).

Portugal

Cristina Silva, IPIMAR, Lisbon

The most important crustaceans species fished by Portuguese trawlers are *Parapenaeus longirostris, Nephrops norvegicus* and *Aristeus antennatus*. *Parapenaeus* is now the most important commercial species.

These fisheries occur at depths of 100-600m mainly in the south and south-west of Portugal. They began in the 1950s and effort increased until 1983 when access was restricted to Portuguese vessels only. They are trawl fisheries and target a number of species simultaneously. Generic regulations on trawl design, vessel size and fishing location are therefore emphasised.

Various regulations are in place; vessels > 100 GT cannot operate inside 6 nm while vessels > 250 GT must operate outside of 12 nm. Trawl mesh is 55 mm and a Vessel Monitoring System (VMS) is used to track the fishing vessels exact location. Using these data, the vessel's average velocity, its fishing activity, time spent to reach the fishing ground, monitoring areas closed to trawling etc. can be calculated. There are seasonal trawl bans from December to February to protect juvenile hake and a TAC exists for *Nephrops*. *Nephrops* landings and CPUE have declined significantly during the 1990s. The catch has been much lower than the TAC (catch ≈ 200 tonnes and TAC set at 800 tonnes), thus the TAC has had no importance whatsoever in regulating the fishery and as such it cannot be considered a management measure.

A limited entry system now exists and no new licenses have been issued for fishing crustacean species. There is a permanent ban on trawling inside of 6 nm.

Trapping for *Palinurus, Homarus, Cancer, Maja* occurs inshore by vessels < 100 hp and < 9 m in length. Licences, closed seasons and gear limits are used to regulate fishing.

The management process
Scientific results are reported regularly to the administration. Whenever necessary *ad hoc* meetings take place between representatives of the industry, IPIMAR and the administration for consultations on new management measures and to discuss the problems of the industry. Scientific results may also be presented at these meetings. Depending on the situation these meetings are organised by the central administration or IPIMAR or on request from the industry representatives.

Submissions for the introduction or change in regulations are also made by written request from the central administration to IPIMAR and to the stakeholders.

For species where there is no quantitative assessment information available IPIMAR must also advise on a precautionary basis using a 'common sense' approach.

Concerning the local inshore fisheries the consultation occurs locally but the power to regulate is still central.

England and Wales

Julian Addison, CEFAS, Lowestoft, UK and David Symes, University of Hull, Hull, UK

The crustacean fisheries
The main crustacean fisheries in England and Wales are for *Cancer pagurus*, *Homarus gammarus, Necora puber, Maja squinado* (south coast), *Palinurus elephas* (south west coast). These are generally caught by traps inshore (tangle nets are used for the small *Palinurus* fishery) although offshore fishing for *Cancer* and *Homarus* has increased over the past 15 years. Effort, as in the number of pots fishing at a given time, has generally increased over the past 10 years and on the South coast parlour pots have increased in popularity.

Various technical conservation limits and local regulations are in force (see 'Regulations used in the management of crustacean fisheries in Europe' above)

The management process
The Department of Fisheries and Rural Affairs (DEFRA) retain overall authority for the management of crustacean fisheries in England and Wales. In addition there are 12 Sea Fisheries Committees (SFCs) with delegated powers to implement and enforce regulations for the conservation of local sea fisheries around virtually the entire coastline of England and Wales. SFCs were established in the 1880s; they are funded by the constituent local authorities and since 1995 their powers have been widened to include the regulation of sea fisheries for environmental reasons. A significant and possibly unique feature of SFCs is thie independent enforcement capability both onshore and at sea. All but one of the 12

Committees have their own patrol boats that are able to operate out to the 6 nm limits. Details of the operation of SFCs can be found in 'European fisheries inside 12 nm: the role of delegation in effective management' on page 90 of this report.

Scotland

David Symes, University of Hull, Hull, UK

Unlike the situation described above for England and Wales, inshore fisheries in Scotland are currently managed through SEERAD under the provisions of the Inshore Fishing (Scotland) Act 1984. This grants the Minister powers to regulate sea fisheries within specified areas of the inshore zone through orders which may prohibit "all fishing for sea fish... fishing for a specified description of sea fish...fishing by a specified method... fishing from a specified description of fishing boat" for a given period of time. Orders are laid before the Scottish Parliament on a roughly triennial cycle setting out any new prohibitions and annulling those no longer considered relevant.

Responsibility for initiating new proposals rests largely with the fishing industry. At the outset of the triennial cycle national and local fishermen's associations (and others) are invited to submit proposals for any new orders which are then subjected to internal review by the Inshore Fisheries Branch of SEERAD, with the assistance of the Scottish Inshore Fisheries Advisory Group (SIFAG), a stakeholder group drawn from the main fishermen's organisations, conservation organisations, scientists and the fisheries protection agency. Subsequently proposals are submitted for expert opinion to the Fisheries Research Service (FRS) for consideration of the scientific justification, Scottish Natural Heritage (SNH) for opinion of their possible environmental impacts and the Scottish Fisheries Protection Agency (SFPA) to assess their enforceability. At present, the great majority of the 40 or so active prohibitions are concerned with the resolution of gear conflicts through the separation of mobile and static fishing gear activities for shellfish, and refer to relatively small areas of the Scottish coast. A few are concerned with restrictions in fishinf effort through weekend fishing bans (the Clyde) and banning the use of parlour pots for the Nephrops fishery in the Western Isles. Very occasionally the prohibitions lay the basis for a more comprehensive lcoal management scheme as in the case of the Loch Torridon *Nephrops* fishery where the designation of a creel only fishing area has led to a detailed management plan setting out maximum number of creels/boat, number of days fishing/year and the compulsory fistting of escape panels to all prawn creels.

An important new development in shellfish management in Scotland has been the belated adoption of ROs under the Sea Fisheries (Shellfish) Act 1967. To date only one such order has been granted – for the Shetland Islands, covering a wide range of specified shellfish species, including crab and lobster. Management of the ROs is in the hands of a limited company (as the designated organisation) with directors drawn from local fishermen, the local authority, SNH inter alia. This is the first example of a statutory devolved management organisation for inshore management in Scotland, though others are expected to follow. Currently SEERAD is conducting a review of the inshore management system.

Ireland

Oliver Tully, BIM, Galway, Ireland

Fisheries
Important fisheries for crustaceans in Ireland include trawl fisheries for *Nephrops* in the Irish Sea and off the west coast. *Cancer pagurus* is caught by traps in inshore waters and offshore to the edge of the continental shelf and is the 3rd most important fish species nationally. Trap fisheries for *Homarus gammarus* usually within 10 km of the coast, local trap fisheries for

Palaemon serratus, Necora puber, Maja squinado and tangle net fisheries for *Palinurus elephas* are also important.

About 2000 vessels and 3000-4000 people are directly dependent on inshore crustacean fisheries. These are open vessels under 7 m in length and half deckers 8-12 m in length.

Regulation
The fisheries are regulated usually by minimum landing size. In addition there is a quota restriction on *Nephrops*, a closed season for *Palaemon serratus* and local by-laws banning the use of tangle nets for *Palinurus elephas*. An important v-notch program exists for *Homarus gammarus* which has had a real positive effect on conservation and conservation awareness in this fishery. National fleet capacity is limited by MAGP but national segmentation of this capacity does not allow effort limitation at the level of crustacean fisheries or for particular species. Voluntary trap limits are in operation locally but are not supported by national legislation. Shellfish or specifically lobster licencing has been on the agenda for a number of years but as yet no limited entry has been established for any crustacean fishery.

Management process
Crustacean fisheries like all sea fisheries are administered by the central government that retain control over all aspects of the management of the fisheries. The Marine Institute have responsibility to provide stock assessment advice. The Irish Sea Fisheries Board (BIM) have a remit to provide for sustainable development of fisheries. In recent years (since 1999) increasing attention has been paid to the inshore fisheries sector fishing inside 12 miles and operating vessels < 12 m in length. Data collection programs are now being established with a view to providing stock assessment advice for crustacean fisheries.

Legislation is enacted by the Department of Communications, Marine and Natural Resources. This is either transposed from EU legislation or is brought about by locally driven initiatives with industry input. Although no powers or responsibility have been devolved to regions or local areas local industry groups have been effective, with the assistance of local fisheries facilitators employed by the state, in arguing for the introduction of local measures to protect stocks e.g. local tangle net bans for *Palinurus elephas*. In other instances and when it impinges on the fishing entitlements of other sectors of the fleet, local initiatives and consultations have been less effective and the process of developing new access rules to fisheries is quite slow.

Industry groups who target crustacean fisheries are not highly organised although the grant aided v-notch schemes for *Homarus gammarus* have been a driving force for organisation. Many groups have set up co-operatives. These have active committees who oversee lobster v-notching and who are consulted by central government on licencing policy. These co-ops have representatives from different ports who communicate issues to individual fishermen locally.

Norway

Ann Lisbeth Agnalt, IMR, Bergen

The fisheries and regulation
Crustaceans of commercial interest in Norway are currently northern prawn (*Pandalus borealis*), edible crab (*Cancer pagurus*), red king crab (*Paralithodes camtschatica*), Norway lobster (*Nephrops norvegicus*) and European lobster (*Homarus gammarus*).

Two stocks of northern prawn are harvested in the Barents Sea and Svalbard region (30-50,000 tonnes) and in the North Sea and Skagerrak (10,000 tonnes). The northern fishery is regulated through licences, MLS of 15 mm CL and by-catch regulations of juvenile fish (cod/haddock/blue halibut). The fishery is basically offshore, and no TAC is set. Norway is also given quotas off Greenland and Flemish Cape off the east coast of Canada. The fishery in the North Sea and Skagerrak area is regulated through an agreement with EU, and has generally been less than the agreed TAC. Including discards, however, the TAC was overfished in 1996 and 1997. A TAC of 14,500 tonnes was set for 2002 and 2003.

Reported annual landings of *Cancer pagurus* vary from 3- 4,000 tonnes. Recreational fishers legally catch unknown quantities, and in the southern part of Norway landings by commercial fishers are also unrecorded. The stock is regulated by MLS of 130 mm carapace width (CW) north of Hordaland and 110 mm CW south and southeast of Rogaland.

The red king crab fishery has a special status in Norway. The Russians introduced the species to the North Atlantic from the Pacific in the 1960's to 1970's. The crab originated mainly from Peter the Great Bay and from the south-western coast of Kamchatka. These were released in Kol'skij Zaliv or Kolsky Bay close to Murmansk. By 1998 the king crab had established a self-sustaining population in Norwegian Territory. The experimental fishery started in 1994, and quotas and MLS for males are set in agreement with the Russians. In 2002 the fishery was given a commercial status. An agreement has been reached between Norway and Russia to annually land 20% of the catchable portion of the population. For 2003 the quota was set to 200,000 males above MLS for Norway and 600,000 males in the Russian zone.

The Norwegian landings of *Nephrops norvegicus* increased from 9 tonnes in the early 1970's to 330 tonnes in 2000. The majority are caught in the Skagerrak area.

The annual harvest of European lobster has fluctuated widely. Annual reported landings since 1980 have not exceeded 60 tonnes. Recreational fishers, however, legally catch unknown quantities of lobster. The fishery is regulated through MLS, closed season and gear restriction (lobster pots only). The MLS is set to 88 mm CL northwards of Rogaland County, and 85 mm CL in the eastern and southern part of Norway. The closed season varies from region to region, but from 2002 it is from 1 January to 30 September.

The management process

Stocks of *Pandalus* and *Nephrops* are monitored through annual surveys (different months for the different regions for the different stocks and species) and by monitoring of the commercial fishery (log books and/or length frequencies). Annual surveys of red king crab are also undertaken to estimate stock size and recruitment. Tagging studies are made to assess migration, growth and reproduction. In edible crab there is no monitoring, nor estimation of stock size. However, a research program commenced in 2001, with a focus on the west coast of Norway. There is likewise no management, of European lobster except for those measures mentioned previously. Logbooks and length frequencies are recorded in the southern part of Norway and this time series goes back to 1928.

A new law, the Sea Ranching Act, gives a property right to individuals who release crustacea, molluscs and echinoderms. This law was accepted in the Norwegian Parliament 1 January 2001 but no concessions have been granted to date. The provisions of the Act are now close to finalization, and some issues have come to light. The ownership of ranched animals raises controversy in relation to "common property", which is also established in Norwegian law.

4. International Regulatory Framework Surrounding Decapod Species in Europe

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Introduction

The regulation of the European decapod crustacean fisheries, like any fisheries or indeed natural resource regulation, is seemingly complex, with the industry being managed pursuant to a number of legislative enactments. The different laws and regulations can be classified by the functions by which they operate[1]. Primary distinctions can be observed between regulations that are species specific, and those that are non-specific (i.e. refers generally to "fisheries" or "crustaceans"); or between legislation that is activity specific and those regulations that are generalist measures relevant for any activity[2]. In addition to these distinctions the geographical extent of the law and regulations varies with measures being regional or local in nature.

This paper provides an overview of the international regulatory framework surrounding decapod species in Europe. Initial discussion shall focus on those international measures and obligations that may apply to the industry in Europe, and it shall then go on to discuss the specific laws and regulations that are in force under European Law. Whilst specific national, or indeed sub-national, provisions exists it is the international and more pertinently the European legislation which sets the scope and form of the national responsibilities. This paper, therefore, provides detail of the framework within which the management of decapod fisheries sits.

International Law and the Management of Decapod Crustacean Fisheries

International law is a unique body of law that has no single international body responsible for law making; it is instead derived from a number of sources and through a diversity of institutions. Further the level of enforcement and legal status of the various international obligations vary. A distinction can be made between three types: the law of treaties, international customary law, and "soft" international law[3]. Under the auspices of international law there are measures which relate specifically to the fisheries industry; those that are concerned with the marine environment per se; and those concerning conservation and biological diversity, and that may have an application to the fisheries industry. Some of these provisions are outlined below with their primary obligations being highlighted[4].

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[1] Activity functions are used in legal studies to enable comparisons to be made between various laws. It is commonly used in comparative legal studies to ensure that some form of "like for like" is recognised in analysis, however, it also enables clearer distinction in the various laws and regulations applicable to many industries.

[2] N.B. in most cases a list of activities will be discussed in the legislation, for example in the Annex, and the use of the term "any" is used merely to draw distinction from legislation which applies to one specific activity, e.g. aquaculture.

[3] Treaties are agreements made between states that need to be both signed and ratified by the signatory states; International customary law consists of those rules long practiced in international relations among States, that have been accepted as binding norms in their mutual relations without any prescription within Treaty law; "Soft" law instruments include codes of practice, recommendations, guidelines, resolutions and declarations of principle to which states are expected to adhere. They are voluntary and non-binding peer documents of declared conduct, best practice or intent

[4] Table 3, International Obligations.

UN Convention on the Law of the Sea (UNCLOS)

UNCLOS provides an "umbrella" under which global, regional and national action can take place. It imparts an all embracing and integrated concept in which the ocean is an exhaustible and finite resource. It governs all aspects of ocean space, including the allocation and zoning of jurisdictional rights, environmental control, marine scientific research and economic and commercial activities and enshrines the notion that all problems of ocean space are closely interrelated and need to be addressed as a whole.

UN Fish Stocks Agreement (1995)

The agreement was adopted in 1995 by the UN Conference on straddling fish stocks and highly migratory fish stocks, and implemented aspects of UNCLOS. Within the agreement principles are set out for the conservation and management of those fish stocks (straddling fish stocks and highly migratory fish stocks) and establishes that such management must be based on the precautionary approach and the best available scientific information[5]. This agreement elaborates on a fundamental principle of UNCLOS, that States should cooperate to ensure conservation and promote the objective of the optimum utilization of fisheries resources both within and beyond the exclusive economic zone, by providing a framework for cooperation in the conservation and management of those resources.

FAO Code of Conduct for Responsible Fisheries 1995

The Code of Conduct for Responsible Fisheries was adopted in 1995 at the 28th session of the United Nation's Food and Agricultural Organisation's (FAO) Conference in Rome, Italy. The Code seeks to lay down a comprehensive set of guidelines and principles, in accordance with the relevant rules of international law, which inter alia promote responsible fishing and fisheries activities, taking into account all their relevant biological, technological, economic, social, environmental and commercial aspects (Art. 2).

The territorial scope of the Code is global, directed at members and non-members of the FAO, fishing entities, sub-regional, regional and global organisations, whether governmental or non-governmental, and all persons concerned with the conservation of fishery resources and management and development of fisheries, such as fishers, those engaged in processing and marketing of fish and fishery products and other users of the aquatic environment in relation to fisheries. The Code applies to all fisheries, inclusive of the capture, processing and trade of fish and fishery products, fishing operations, aquaculture, fisheries research and the integration of fisheries into coastal area management.

Specific provisions of the Code of note include Article 7 which deals with fisheries management aspects and the requirement for a precautionary approach to be taken, and Article 8 which outlines requirements for fishing operations. More generally Article 10 identifies the larger framework of coastal zone management in which fisheries activities are to sit.

Under the Code of Conduct for Responsible Fisheries the FAO has developed International Plans of Action (IPOA's). Of particular note here is the IPOA to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing.

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[5] The precautionary approach or principle is particularly evident in the marine environment. Whilst there are a number of different interpretations it generally describes an approach to the protection of the environment around precaution even when there no clear scientific evidence of harm of risk from an activity.

Agreement for the establishment of a general fisheries council for the Mediterranean 1949 (as amended 1997)

This agreement is a regional measure with its territorial scope being the Mediterranean Sea, the Black Sea and connecting waters. Its aim in establishing the GFCM was to enable the particular attributes of the Mediterranean to be recognised and for there to be the promotion of the development, conservation and management of living marine resources, and to formulate and recommend conservation measures. This is a "general measures" agreement in that it applies to all marine species found in the Mediterranean area.

Berne Convention on the Conservation of European Wildlife and Natural Habitats 1979

The Convention has a threefold objective:
- to conserve wild flora and fauna and their natural habitats;
- to promote co-operation between states;
- to give particular emphasis to endangered and vulnerable species, including endangered and vulnerable migratory species.

To achieve this multi-faceted objective, the contracting parties have undertaken, *inter alia,* to protect the habitats of wild flora and fauna species (Chapter II), and to give special attention to the conservation of the wild flora and fauna species listed in Appendices I and II, as well as to the protection of the fauna species listed in Appendix III (Chapter III). A variety of European marine species are included within these Appendices.
- Appendix I - strictly protected flora species
- Appendix II - strictly protected fauna species
- Appendix III - protected fauna species

Appendix IV details the prohibited means and methods of killing, capture and other forms of exploitation.

Convention on Biological Diversity

At the Earth Summit in Rio de Janeiro, June 1992, a United Nations Convention on Biological Diversity (CBD) was drafted, which entered into force late in 1993 with 168 States being a party to it.

The definition of biodiversity used within the Convention sets aquatic biodiversity firmly on the CBD's agenda. Aquatic biodiversity includes not only the target plants and animals that are harvested or farmed but also the many microbial, plant and animal species that feed and shelter them and that maintain their environment. The CBD is currently focusing a major part of its efforts on aquatic species and ecosystems, as it has done over the last decade. In 1995, its Second Conference of the Parties (COP) resolved to address the conservation and use of marine and coastal biodiversity[6]. In 1996, the third COP produced the "Jakarta Mandate on Marine and Coastal Biodiversity" and a subsequent meeting of marine experts in March 1997 began to develop a work programme in five thematic areas: integrated marine and coastal management; marine and coastal protected areas; sustainable use of coastal living resources; mariculture; and alien species.

The CBD gives extensive rights to the Parties over the biological resources within their boundaries. It also sets out obligations for the Parties to document their biodiversity and to evolve strategies for its conservation and sustainable and equitable use. The manner in which each State achieves this, however, involves a certain degree of discretion. For example, the Jakarta Mandate encourages the Parties to the Convention to "establish and/or strengthen, where appropriate, institutional, administrative, and legislative arrangements for the development of integrated management of marine and coastal ecosystems, plans and

[6] Joergensen, M. (1996)

strategies for marine and coastal areas, and their integration within national development plans"[7]. However, it does not lay down how this should be achieved, although this may change in future. In the subsequent conferences of the Parties, States have been tasked with identifying gaps in their legislative and institutional provision and terms of reference have been drawn up and approved for the formation of technical expert groups on, inter alia, marine protected areas and aquaculture[8]. It may be that greater guidance will be forthcoming.

EC Law and the Management of Decapod Crustacean Fisheries

As discussed above international laws provide a framework under which other laws and regulations can sit, and in some cases provides a benchmark for "good practice". However, at a procedural and administrative level the fisheries industry is regulated through regional measures, and specifically within Europe this is provided for under European law[9]. A number of European legislative enactments and regulations provide the framework for the management of decapod fisheries. These measures can crudely be divided into three categories: technical measures; habitat and nature conservation; and the common organisation of the markets.

However, the fishing industry within Europe operates under the umbrella of the Common Fisheries Policy and therefore a brief discussion of this is provided before the specific legislative and regulatory requirements are addressed.

Common Fisheries Policy

The Common Fisheries Policy of the European Union was first introduced almost twenty years ago in 1983, responding to the EC Treaty requirements for the management of common resources, with its prime objective being to manage fisheries for the benefit of both fishing communities and consumers. The CFP applies to the biological, economic and social aspects of the fishing industry with there being four main areas within the CFP for which common measures are agreed. These are:

- The conservation of fish resources and the relationship between fisheries and the environment;
- The common organisation of markets in fisheries products;
- Structural policy; and
- The external relations relating to fisheries beyond Community waters[10].

The mandatory requirement for Member States to comply with Community regulations makes the CFP unique in the world of fishery management, however this common management can be awarded no value unless there is effective supervision and enforcement of the legislation itself[11].

The extent to which the CFP has been effective in terms of the success of its objectives and its enforcement has been examined through a review process. The first review of the CFP took

[7] "Jakarta Mandate on Marine and Coastal Biodiversity" adopted at the Second Conference of the Parties (COP-2) in November 1995.
[8] Fifth Conference of the Parties (COP-5) of the Convention on Biological Diversity (CBD), Nairobi, Kenya, May 15-26, 2000.
[9] The use of the term Europe refers to those Member States of the European Union for the purposes of this report.
[10] European Commission (2001) Green Paper: The future of the common fisheries policy. Office for Official Publications of the European Communities, Luxembourg.
[11] Long, R. J and Curran, P.A. (2000) Enforcing the Common Fisheries Policy. Fishing News Books, Oxford.

place in 1992, and was completed in 2002 as a prelude to a substantially revised CFP[12]. The review has highlighted the poor state of many fish stocks that are outside safe biological limits, as well as the fact that the fishing capacity of the Community fleets far exceeds that required to harvest the available fishery resources in a sustainable manner. A decline in the economic performance of the industry has also been observed. This review process has involved wide consultation with all interested parties and from this necessary outcomes have been formulated.

The reformed CFP is aimed at achieving:

- Responsible and sustainable fisheries and aquaculture activities that contribute to a healthy marine environment;
- An economically viable and competitive fisheries and aquaculture industry which will benefit the consumer;
- A fair standard of living for those who depend on fishing activities.

Ensuring that there is:

- Openness and transparency, in particular by improving the quality and transparency of the scientific advice and data on the basis of which policy decisions are taken;
- Participation, through greater and broader stakeholder involvement from conception to implementation of policy; including at regional and local level;
- Accountability through a clearer definition of responsibilities at European, national and local level;
- Effectiveness, though decision making processes whose results are properly evaluated, controlled and complied with and
- Coherence with other Community policies, in particular environment and development policies, through a cross-sectoral approach

Little in the revised policy (Regulation 2371/2002) is of direct relevance to decapod fisheries, except for the extension of Member states responsibilities for regulation and enforcement within the 12 nm zone applicable to all vessels fishing within that zone. Provision is also made for multi-annual management plans for the exploitation of commercial species, the introduction of emergency measures and the establishment of Regional Advisory Councils (RACs).

Technical Measures

Technical measures are defined as the use of technical regulations on fishing gears and activities in order to obtain the overall goal of high sustainable yield in the fishery. Under the CFP the EC has brought into force a number of Regulations that detail the technical measures for the fisheries industry, mainly in an ad hoc fashion, with those relevant to crustacean fisheries outlined below.

> *Council Regulation (EC) No 850/98 of 30 March 1998 for the conservation of fishery resources through technical measures for the protection of juvenile marine organisms; (and its amendments… 724/2001, 1298/2000, 812/2000, 2723/1999, 1459/1999, and 308/1999[13]).*

[12] Ibid no. 9 and European Commission (2001). Green Paper: The future of the common fisheries policy. **II**.

[13] See Table 1, European Legislation for Selected Decapods.

This regulation lays down technical conservation measures that are to be applied to the taking and landing of fishery resources occurring in maritime waters under the sovereignty or jurisdiction of the Member States, and other regions as specified[14].

The regulation details general provisions for nets; minimum size constraints for marine organisms[15]; and more specifically it details special provision relating to fishing for certain marine organisms. These include in Article 25 "restrictions on fishing for shrimps to protect flat fish".

Named decapod species that are included within the Directive, in particular concerning minimum size constraints are: *Maja squinado, Pandalus borealis, Parapenarus longirostris, Nephrops norvegicus, Homarus gammarus, Palinurus spp., Palaemon adspersus, Aristeus antennatus, Aristeomorpha foliacea, Crangon crangon, Cancer pagarus, Palaemon spp*.

Council Regulation 894/97 laying down certain technical measures for the conservation of fishery resources

This regulation replaces the previous primary regulation enacted in 1986 which had been amended approximately 20 times[16]. It applies to the taking and landing of fishery resources occurring in all maritime waters in Member States (for exceptions see article 1), and details the net sizes and the conditions in which they can be used to ensure species are protected. Further this regulation prescribes the minimum size of crustaceans, and specifically the decapod species of *Pandalus borealis, Cancer pagarus, Nephrops norvegicus, and Pandalus montagui*.

Further provisions include the granting of powers to the Commission and Member States to take action where the conservation of certain species is compromised, for example through the use of quotas or moratoriums on the species harvest.

Commission Regulations (EEC) No 3718/1985, No 3717/1985, No 3716/1985, No 3715/1985, and No 3531/1985 laying down certain technical and control measures relating to the fishing activities of the specified vessels[17].

These regulations detail technical and control measures for specific areas and fleets for Spain and Portugal. These measures are adopted without prejudice to EC Regulations concerning the technical measures for the conservation of fishery resources, however, they do highlight

[14] Article 1
[15] Articles 17-19
[16] Council Regulation (EEC) No 3094/86 of 7 October 1986 laying down certain technical measures for the conservation of fishery resources
[17] Commission Regulation (EEC) No 3718/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Portuguese waters of vessels flying the flag of Spain; Commission Regulations (EEC) No 3717/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Spanish waters of vessels flying the flag of Portugal; Commission Regulation (EEC) No 3716/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Spanish waters of vessels flying the flag of another Member State; Commission Regulation (EEC) No 3715/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities of vessels flying the flag of Portugal in the waters of other Member States except Spain; and Commission Regulation (EEC) No 3531/1985 of 12 December 1985 laying down certain technical and control measures relating to the fishing activities of vessels flying the flag of Spain in the waters of the other Member States, except Portugal.

the historical situation concerning the accession of these two countries to the European Union in 1985[18].

> *Council Regulation (EC) No 2341/2002 of 20 December 2002 fixing for 2003 the fishing opportunities and associated conditions for certain fish stocks, applicable in Community waters and, for Community vessels, in waters where limitations in catch are required.*

The regulation fixes for 2003, for certain fish stocks and groups of fish stocks, fishing opportunities, and the specific conditions under which these fishing opportunities maybe utilised. It should be noted that this regulation allows for the year to year management of fish stocks and will be revised after the 2003 period.

Within the regulations introduced the technical measures are generally defined by specified geographical areas and include the use of minimum net mesh sizes, the use of selective fishing gear, and closed areas and seasons. Their use is aimed at reducing the catches of younger fish, reducing by-catches in mixed fisheries and ensuring that the number of discards is limited. The extent of technical measures is widening and increasingly their use is concerned with the overall ecosystem effects with measures not only concerning the target species of that fishery but also the by-catch.

Habitat and Nature Conservation
Conservation, as discussed above, refers primarily to the conservation of the fishery resource, and specifically the target species, itself. However, increasingly the conservation of the non-target species and the marine habitat itself are set at a higher priority. General conservation legislation is therefore important in outlining specific conservation objectives and offering statutory powers for these to be met. At the EU level the primary conservation law of relevance is the Habitats Directive, however regional measures are also in existence.

Habitats Directive (92/43/EEC) and 97/62/EC (adapting to scientific and technical progress)

The Habitats Directive was enacted in order to provide overall habitat protection within the Member States of the European Union. It was arguably driven by the Convention on Biological Diversity, but more notably it meets the EU's requirements as regards the Berne Convention[19]. In order to achieve habitat protection there are some measures of importance to the protection of individual animal and plant species where they are included in the annexes to the Directive.

Decapod species are discussed both generally in the Directive, but also specific species. The order Decapoda is included in Annex II of the Habitats Directive which designates "animal and plant species of community interest whose conservation required the designation of Special Areas of Conservation (SACs)".

More specifically the species *Scyllarides latus* is included within the list of species in Annex V of the Directive detailing the "(A)nimal and plant species of Community Interest whose taking in the wild and exploitation maybe subject to management measures". Further under Article 15 it is stated that "(I)n respect of the capture or killing of species of wild fauna listed in Annex V(a)…, Member States shall prohibit the use of all indiscriminate means capable of causing local disappearance of, or serious disturbance to, populations of such species". This requirement therefore puts the onus on the sustainable management of decapod fisheries.

[18] Iberian Act of Accession (Articles 154-166 and 346-353)
[19] See earlier discussion of the Convention on Biological Diversity and the Berne Convention.

However, whilst the identification of specific species is important, the general requirement for the demarcation of SAC's equally will impact on the management of decapod fisheries with specific conservation objectives to be implemented. Currently a number of sites are proposed for SAC's, including marine sites[20]. To date almost all marine SACs are proposed for inshore waters (<12nm). A landmark decision taken under the revised CFPs emergency powers to declare the Darwin Mounds as a protected area sets precedent for the extension of SACs into offshore waters.

Protocol Concerning specially protected areas and biological diversity in the Mediterranean, 1995

This protocol was passed in order to provide for the designation of a list of specially protected areas of Mediterranean importance (SPAMI list), and for the protection and conservation of species (Part III). It is a regional measure applying to the Mediterranean Sea area only.

Under this protocol the exploitation of certain species is regulated, and notably the decapod species of *Maja squinado, Homarus gammarus, Scyllarides latus,* and *Scyllarus arctus* are included. The parties to the Convention are therefore required to authorise and regulate the exploitation of these species, so as to ensure and maintain their favourable state of conservation.

Common Organisation of the Market in Fishery and Aquaculture Products

Council Regulation (EC) No 104/2000 of 17 December 1999 on the common organization of the markets in fishery and aquaculture products

Under Articles 39-43 of the EC Treaty the establishment of a common organisation of the market for fishery products was required, in order to ensure a reasonable income to the producers and stable supplies to the consumers. Initially the common organization of the markets was implemented through the adoption of Council Regulation No. (EC) 2142/70, however, this has subsequently been revised and updated to take into account market developments and changes in fishing activity. Currently regulation establishes a common organisation of markets in fishery products which comprises a price and trading system, and also common rules on competition.

The regulation refers to crustaceans (to include decapods) but also provides specific measures for the following species: Crangon crangon; Pandalus borealis; Cancer pagarus; and Nephrops norvegicus. These are listed in Annex I to the Regulations with specific requirements attached. These include the need for producer organisations to draw up operational programmes for the listed species including a marketing strategy, a catch plan, and penalties for infringements (Art. 9).

Within the market organisation five components can be identified: common marketing standards; consumer information; producer organisations; a price support system based on intervention; and arrangements for trade with third countries. Implementing measures that are applied to the decapod crustacean fisheries include the regulations governing marketing standards detailed below.

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[20] The number of proposed sites and their current status is shown on the "Natura Barometer" from the European Commission:
http://europa.eu.int/comm/environment/nature/barometer/barometer.htm.

Council Regulation (EC) No 2406/1996 of 26 November 1996 laying down common marketing standards for certain fishery products; and its amendments Council Regulation (EC) No 2578/2000.

This Regulations sets out for certain fishery products, the common marketing standards. The specific products are detailed in Article 3 of the Regulation and include: Crangon crangon, Pandalus borealis, Cancer pagarus and Nephrops norvegicus. The marketing standards are to comprise both freshness categories and size categories. The freshness categories are detailed in Articles 4-6 and in Annex I to the Regulations. The size categories are found in Articles 7-10 and in Annex II.

Commission Regulation (EEC) No 3863/1991 of 16 December 1991 determining a minimum marketing size for crabs applicable in certain coastal areas of the United Kingdom.

This is a regional measure applicable to parts of the United Kingdom specifying the minimum marketing size of crabs (*Cancer pagarus*) for specific coastal areas.

Directive 91/67/EEC concerning the animal health conditions governing the placing on the market of aquaculture animals and products; and amending Directive 93/54/EEC.

This Directive controls animal health and the movement of shellfish in order to prevent the spread of disease. When shellfish are to be introduced into an approved zone they must be accompanied by a ‘movement document’, certifying that they originate from a zone of the same health status, from an approved farm in a non-approved zone or from a farm which may be situated in a non-approved zone, on condition that such a farm contains no susceptible species and is not connected to a watercourse, coastal or estuarial waters.

This Directive is not species specific but discusses measures to be taken for all “fish, crustaceans and molluscs”.

In summary, fisheries products (including decapod crustacean species) may be sold or marketed only if they satisfy marketing standards covering classification by quality, size or weight categories, packaging, presentation and labelling. The onus is on the individual Member States to ensure compliance is met.

Other Regulations

In addition to the three categories discussed above there are some other regulations that fall outside these including aspects of data collection requirements in the fisheries sector, fishing permits and the management of fishing effort. These regulations, along with those discussed in more detail are found in Tables 1 and 2 in the Annex, detailing the selected species and the keywords for these legislative provisions.

Summary

The above has provided an overview of the laws and regulations that may apply to decapod crustacean fisheries. These comprise the generic provisions, for example international obligations, and the Habitats Directive at EU level, but additionally include measures that are applied purposely to the fisheries industry with certain decapod species being specified.

Where this is the case the measures detailed are often applied within certain geographic boundaries. A further distinction to be made is between the different aspects of the industry that is regulated. This is self evident through the organisation of this overview with the primary aspects being technical conservation measures, habitat and nature conservation and the common organisation of the markets; the first and latter of these being requirements under the Common Fisheries Policy.

In conclusion, the framework provided by European and International regulations is quite complex, a factor true for finfish as much as crustacean fisheries, addressing various factors through numerous legislative enactments. Whilst the Common Fisheries Policy has moved some way to provide an umbrella to include all the provisions there are some notable exceptions, which include *inter alia* proper coverage for the nature and habitat conservation and other environmental requirements. These issues were discussed in the Green Paper on the future of the Common Fisheries Policy[21]. There is now increasing emphasis within the CFP for multi-annual management plans and ecosystem approaches to fisheries.

[21] European Commission (2001). Green Paper: The future of the common fisheries policy. Volumes 1 and 2

Table 1. European legislation for selected decapod species. Note : where no species are selected it applies generally to crustacean/decapod fisheries

Reference	**Legislation**	**Maja squinado**	**Pandalus Borealis**	**Parapenaeus longirostris**	**Cancer Pagurus**	**Nephrops norvegicus**	**Homarus gammarus**	**Palinurus spp**	**Palaemon adspersus**	**Palaemon spp**	**Aristeus antennatus**	**Aristeomorpha foliacea**	**Crangon Crangon**	**Scyllarides latus**	**Scyllarus arctus**
P1995 0610	Protocol concerning specially protected areas and biological diversity in the Mediterranean, 1995/06/10, Official Journal L 322 , 14/12/1999 p. 0003 - 0017													*	*
CR2002 2341	Council Regulation (EC) No 2341/2002 of 20 December 2002 fixing for 2003 the fishing opportunities and associated conditions for certain fish stocks, applicable in Community waters and, for Community vessels, in waters where limitations in catch are required.		*												
CR2001 1639	Commission Regulation (EC) No 1639/2001 of 25 July 2001 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000		*			*									
CR2001 0724	Council Regulation (EC) No 724/2001 of 4 April 2001 amending Regulation (EC) no 850/1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms				*					*					
CR2000 2578	Council Regulation (EC) No 2578/2000 of 17 November 2000 amending Regulation (EC) No 2406/1996 laying down common marketing standards for certain fishery products														

CR2000 1298	Council Regulation (EC) No 1298/2000 of 8 June 2000 amending for the fifth time Regulation (EC) No 850/1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms							*							
CR2000 0104	Council Regulation (EC) No 104/2000 of 17 December 1999 on the common organisation of the markets in fishery and aquaculture products		*												
CR1999 1459	Council Regulation (EC) No 1459/1999 of 24 June 1999 amending Regulation (EC) No 850/1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms			*						*	*	*	*		
CR1998 0850	Council Regulation (EC) No 850/1998 of 30 March 1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms (And its amendments 724/2001, 1298/2000, 812/2000, 2723/1999, 1459/1999 and 308/1999)	*	*	*		*	*	*	*	*	*	*	*		
CR1997 0894	Council Regulation (EC) No 894/1997 of 29 April 1997 laying down certain technical measures for the conservation of fishery resources		*												
CR1996 2406	Council Regulation (EC) No 2406/1996 of 26 November 1996 laying down common marketing standards for certain fishery products		*		*	*							*		
CR1995 1340	Commission Regulation (EC) No 1340/1995 of 13 June 1995 amending Regulation (EC) No 3263/1994 fixing the standard values to be used in calculating the financial compensation and the advance pertaining thereto in respect of fishery products withdrawn from the market during the 1995 fishing year		*										*		

CR1995 685	Council Regulation (EC) No 685/95 of 27 March 1995 on the management of the fishing effort relating to certain Community fishing areas and resources														
CR1994 3264	Commission Regulation (EC) No 3264/1994 of 20 December 1994 fixing the amount of the carry-over aid for certain fishery products for the 1995 fishing year (Text with EEA relevance)				*										
CR1994 3237	Commission Regulation (EC) No 3237/1994 of 21 December 1994 laying down detailed rules for the application of the arrangements for access to waters as defined in the Act of Accession of Norway, Austria, Finland and Sweden		*			*							*		
CR1994 1627	Council Regulation (EC) No 1627/94 of 27 June 1994 laying down general provisions concerning special fishing permits														
CR1991 3863	Commission Regulation (EEC) No 3863/1991 of 16 December 1991 determining a minimum marketing size for crabs applicable in certain coastal areas of the United Kingdom				*	*							*		
CR1991 1382	Council Regulation (EEC) No 1382/1991 of 21 May 1991 on the submission of data on the landings of fishery products in Member States				*	*	*								
CR1985 3718	Commission Regulation (EEC) No 3718/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Portuguese waters of vessels flying the flag of Spain		*										*		

CR1985 3717	Commission Regulation (EEC) No 3717/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Spanish waters of vessels flying the flag of Portugal		*										*		
CR1985 3716	Commission Regulation (EEC) No 3716/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Spanish waters of vessels flying the flag of another Member State except Portugal		*										*		
CR1985 3715	Commission Regulation (EEC) No 3715/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities of vessels flying the flag of Portugal in the waters of the other Member States except Spain		*										*		
CR1985 3531	Commission Regulation (EEC) No 3531/1985 of 12 December 1985 laying down certain technical and control measures relating to the fishing activities of vessels flying the flag of Spain in the waters of the other Member States, except Portugal		*										*		
CR1983 0302	Commission Regulation (EEC) No 302/1983 of 2 February 1983 amending Regulation (EEC) No 2931/1981 suspending the customs duties applicable on import into the Community of Nine of certain agricultural products coming from Greece		*			*									
CD2001 0936	2001/936/EC: Commission Decision of 28 December 2001 derogating from Council Decision 2001/822/EC, as regards the rules for origin for prepared and preserved shrimps and prawns from Greenland (notified under do. No. C(2001) 4648		*												

CD1998 0746	1998/746/EC: Council Decision of 21 December 1998 concerning the approval, on behalf of the Community, of amendments to Appendices II and III to the Berne Convention on the conservation of European wildlife and natural habitats adopted at the 17th meeting of the Convention's Standing Committee	*					*	*						*	*
CD 1997 62	Council Directive 1997/62/EC of 27 October 1997 adapting to technical and scientific progress Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora														
CD1992 0043	Council Directive 1992/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora													*	
CD 1991 67	Council Directive 1991/67/EC concerning the animal health conditions governing the placing on the market of aquaculture animals and products: and amending Directive 93/54/EEC														

Table 2 European legislation and key words as they apply to particular species

Reference	Legislation	Keywords	Specified Species
P1995 0610	Protocol concerning specially protected areas and biological diversity in the Mediterranean, 1995/06/10, Official Journal L 322 , 14/12/1999 p. 0003 - 0017	*biodiversity, conservation of resources, protected area, protected species, EC Protocol, Mediterranean Sea.*	*Scyllarides latus, scyllarus arctus.*
CR2002 2341	Council Regulation (EC) No 2341/2002 of 20 December 2002 fixing for 2003 the fishing opportunities and associated conditions for certain fish stocks, applicable in Community waters and, for Community vessels, in waters where limitations in catch are required.	*fishing regulations; conservation of fish stocks; Community waters; Catch quota; third country*	*Pandalus borealis*
CR2001 1639	Commission Regulation (EC) No 1639/2001 of 25 July 2001 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000	*Community programme; data collection; fishing industry; common fisheries policy.*	*Pandalus borealis, Nephrops norvegicus, Penaeus spp.*
CR2001 0724	Council Regulation (EC) No 724/2001 of 4 April 2001 amending Regulation (EC) no 850/1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms	*conservation of fish stocks; fishing regulations; fishery resources; fishing net; fishing area; protection of animal life*	*Cancer pagarus, Palaemon spp., Pandalus montagui*
CR2000 2578	Council Regulation (EC) No 2578/2000 of 17 November 2000 amending Regulation (EC) No 2406/1996 laying down common marketing standards for certain fishery products	*fisheries product; fresh fish; marketing standard; product quality; European standard*	

CR2000 1298	Council Regulation (EC) No 1298/2000 of 8 June 2000 amending for the fifth time Regulation (EC) No 850/1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms	*conservation of fish stocks; fishery resources; fishing area, fishing net; fishing regulations; fishing rights*	*Palinurus spp.*
CR2000 0104	Council Regulation (EC) No 104/2000 of 17 December 1999 on the common organisation of the markets in fishery and aquaculture products	*aquaculture; common organization of markets; fisheries products*	*Pandalus borealis*
CR1999 1459	Council Regulation (EC) No 1459/1999 of 24 June 1999 amending Regulation (EC) No 850/1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms	*conservation of fish stocks; fishery resources; fishing area; fishing net; fishing regulations; protection of animal life*	*Parapenaeus longirostris, Palaemon spp., Aristeus, Pandalus montagui, Aristeomorpha foliacea, Crangon crangon*
CR1998 0850	Council Regulation (EC) No 850/1998 of 30 March 1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms (And its amendments 724/2001, 1298/2000, 812/2000, 2723/1999, 1459/1999 and 308/1999)	*conservation of fish stocks; fishery resources; fishing areas; fishing net; fishing regulations; protection of animal life*	*Maja squinado, Pandalus borealis, Parapenaeus longirostris, Nephrops norvegicus, Homarus gammarus, Pallnarus spp., Palaemon adspersus, Aristeus antennatus, Aristeomorpha foliacea, Crangon crangon*
CR1997 0894	Council Regulation (EC) No 894/1997 of 29 April 1997 laying down certain technical measures for the conservation of fishery resources	*conservation of fish stocks; conservation of resources; fishery management; fishing area; fishing regulations; EC countries*	*Pandalus borealis, Cancer pagarus, Nephrops norvegicus, Pandalus montagui*

CR1996 2406	Council Regulation (EC) No 2406/1996 of 26 November 1996 laying down common marketing standards for certain fishery products	*fisheries product; fresh fish; marketing standard; product quality; European standard*	*Pandalus borealis, Cancer pagarus, Nephrops norvegicus, Pandalus montagui, Crangon crangon*
CR1995 1340	Commission Regulation (EC) No 1340/1995 of 13 June 1995 amending Regulation (EC) No 3263/1994 fixing the standard values to be used in calculating the financial compensation and the advance pertaining thereto in respect of fishery products withdrawn from the market during the 1995 fishing year	*crustacean; fishery resource; market intervention; withdrawal from the market place; withdrawal price*	*Pandalus borealis, Crangon crangon*
CR1995 685	Council Regulation (EC) No 685/95 of 27 March 1995 on the management of the fishing effort relating to certain Community fishing areas and resources	*conservation of fish stocks, fisheries policy, fishery management, fishery resources, fishing area*	
CR1994 3254	Commission Regulation (EC) No 3264/1994 of 20 December 1994 fixing the amount of the carry-over aid for certain fishery products for the 1995 fishing year (Text with EEA relevance)		
CR1994 3237	Commission Regulation (EC) No 3237/1994 of 21 December 1994 laying down detailed rules for the application of the arrangements for access to waters as defined in the Act of Accession of Norway, Austria, Finland and Sweden	*enlargement of the community; fishing area; fishing licence; fishing regulations; fishing rights; fishing vessel*	*Pandalus borealis, Nephrops norvegicus, Crangon crangon*
CR1994 1627	Council Regulation (EC) No 1627/94 of 27 June 1994 laying down general provisions concerning special fishing permits	*fishery management, fishing licence, fishing permit, third country, EC countries, information transfer*	

CR1991 3863	Commission Regulation (EEC) No 3863/1991 of 16 December 1991 determining a minimum marketing size for crabs applicable in certain coastal areas of the United Kingdom	*crustacean; United Kingdom; coastal region; marketing standard*	*Cancer pagarus,Nephrops norvegicus, Crangon crangon*
CR1991 1382	Council Regulation (EEC) No 1382/1991 of 21 May 1991 on the submission of data on the landings of fishery products in Member States	*fisheries product; quantity of fish landed; Community statistics; EC countries*	*Cancer pagarus, Nephrops norvegicus, Hommarus gammarus*
CR1985 3718	Commission Regulation (EEC) No 3718/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Portuguese waters of vessels flying the flag of Spain	*Spain; Portugal; fishing controls; common fisheries policy; fishing regulations; fishing permit*	*Pandalus borealis, Crangon crangon*
CR1985 3717	Commission Regulation (EEC) No 3717/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Spanish waters of vessels flying the flag of Portugal	*fishing permit; Portugal; fishing controls; fishing regulations; Spain; common fisheries policy*	*Pandalus borealis, Crangon crangon*
CR1985 3716	Commission Regulation (EEC) No 3716/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities in Spanish waters of vessels flying the flag of another Member State except Portugal	*Atlantic Ocean; Spain; common fisheries policy; fishing permit; fishing controls; fishing regulations*	*Pandalus borealis, Crangon crangon*
CR1985 3715	Commission Regulation (EEC) No 3715/1985 of 27 December 1985 laying down certain technical and control measures relating to the fishing activities of vessels flying the flag of Portugal in the waters of the other Member States except Spain	*ship's flag; Portugal; authorised catch; Spain; fishing controls; accession to the Community*	*Pandalus borealis, Crangon crangon*

CR1985 3531	Commission Regulation (EEC) No 3531/1985 of 12 December 1985 laying down certain technical and control measures relating to the fishing activities of vessels flying the flag of Spain in the waters of the other Member States, except Portugal	*fisheries regulations; ship's flag; Spain; fishing rights; fishing licence; common fisheries policy*	*Pandalus borealis, Crangon crangon*
CR1983 0302	Commission Regulation (EEC) No 302/1983 of 2 February 1983 amending Regulation (EEC) No 2931/1981 suspending the customs duties applicable on import into the Community of Nine of certain agricultural products coming from Greece	*suspension of customs duties; Greece; accession to the community; agricultural product*	*Pandalus borealis, Nephrops norvegicus,*
CD2001 0936	2001/936/EC: Commission Decision of 28 December 2001 derogating from Council Decision 2001/822/EC, as regards the rules for origin for prepared and preserved shrimps and prawns from Greenland (notified under do. No. C(2001) 4648	*derogation from Community law; originating product; Greenland; crustacean; prepared foodstuff; food preserving*	*Pandalus borealis*
CD1998 0746	1998/746/EC: Council Decision of 21 December 1998 concerning the approval, on behalf of the Community, of amendments to Appendices II and III to the Berne Convention on the conservation of European wildlife and natural habitats adopted at the 17th meeting of the Convention's Standing Committee	*environmental protection; protected species; protection of animal life; protection of plant life; wildlife; European convention*	*Maja squinado, Palinurus spp.,Scyllarides latus, Scyllarus arctus*
CD1997 62	Council Directive 1997/62/EC of 27 October 1997 adapting to technical and scientific progress Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora	*environmental protection; protected area; protection of animal life; protection of plant life; technological change, wildlife*	

CD1992 0043	Council Directive 1992/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora	*wildlife; protected species; environmental protection; protection of animal life; protection of plant life; protected area*	*Scyllarides latus*
CD1991 67	Council Directive 1991/67/EC concerning the animal health conditions governing the placing on the market of aquaculture animals and products: and its amending Directive 93/54/EEC	*marketing; prevention of disease; fish product; aquaculture; transport document*	

Table 3. International obligations

Year	Title	Coverage
1982	UNITED NATIONS CONVENTION ON THE LAW OF THE SEA (UNCLOS)	Global
1995	UNITED NATIONS FISH STOCKS AGREEMENT	Global
1995	UNITED NATIONS FOOD AND AGRICULTURAL ORGANISATIONS'S CODE OF CONDUCT FOR RESPONSIBLE FISHERIES	Global
1949	AGREEMENT FOR THE ESTABLISHMENT OF A GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN (as amended 1997)	Regional
1979	BERNE CONVENTION ON THE CONSERVATION OF EUROPEAN WILDLIFE AND NATURAL HABITATS	Regional
1992	UNITED NATIONS CONVENTION ON BIOLOGICAL DIVERSITY	Global

5. Squaring the circle of crustacean fisheries management: some institutional issues relating to regionalisation

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Abstract

The spatial structures of commercial crustacean stocks appear to set somewhat different requirements for their assessment and management than those commonly associated with other fisheries. In particular, there is a strong theoretical argument for separating strategic management at the regional (metapopulation) level from detailed regulation at the local (sub-population) level. To some extent this argument is overtaken by several new developments affecting fisheries management in general – namely the concepts of regionalisation, good governance and integrated management which have come to the fore in debates concerning the reform of the CFP. This presentation will examine the relevance of such concepts to crustacean management. It asks questions about the appropriate scales of crustacean management and how to ensure effective co-ordination between the different levels; it examines how concepts of co-management and good governance might work out in practice; and it explores the implications of integrated management and the emergence of an ecosystem based approach to fisheries management.

Introduction

From the outset of EDFAM, attention has been drawn to the different spatial structures of commercial shellfish stocks which appear to set the requirements for crustacean fisheries apart from most other forms of fisheries management. Although the strong persistent spatial structures associated with most crustacean populations are instrumental in the search for new and more appropriate stock assessment models and in arguing for distinctive management approaches, the concept of crustacean fisheries is a misleading and potentially dangerous one. For a variety of reasons summarised in Orensanz and Jamieson (1998), stock assessment tools developed for fin fish are no appropriate for the analysis of invertebrate populations. But nor is there a unique systems of assessment and management applicable to all crustacean stocks. The very diversity of key behavioural characteristics, spatial distributions and fishing patterns makes generalisations about their management requirements difficult and dangerous. While in the past very many different forms of management have evolved to take account of this diversity especially in inshore waters, the tendency throughout much of the second half of the 20th century has been for a greater centralisation and standardisation of management systems which have left them less sensitive to variations in both species behaviour and fishing patterns.

Most recently, however, there has been something of a backlash to these ‘monolithic’ and ‘bureaucratic’ forms of management, initially through the advocacy of co-management (the sharing of responsibilities for management between government and the fishing industry) and latterly in the pursuit of good governance. As a result, much closer attention is now being paid to the ways in which management decisions are being formulated and implemented. According to Phillipson (2002:54) “the focus is on getting the procedures right which is seen to be just as, if not more, important as making appropriate selections of regulatory instruments”. Again, it may be relatively easy to generalise about what constitutes good governance in theory – transparency, stakeholder participation, subsidiarity, replacing the role of central organisations by integrated networks of individuals and local organisations, democratic accountability…- but it is much more difficult to translate such noble aspirations into real world constructs capable of dealing with resource management issues where scientific uncertainty and idiosyncratic human behaviour abound.

Even more recently the pleas for co-management and good governance have been joined by the demand for regionalisation of fisheries management within Europe. Regionalisation is seen not only as a framework for co-management with regional advisory councils considered as appropriate for a for the accommodation of stakeholder views (Commission, 2002a) but also as a means of promoting the closer integration of concerns for environmental protection within fishing management. But once again, we are dealing with an imprecise term of indeterminate scale. When used in reference to fisheries management it can man anything from a major division of the oceans – the North East Atlantic Fisheries Commission (NEAFC) and the North Atlantic Fisheries Organisation (NAFO) are 'regional organisation' – to relatively small areas such as those administered by Sea Fisheries Committees in England and Wales. So when Tully (2000) insists that lobster management structures should be regional rather than local in scale, what precisely does he mean ?. By inference, in the case of Irish lobster fisheries it is that management should be conducted at a scale larger than that of most existing lobster co-operatives. Whereas, when the argument is made for the establishment of regional management organisations to assist the decentralisation of the CFP, what is implied is something a good deal smaller than the 'common pond' stretching through 30^{o} of latitude, preferably characterised by some formal or functional unifying characteristics. The term 'regional sea' (the Baltic, North or Irish Sea) is sometimes loosely used as a correlate of a large or medium scale marine ecosystem.

The aim of this paper is to explore the ways of facilitating the basic requirements for the effective management of crustacean fisheries through 'institutional arrangements' which conform to the principles of good governance. It focuses on three key issues :

- How to ensure coordination between the different scales and functions of crustacean management as between stock conservation at the metapopulation scale and resource allocation, harvesting and marketing strategies at the local scale;
- How to optimise the internal structures of the management organisations; and
- How to manage the changing emphasis in fisheries management from its present relatively simple preoccupation with stock assessment and conservation to the broader concerns for the sustainability of the marine ecosystems within which commercially exploited crustacean fish stocks exist.

Existing systems of management

Throughout much of Europe the management of inshore fisheries remains, surprisingly, a somewhat neglected area. Vestiges of traditional management systems survive, especially in the western Mediterranean with the Prud'hommie in France and the Cofradia in Spain. But these hold to essentially conservative organisational forms, linked principally to notions of local social justice through close attention to the allocation of fishing rights, and are unable to cope effectively with the challenges of modernisation (Frangoudes, 1999; Alegret, 1999). Elsewhere responsibility for inshore management rests largely with central government with little by way of either delegation of responsibilities to local or regional organisations or close consultation with local fishing interests.

Just occasionally this patterns is interrupted by more comprehensive systems of 'regional'management backed by statutory authority which successfully combine the functions of stock conservation with control of access to the resource. The most notable of these exceptions are the Sea Fisheries Committees (SFCs) in England and Wales – discussed in greater detail later in the paper – and the *Comites de Peche* (CPs) in France. The latter are more bureaucratic and hierarchical in structure, lacking the degree of autonomy that distinguishes SFCs as well as their independent enforcement capability (see Phillipson and Thom, 2001 for a detailed comparison of the two types of inshore management system). Otherwise, locally based management, as in the case of the shellfish co-operatives in Ireland, tend to become concerned with defining local rules for engagement in fishing activity designed largely to regulate access to the fishery and to improve marketing of the members catches. Except where they have become involved with schemes for v-notching of lobsters for example, these local organisations make little direct input into conservation of stocks.

The generally weak level of development of structures for inshore fisheries management throughout much of Europe might seem to imply that the burden of responsibility for crustacean management should fall principally on the European Community and the individual member state. However, the widespread but not wholly accurate assumption that crustacean fisheries are largely confined to inshore waters – that is within the 12 nm limits – has led to an abrogation of responsibility for detailed management of most crustacean fisheries on the part of the European Commission. With the exception of *Nephrops* and *Pandalus*, managed as pressure stocks through licencing, TACs and quotas and gear regulation, almost all other crustacean fisheries area at the European level subject merely to minimum landing size (MLS) restrictions. Even in those member states where there are no statutory regional management organisations, national strategies for stock conservation rarely venture beyond varying the EC norms for MLS. With the absence of local or regional management structures there is all too often a dearth of reliable data on harvesting rates etc and little information on the need for regionally specific management measures.

Regionalisation : a question of scale ?

Several questions need to be answered in deciding whether, and in what form, to develop a regional management system for crustacean fisheries. Principal among these are issues relating to the functions of regional and local management; the appropriate scales at which these should be conducted; and whether to posit the creation of separate management organisations dedicated to shellfish (or more specifically crustacean) fisheries or to rely on other organisations with a remit to manage the full range of capture fisheries.

The literature clearly distinguishes between the strategic functions of a large scale management authority essentially concerned with stock conservation and ecosystem sustainability, but with relatively few specific regulations decided at the macro-level, and the operational activities of much smaller, local management organisations charged with the implementation of conservation measures – possibly varied from the regional norm to suit local conditions – and the optimisation of fishing patterns (see Table 1). As the scale of management decreases, so the objectives of management will alter from a focus on resource conservation to the maximisation of the economic and social benefits of the fishery through harvesting and marketing plans. A distinction is thus drawn between management of the fish stocks and regulation of the fishery.

Table 1. Comparisons of large (regional) and small (local) management of crustacean fisheries

	Regional	**Local**
Basic advantages	Awareness of broader issues	Sensitivity to local conditions, issues and norms
	Harmonisation of policies	
Functions	Long term strategy of sustainable fisheries	
	Scientific stock assessments	
	Basic regulation of	Detailed regulation of fishing activity

	fishing activity - Fishing gear - MLS - Discard rules - Location of major refugia (MPAs)	- Daily catch limits - Variation of gear and MLS rules - Real time closure of fisheries - Allocation of fishing rights (fishing spots) - Proactive stock conservation (v-notching, hatcheries) - Marketing plans - Negotiation with other users of the marine space

However, the literature is much less forthcoming in describing the precise geographic connotations of 'large' and 'small' scale management authorities – and for very good reasons. What is abundantly obvious is that no one scale of management works equally well for all species. Orensanz and Jamieson (1998) make the simple point that different types of fisheries pelagic, demersal and shellfish – will tend to have their management scales determined in the first instance by the geographical distributions of the stocks, and by the mobility of the species. The same is true when we consider shellfish as a separate concern – distinguishing between the sessile molluscan fisheries and the more mobile crustacean fisheries – and again with the crustacean fisheries between shrimp and *Nephrops* with comparatively large territories, on the one hand, and the more localised crab and lobster, on the other. Indeed the question arises as to whether the geographical distributions of crustacean populations are supra- or sub-national in scale. In many parts of the world, it would be reasonable to argue that management strategies for the majority of crustacean species could be contained within national maritime boundaries (European Economic Zones, EEZ). However, because of the peculiarity of the EC where the fishing zones of member states beyond the 12 nm limits have been merged into a single 'common pond' to which vessels from any member state have rights of access, it is extremely doubtful whether national or sub-national forms of regional management could sufficiently encompass the metapopulation distributions of crustaceans such as *Cancer* or *Nephrops* but may do so in the case of *Homarus* and *Palaemon*.

There can be no easy answers to the question of the appropriate scale of management for crustacean fisheries beyond reasserting the need for strategic regional management to be complemented by detailed regulation of fishing activity at the local level. The interplay of several different factors relating to the biological parameters of the stocks involved, patterns of fishing activity and the prevailing forms and practice of fisheries management in the countries concerned will determine specific solutions. No one simple model can satisfy all circumstances. One can perhaps risk a simple conclusion : with the move towards more integrated management of marine resources (see below), it seems highly unlikely that a separate regional organisation dedicated solely to crustacean management can be justified. This would not, of course, rule out the servicing of regional management organisations by expert sub-committees. Indeed, even at the local level, where shellfish co-operatives have flourished in a number of countries, the trend today is for generic rather than specific forms of management.

Perhaps the real issue is not the scale of the management organisation *per se*, but the need to ensure effective coordination of management decisions taken within the system as a whole; coordination vertically between regional and local levels and horizontally between neighbouring organisations. Coordination implies much more than the harmonisation of rules. It requires a clear division of responsibilities between the different levels of management, maintaining good lines of communication and the development of mutual respect and trust. Whether these essential ingredients are best achieved through a 'federal' model building upwards from local organisations or the more familiar delegation of responsibility throughout a hierarchy of structures remains a moot point.

Co-management : a question of structures

Whatever the choice of scale for crustacean management, it is important that the organisational structures conform to the principles of good governance outlined in the introduction. As a precursor of good governance, co-management looked to achieve two objectives : first, the delegation of certain responsibilities for the implementaion of policy (as in the deployment of producer organisations in the UK to deliver sectoral quota management for demersal pressure stocks); and, secondly the direct involvement of user groups in the decision making process, usually in an advisory rather than executive capacity. The incorporation of user groups within the policy community completed the cadre of professional elite (administration, the scientific establishment and commercial fishing interests) considered essential to effective policy making. It was expected that co-management would lead to a more open, transparent and less hierarchical management system; broaden the basis of information and knowledge on which policy decisions were made; increase the legitimacy of the policy process and so generate commitment and compliance on the part of the user groups (Symes and Phillipson, 1999). There was also an expectation in some quarters that co-management might provide the basis for cost sharing in relation to stock assessment and management (seen Orensanz and Jamieson, 1998:452).

Even in a rather elemental form, co-management remains quite a rare phenomenon. One remarkable exception – Sea Fisheries Committees in England and Wales – predates the theoretical exposition of co-management in the 1980s by almost a century. Developed initially in the 1880s, the 12 SFCs have acquired considerable executive authority for the management of inshore fisheries within the 6 nm limits, with byelaw making powers for fisheries and environmental conservation backed by an independent enforcement capability. Membership of the committees is divided equally between elected representatives of the local authorities which fund the SFC and local stakeholder interests, principally drawn from the commercial fishing industry, appointed by the central government fisheries department (DEFRA). There is, however, no place reserved for fisheries scientists, though some of the larger and better endowed SFCs have their own limited capacity for stock assessments and other scientific research.

The system works remarkably well (Symes 2002). There is little political interference on the part of central or local government: the unwritten rules of engagement ensure that the local authority members rarely involve themselves in technical discussions, while the industry representatives are usually content to leave budgetary matters to the local authority members. The presence of local authority representatives strengthens the democratic accountability of SFCs and helps to reinforce the local dimension of inshore management. Such a system will not work equally well in all countries – it will depend, for example, on the strength and nature of local government and the ability to fund inshore management from local revenues.

The composition of SFCs raises on important question, namely the means by which user group representatives are selected. In the case of SFCs their appointment by DEFRA does engender some suspicion within the industry that selection will be designed to rule out the more politically active members of the fishing community. On the other hand, the nomination of industry representatives by their own professional organisations risks making SFCs more overtly political and invites criticism that the chosen representatives will reflect sectoral or geographical constituency interests rather than the well being of inshore fishing as a whole.

Recently the emergence of notions of ‘good governance’ has been the broadening of the policy community to involve representation from ‘civil society’ including, for example, consumer affairs, marine nature conservation and recreational interests. Something of this trend has already impacted on the membership of the SFCs with seats now formally reserved for conservation interests and informally for recreational fishing interests – leading to concern on the part of the commercial fishing industry at the dilution of their representation. Civil society's role in fisheries management is difficult to define beyond that of 'public watchdog' : it widens the parameters of decision making., introduces a potentially disruptive influence and is perhaps only explained in the context of a shift towards a more holistic form of fisheries management. Moreover, it creates an immediate problem of how to accommodate a large and diverse range of interests in a single organisational structure and still permit it to reach clear, balanced decisions.

Integrated fisheries management : a question of emphasis

The widening of the policy community goes hand in hand with a broadening of the objectives of fisheries management. Integrated management implies a move away from a narrow preoccupation with the biological renewal of commercial fish stocks towards a more balanced set of aspirations in terms of economic and social goals, together with a deeper and more structured concern for the sustainability of the marine ecosystem in terms of its overall productivity, biodiversity and functional integrity. Logically, in prioritising the expanded range of objectives, sustainability of the marine ecosystem is likely to become the principal driver of fisheries management in the future.

An ecosystem based approach (EBA) has assumed several different guises – the integration of environmental protection requirements (Commission, 2001), responsible fisheries (FAO, 1994) – as well as more explicit references in both America and Europe. (NMFS, 1999;Commission, 2002b). But, as yet, EBA is in its infancy ; it has few practical applications to date, though the aspirations to develop a scientific basis for the implementation of EBA have been summarised in Pope and Symes (2000). The details need not concern us here, except to stress that EBA seeks to place fisheries management much more firmly in the context of ecosystem sustainability. The starting point is to focus attention on 'essential habitats' and extend the principles of precautionary management, recently developed for a limited range of demersal fish stocks, to all key predator and prey species within the ecosystem.

Expressions of concern for the wider marine environment are sometimes seen by the fishing industry as threatening to limit still further the opportunities for fishermen to exploit the natural resources of the oceans. This is not necessarily the case.

Balancing fishing capacity and resource potential will be an important first stage in the move towards EBA, just as it will be in strategies to put commercial fisheries on a sounder footing. Thereafter, fishing effort will be kept in check by much the same instruments as in present management schemes though with a shift in emphasis from outputs to input restrictions and technical conservation measures. One instrument likely to gain in importance is the introduction of permanent refugia in the form of marine protected areas or to take zones to conserve essential habitat and safeguard vital life cycle stages for key commercial and non commercial species. Such measures already figure largely in the scientific literature concerning shellfish management (see Orensanz and Jamieson, 1998: 449-450) though not as yet in management practice.

Environmental concern is a two way process – both equally important for EBA. In the past, concern has tended to focus more on the impact of fishing activity upon the marine ecosystem (disturbance to benthic habitats and communities from bottom trawling); changes to the balance and size structures of species within the ecosystem; deliberate or accidental introductions of exotic species and genetic change *inter alia*). There is also considerable concern at the impacts of non-fishing activities on essential fish habitats and fishing opportunities (viz pollution, oil and gas developments, aggregate dredging, wind farms, recreational activities including diving etc). These tend to exert a greater influence on inshore waters and shellfisheries in particular; their control is therefore often central to the effective management of coastal fisheries. To a degree, EBA has been given added relevance by mounting concern over the consequences of environmental change (climate change, sea level rise, tidal regimes etc), which are of considerable significance to shallow water fisheries in particular. EBA must be both robust and flexible enough to accommodate the effects of long-term environmental regime shifts.

Already, inshore fisheries in England and Wales have begun to feel the effects of the new emphasis in fisheries management. The remit of the SFCs have been extended: they are now required to take full account of environmental issues in the enactment of byelaws and they have new powers to make byelaws specifically for environmental purposes. They now have environmental expertise available to them both on the management committee and increasingly among their fisheries officers. Moreover, they have become closely involved in local marine environmental management schemes and are widely consulted on a range of matters relating to non-fishing activities and environmental issues in the coastal zone (Symes, 2002).

The widening of the policy community through the involvement of both professional stakeholders and civil society interests should certainly assist the development of a more integrated approach to fisheries management. The presence of fishing industry representatives will ensure that economic and social objectives are kept firmly in view, while the incorporation of environmental interests should aid the development of EBA. It should be emphasised, however, that EBA must be rooted in 'good science' and in an expanding knowledge and understanding of the functioning of marine ecosystems, under pressure from human exploitation. Herein may lie EBA's 'Achilles heel'.

Conclusion

Although crustacean fisheries do not sit all that comfortably with management systems designed to deal mainly with finfish, it seems unlikely that separate regional organisations will be set up exclusively for crustacean management. Apart from the need to avoid adding unnecessarily to the raft of bureaucratic structures which threaten to engulf fisheries today – and which serve largely to diminish flexibility of response to changing circumstances within the industry it is unlikely that such organisations would work. Overall, the need is for closer coordination in the management of different groups of species rather than increasing specialisation and compartmentalism

The CFP reform agenda contains proposals for the creation of regional advisory councils (RACs) operating at the level of the regional seas. They are intended to bring together opinion from national (or regional) administrations., fisheries science and industry, together with other stakeholders interests, to advise the Commission and member states on matters relating to fisheries management. Essential to the discharge of their tasks will be effective two way flows of information between the RACs and organisations at EC, member state and local levels responsible for the formulation and implementation of management policy. In particular, the RACs may need to recruit specialist advice from expert working groups dealing with specific fisheries, including crustacea.

Probably the more urgent need is for the development of local management organisations, similar though not identical in form and function to SFCs in England and Wales, with responsibility for inshore fisheries (< 12 nm). By definition, these would encompass the detailed regulation of all crustacean fisheries occurring within inshore waters. The structure of such organisations should adhere closely to the principles of co-management and 'good governance' finding space for the representation not only of technical expertise but also marine nature conservation and recreational fishing interests on their management committees.

Crustacean fisheries are, by and large, innocent of many of the charges in relation to damage to the marine environment which are commonly laid against fishing in general. Where passive gears are deployed they exert few direct impacts on the ecosystems, though for certain fisheries (eg shrimps, *Nephrops*) where bottom trawls are used problems of by-catch and discards to occur. In general, however, crustacean fisheries have little to fear from the adoption of EBA. Indeed, if the sustainability of the marine ecosystem is placed high on the agenda of fisheries management, they have much to gain from a system which aims to rein in some of those marine activities which damage or disturb essential habitats within shallow inshore waters.

The paper has touched upon a number of current issues affecting institutional arrangements for fisheries management in general. It may not always be clear precisely in what ways these will impact on crustacean fisheries management in particular. What is assured is that crustacean fisheries will eventually be caught up in these developments to a greater or lesser extent. Early consideration of the issues raised ma help to define the patch to more effective crustacean management.

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6. The management of crab, lobster and shrimp fisheries in northern Europe

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Abstract

Crab (*Cancer pagurus*), lobster (*Homarus gammarus*) and shrimp (*Paleamon serratus*) are socially and economically important fisheries in northern Europe (Ireland, UK and France). All 3 species are fished with traps. The population structure is open on a regional or international scale in the case of crab indicating that management needs to account for local stakeholders and industrial fleets in the same system and cross national boundaries. Lobsters may be distributed as a metapopulation with some connectivity between stocks in coastal regions within countries. This largely depends on larval drift rather than adult movements. There is some variability in biological characteristics of adults on a regional (10s of kms) scale. Current spawning stock at less than 10% of virgin egg per recruit probably limits recruitment. Shrimp are distributed as local stocks and subject to periodic failure in recruitment due to unfavourable environmental conditions at the northern edge of their range in Ireland and Britain and due to local overfishing of spawning stock. Optimising yield per recruit is an important objective in this short lived species.

Regulations currently rely on minimum sizes and there is no capacity to limit input (fishing effort) or output (landings) from either fishery although crab and lobster are effort limited in northern France.

No stock assessments are routinely undertaken and in the medium term monitoring and management will need to rely on commercial catch rate data. These data need to be of high quality and standardised catch rate models need to be developed.

Introduction

Crustacean fisheries in northern Europe are by in large mixed fisheries in the sense that individual fleets target different species on a season basis. The regulatory framework usually relies on the use of minimum landing sizes (MLS) only. Current licencing policy does not generally restrict fishing effort or limit catches. In the absence of input or output controls fishing effort and mortality is determined more by economic and social conditions, market forces and short term changes in stock abundance than by the management system *per se*. The possibility of introducing integrated or co-ordinated management systems with stakeholder involvement for these fisheries is complicated by contrasts in biological characteristics, scales of distribution and migration and the profile of the fleets, which exploit these fisheries. This paper outlines some of these differences in the case of fisheries for *Cancer pagurus* (brown crab), *Homarus gammarus* (lobster) and *Palaemon serratus* (shrimp) in Ireland, UK and northern France and identifies the particular features and issues that need to be incorporated in the management system in order to link biological characteristics and higher level management policies with the details of how the management system is implemented.

Biological characteristics

The biological characteristics of larvae and adults that significantly influence population structure of the 3 species are outlined in Table 1.

Table 1. Distribution, settlement and migration patterns in crab, lobster and shrimp

Species	**Larvae duration**	**Larvae distribution**		**Settlement**	**Adults**		
		Vertical	**Horizontal**		**Distribution**	**Migrations**	
						Scale	**Function**
Cancer pagurus	30-50 days	0-100 m	coastal and shelf	coastal	coastal and shelf	100s of Km	larval release ?
Homarus gammarus	30-50 days	0-5 m, neustonic	coastal	shallow coast	coastal and patches offshore	<20 km	foraging movements
Paleamon serratus	30-50 days	0-5 m neustonic	coastal	intertidal	coastal < 80 m usually <20 m	10-20 km	avoidance of low temperatures

Distribution

Brown crab is distributed in coastal waters on hard and mixed sea bed types in the coastal zone of northern Europe from Norway to Spain. In addition it is abundant and is fished offshore to the edge of the continental shelf off north west Ireland and west of Scotland, in the Celtic Sea and the English Channel by Irish, UK and French fleets (Tully *et al* 2002)

Lobster is a coastal species exploited primarily within 5 km of the coast although offshore patches occur where ground is suitable (Tully 2001)

Shrimp is a shallow water coastal species most abundant at 0-10 m depth (Fahy and Gleeson 1996)

Migration

Brown crab undertake migrations of hundreds of kilometres. Many of the tagging studies in Ireland, UK and France have shown southwesterly movements of adults although more recently return (northeasterly) migrations have been detected in Irish stocks. The reasons for the migrations are unclear but may be linked to larval release.

Migration of lobster is restricted to foraging movements in the vicinity of it's lair. Occasionally larger scale movements of over 100 km have been reported (south east Ireland) although this was restricted to a few individuals among thousands of tag releases.

Shrimp occur in depths of 0-10 m in summer but migrate to deeper waters during autumns and winter at depths of 10-50 m. The extent of offshore distribution however is unknown. In Ireland fishing offshore in depths of up to 50 m increases in October-December following the migration of shrimp from coastal areas.

Larval biology and dispersal

All 3 species produce pelagic larvae with a duration of between 30-50 days depending on temperature. This is an important dispersal phase. Crab larvae are widely distributed on the continental shelf to depths of at least 60 m although their abundance increases towards the coast. Larvae of lobster and shrimp are primarily neustonic (sea surface) at least during the later larval stages. Onshore wind and tidal drift may therefore be important in limiting alongshore and offshore dispersal and in delivering larvae to the coastal strip where settlement occurs. Dispersal of larvae produced locally may therefore be limited in these two species. Lobster larvae do not tend to swim through thermoclines and may therefore fail to settle if they drift offshore. They have the ability to dive repeatedly in search of suitable substrate. This behaviour may further limit dispersal offshore. Crab is know to settle in gravel and cobble substrate in the coastal zone. Lobster probably also settles in the same areas (if similar to American lobster). Shrimp settle into intertidal areas in late summer and autumn.

Longevity
Crab and lobster are long lived although the actual age distribution of the populations are unknown. Lobster certainly live for over 20 years and maybe as long as 50-70 years. Shrimp are short lived and typically do not survive beyond the 3rd year.

Population structure

Crab: The population structure can be inferred to some degree from the known distribution of adults, larval biology and dispersal, settlement habitat and scales of migrations. Given that adult migrations are extensive and larvae are distributed widely over the continental shelf the population structure is open on a scale of 100s of kms. For example a single population probable exists from the mid west coast of Ireland, the Malin Shelf north to west of Scotland (Fig. 1). Crabs are known to migrate throughout this area and larvae occur throughout the Malin Shelf. High levels of connectivity therefore exist between crabs on the northern and southern edges of this range and especially on the main area of the Malin Shelf and west of Scotland. A second population can be identified on the south coast of Ireland extending into the Celtic Sea. Fishing occurs all along this area from Wexford on the south east coast of Ireland to the Shannon estuary on the south west (Fig 2). The degree to which this population may be connected to the stock in the English Channel and northern France is unknown. The scale of migrations observed off northern France and in the Channel suggests that the stocks in these areas are highly connected.

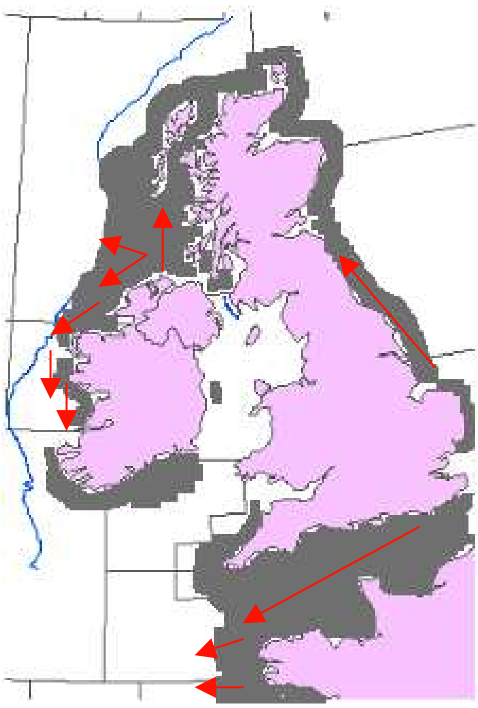

Fig. 1. *Main distribution of fishing (grey) for crab in Ireland, UK and northern France. Red lines indicate known directions and scales of adult migration. The ICES divisions and the 200m depth contour (blue line) is shown*

Lobster : Adult movements are small (<10 km) in scale and larval dispersal may be restricted by the larval distribution and strong swimming behaviour. In Ireland adult lobsters occur throughout the west, north and south coasts. The stock could be defined as a metapopulation in the sense that connectivity between adult stocks probably does exist but is nevertheless restricted. In other words there may neither be discrete local and isolated populations nor a single open population similar to crab. The connectivity between local stocks is somewhere between those extremes. Biological differences between coastal regions in Ireland and indeed UK and France in size at maturity and fecundity are relatively small although these characteristics are at least partially determined by environment are not necessarily indicative of genetically discrete stocks. Stocks are unlikely to straddle national boundaries and are primarily limited to coastal (<12 nm) waters. Larvae have not been recorded in waters distant from the coast and as described above their dispersal may be limited by onshore wind drift.

Shrimp : Adult migration seems to be restricted to relatively small scale offshore migrations in response to changes in sea water temperature in late autumn. The effect of larval behaviour and distribution on dispersal capacity may be similar to that of lobster. Onshore wind drift is probably very important is delivering larvae to the intertidal zone where settlement occurs. Adult distribution is discontinuous (Fig. 3). Stocks may therefore exist as relatively isolated local populations or have local levels of connectivity largely determined by larval rather than adult dispersal.

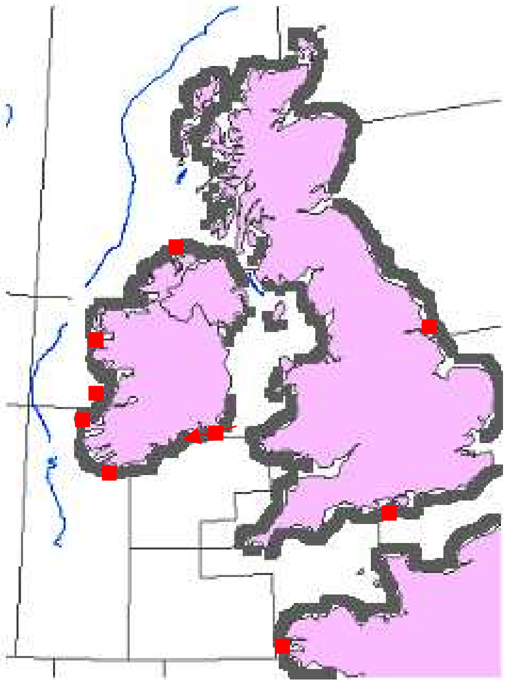

Fig. 2. Distribution of main fisheries for lobster in Ireland, UK and northern France. Red symbols indicate where tagging studies have been undertaken. No significant migrations have been identified. Some larger scale movements by individual lobsters (<0.5% of those recovered) have been identified as in the south east coast of Ireland.

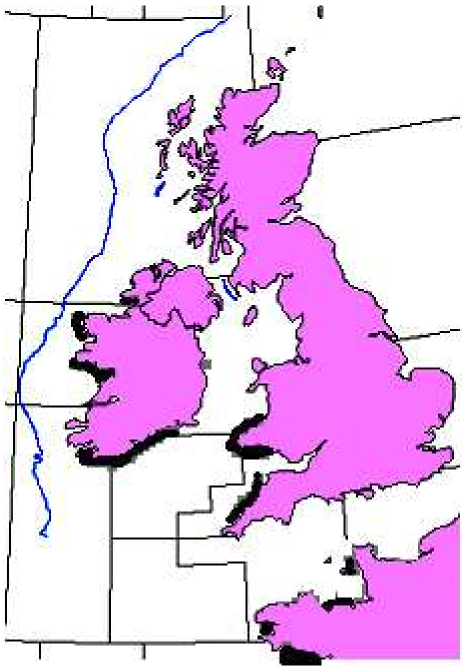

Fig. 3. Main distribution of fishing for shrimp in Ireland, UK and northern France.

Recruitment and prefishery abundance

Fisheries for lobster and crab are traditional and of long standing in northern Europe. Shrimp fishing in Ireland developed in the 1970s. Crab (Tully et al 2002) and lobster (Tully, 2001) fisheries are and have been relatively stable over the past 15 years although in the case of lobster catch rates are low. This stability suggests that recruitment in these species may not be highly variable. However variable growth rates in lobster and crab has a significant smoothing effect on recruitment to the fishery even if recruitment to earlier phases of the life cycle is variable. As it is not possible to identify individual cohorts in the population and no recruitment indices have been developed cohort strength cannot be measured.

Individual and population fecundity is higher in crab than in lobster or shrimp and larvae. Post settlement abundance is also relatively higher in crab (Robinson and Tully 2001) and shrimp than in lobster. In fact early benthic stages of lobster have never been recorded despite numerous surveys. In lobster recruitment and prefishery abundance is probably limited by larval supply given the low individual fecundity and population egg production. The densities of post-settlement stages of brown crab observed in Ireland suggest that post settlement processes such as cannibalism and predation limit recruitment. The same may be true of shrimp although post settlement mortality may be due to unfaviourable environmental conditions as well as predation. The intertidal environment is highly variable in temperature and salinity. Extremes of temperature and salinity experienced by shrimp in northern Europe impose specific physiological stress and this is more severe in smaller individuals and especially post larvae. This species is at it's northern limit in Ireland and UK and may therefore prone to periods of poor recruitment because of unfavourable conditions during settlement or over winter.

The above description (summarised in Table 2) indicates the level of stability that may be expected in these 3 fisheries and the importance of environmental conditions on pre fishery abundance. A number of biological features (variable growth, high larval production or highly developed larval behaviour) will increase stability in recruitment to fisheries in crab and lobster. Sensitivity to conditions in the intertidal environment and limited tolerance of environmental conditions at the extreme of its geographic distribution will decrease stability of recruitment in shrimp. These conclusions are supported by the experience of the fisheries and data on commercial catch rates.

Table 2. Recruitment stability and processes controlling pre fishery abundance in crab, lobster and shrimp in northern Europe

Species	**Settlement**		**Processes affecting pre-recruit abundance**		
	stability	**limiting factor**	**Larval distribution**	**Settlement**	**Juveniles**
Cancer pagurus	High	Advection to coast	ocean currents	advection to coast, suitable substrate	density dependent mortality
Homarus gammarus	Medium	Larval supply, spawning stock, onshore wind drift, temperature	onshore wind drift	diving behaviour for suitable substrate, thermocline important	suitable substrate
Paleamon serratus	Low	Larval supply, spawning stock, onshore wind drift, temperature	onshore wind drift	suitable intertidal habitat	temperature and salinity intertidally

The Fisheries

In northern Europe all 3 species are fished with traps. Edible crab is now one of the most important fisheries in Ireland, UK and France and is ranked in the top 3 fisheries in Ireland and England. Crab fisheries are particularly important in regions such as north west Ireland, west of Scotland, northern France, the English Channel, southern North Sea and in the Celtic Sea. The fishery is exploited by an artisanal fleet in the coastal zone out to 10-15 km. Offshore vessels > 20 m in length fish to the edge of the continental shelf in depths of 200 m. Catch rates are stable in all areas (Tully et al 2001). Although the number of vessels participating in this fishery is not increasing significantly the effort per vessel has increased substantially in the past 10 years in both inshore and offshore fleets. In addition higher vessel engine capacity may increase the number of traps that can be hauled per day.

Lobsters are fished by the artisanal fleets of Ireland, UK and France mainly in summer from May – September in coastal waters out to mainly 5 km. The fishery is socio-economically important in many coastal areas and is the mainstay of the small boat sector. The unit value of lobsters is approximately 10 times that of crab although the volume of the landings are approximately 7 times lower. Catch rates are quite low in most areas compared to historic levels egg per recruit is as low as 7% of unfished levels. Fishing effort per vessel is increasing in most areas. Fishing in offshore areas has increased in the UK in recent years. The implications for recruitment and for inshore lobster fishing of this new activity is unknown.

Shrimp are commercially important on the mid west and south coasts or Ireland, in south west Britain and in northern France. This species is exploited in late summer when juvenile shrimp have grown and recruited to the fishery. It is a highly accessible species to the small boat sector because it is most abundant in very shallow waters and coastal bays and inlets. Very little capital investment is required to participate in this fishery. Fishing effort increases quickly in response to good recruitment and the fishery is typically unstable. The relative importance of overfishing and environmental conditions on recruitment to the fishery is unknown. In Ireland the very high effort in some locations presumably causes significant depletion of local stocks. The unit value is similar to or higher than that of lobster although the volume of the landings in Ireland is approximately 3 times lower.

Table 3. Profile of crab, lobster and shrimp fisheries in northern Europe

Species	**Fishery in northern Europe**				**Fleet and fishery profile**		
	Stability	**Investment**	**Current position**	**Unit value**	**Vessel length**	**Trends in technology**	**Trends in fishery**
Cancer pagurus	High	High offshore	Stable	Low	< 12 m inshore, >24 m offshore	Faster vessels, GPS,	More activity offshore, gear increases per vessel
Homarus gammarus	High	Low-medium	Stable but low catch rates	High	< 12 m	Faster vessels, GPS	Gear increases per vessel
Paleamon serratus	Low	Low	Unstable and declining	High	Mainly < 7 m	None	Gear increases per vessel

Stock Assessments

Stock assessments are not carried out routinely for any of the 3 species in northern Europe. Occasionally yield per recruit or egg per recruit assessments have been undertaken (Tully 2001). Size at maturity is generally known. Data on growth and egg production is quite limited. No directed surveys are undertaken and no estimates of stock biomass are available. Catch rate data are collected in some areas. In north west Ireland a 13 year series of high quality catch rate data is available for the offshore crab fishery. Little data is available from inshore fisheries. Recent trials combining depletion methods with mark recapture methods in north west Ireland and in the North Sea were partially successful (Bell et al 2003) and various mark recapture models have been used to estimated standing stock in Ireland (Tully et al 2002). Size distribution of crab landings and discards are frequently collected but are generally not used in assessments. Lobster catch rate data is becoming increasingly available in Ireland and is routinely collected in the UK from index vessels. Shrimp data are generally not available.

The commercial catch rate data are not standardised for any of the three species and it is unclear how changes in catch rate actually reflect changes in the stock abundance. Commercial catch rate data is likely to be the main source of information on these fisheries in the medium term future. It will be important to increase the volume and quality of these data for future monitoring and to develop standardised catch rate models. Egg per recruit modelling is important in lobster where spawning stock is limited and should be used to formulate advice on technical conservation measures. Yield per recruit models are relevant to shrimp in order to protect against growth overfishing of juveniles in late summer. In all 3 species the development of recruitment indices would be useful in forecasting pre-fishery abundance and allowing the management system to adjust fishing effort. Given that commercial catch rates also lag 5-6 years behind recruitment in lobster and crab the use of a recruitment index combined with commercial catch rate data may prove to be a valuable approach to monitoring the fishery. This however is a long term objective.

Management : higher level policy

Crab, lobster and shrimp fisheries are very important in coastal communities in northern Europe and in absolute economic terms are becoming increasingly important relative to other fisheries. First order policy objectives for these fisheries should be to preserve or where possible enhance their socio-economic value. To achieve this the stocks need to be maintained at a level that is sufficient to enable small vessel operators with restricted and weather dependent access to the stocks to continue to achieve economic return from these fisheries.

Implementation of socio-economic policy objectives requires different approaches for each of the 3 species (Table 3). To conserve spawning stock it is important that additional regulations are introduced that allows fishing effort or landings to be controlled. The regulatory system needs to be strengthened. It is unlikely that harvest volumes can be sustainably increased in any of these fisheries and the emphasis may need to be on rationalising fishing effort and to restore spawning stock biomass where necessary. Emphasis should therefore be placed on optimising post-harvest value and economic return to fishers. There is particular potential to increase post harvest value in brown crab. Quality (meat content) varies significantly on a seasonal and geographic basis and affects post harvest survival and market value which has a knock on effect on the actual effort in the fishery. A proportion of the landings is generally of poor quality and may be dumped or used as bait in whelk fisheries. Significant local employment can be generated from crab fisheries if the catch is processed (meat extraction or other products such as pasteurised vacuum packed crab) rather than exported live. In this case stability of supply is important and can be guaranteed from the offshore larger boat fishery where crab quality also seems to be higher. Landings from coastal vessels are seasonal and weather dependent. It is important to characteris seasonal and geographic variability in quality and to develop methods for selection of higher quality of crab at sea. This can be promoted both by management and marketing policies. For instance individual vessel quotas would promote high grading of crab at sea if the market responded to higher quality. Such a policy could only be used rationally if it was possible to objectively select crab with high meat content at sea.

Management of interactions beteen fisheries is important in the case of crab-whelk and in seasonal switching to lobster which has a high unit value. Large volumes of crab are used in whelk fisheries which is a less than optimal use of the crab resource. These are usually poor quality crab or indeed undersized crab that should be discarded. Switching between fisheries and control of by-catch in other fisheries could be controlled by specific licencing policy

The value of lobster fisheries may be increased by using holding systems for long-term storage so as to avoid saturating the market during the peak season. The price differential between peak season and out of season can be 3 fold. Co-ops or fish merchants generally do not use systems that allow for long-term storage so they cannot adapt appropriately to the market supply and demand. Post-harvest value of shrimp may be increased by optimising sie at first capture, improvement in handling practices and development of live exports which achieve higher price on the market.

Table 4. Summary of policy objectives and issues relevant to the management of crab, lobster and shrimp in Ireland. See text for explanation

Species	**Policy objectives**					
	Conserve spawning stock	**Manage interactions with other fisheries**	**Maximise post-harvest value**	**Maintain current profile**	**Adding value**	**Enforcement of regulations**
Cancer pagurus	MLS and effort or quota control	Prohibit use as bait	Minimise handling and transport mortality	Traditional activity, new activity offshore	Promote on shore processing	International responsibility outside 12 miles
Homarus gammarus	MLS and effort control	Avoid switching behaviour	Market research, holding systems	Traditional activity + recreational	Niche marketing of live product	Regional authority
Paleamon serratus	Closed seasons	Monitor by-catch of juvenile lobster and crab	Optimise Y/R, minimise mortality	Traditional activity	Post harvest survival and live export	Local authority

Management : the regulatory framework

Crab, lobster and shrimp fisheries have traditionally been in open access although this situation is now changing. In France a licencing scheme operates for crab and lobster that also limits the amount of fishing gear each vessel can use. In the UK restrictive licencing that will limit the number of vessels in crab and lobster fisheries to those currently participating will be introduced in 2004. Ireland is currently discussing the introduction of limited entry and industry made a submission to the licencing authority in 2001 for its introduction in lobster fisheries.

Crab and lobster fisheries are currently regulated using minimum landing sizes in Ireland, UK and France. In addition closed seasons for shrimp operate in Ireland. V-notched lobsters are protected in Ireland and the UK. Minimum sizes are suitable and effective measures in these fisheries as discard mortality is negligible (Table 5).

Current regulations, with the exception of those in northern France, have no capacity to limit fishing effort or to limit catches. Crab fisheries especially offshore may be more easily controlled by quotas than by limiting effort. Costs of fishing offshore are high and vessels need to be able to decide when and how to fish. In fact Individual Quotas may have merit in this fishery in securing investment and to promote high grading for quality crab at sea. This is a legitimate objective in fisheries where discard mortality is negligible. Inshore quota control is more difficult to implement but nevertheless removes the need to enforce gear limits at sea. Quota control on lobster would be more difficult given the number of commercial and recreational users and the very high number of landing places. As a first step gear limitations with limited entry may be more feasible. In any case it is difficult to calculate the quota with any certainty given the current lack of research and monitoring data. In shrimp closed seasons can be used to protect spawners and to improve yield per recruit. Grading or sorting systems could however achieve the same effect.

Table 5. Suitability of different management measures and stock assessments for shrimp, lobster and crab in northern Europe

Species	**Management measures**			**Stock assessment**
	TCMs	**Input control**	**output control**	
Cancer pagurus	Effective (but some discard mortality)	Desirable. Access to offshore stocks increasing	Increases security, investment and promotes high grading	Recruitment index, Y/R, spatial mapping of catch rates
Homarus gammarus	Effective (no discard mortality)	Desirable because access is easy, spawning stock may be limiting recruitment	Difficult to monitor	Egg per recruit, catch rates
Paleamon serratus	Less effective (sorting the catch is more difficult)	Desirable because access is easy and spawning stock is potentially limiting	Locally easy to monitor	Recruitment index, Y/R, TAC if output control is used

Management : structure and scale

The institutional arrangements for management of crab fisheries needs to be transnational as many of the stocks are fished by fleets from more than one country eg Ireland-Scotland, France-UK, France-Ireland (Table 6). International management structures therefore need to be developed that also incorporates input from local inshore fleets as coastal vessels fish the same stock as larger offshore vessels. Integration of local, regional and national scales of management is therefore necessary. The inclusion of stakeholders in this system would not be difficult especially for the offshore fishing sector where the number of participants is low.

In the case of lobster the management scale should be regional within countries eg in Ireland 4 coastal regions or in the UK by co-operation between SFCs. This scale may be consistent with the population structure of stocks and regional variability in biological characteristics. In this fishery the fleet is not highly mobile and there is a high local preference of access to the stocks.

Shrimp stocks vary in biology and recruitment over short spatial scales. Bay management by local stakeholders would seem to be appropriate and consistent with the population structure.

The frequency of meetings between stakeholders and management should be at least annual in the case of lobster and crab but seasonal in the case of shrimp where rapid response to local stock conditions is required to avoid local recruitment overfishing.

Table 6. Management structures and measures appropriate to crab, lobster and shrimp fisheries in northern Europe.

Species	**Management structure**			**Management process**		
	scale	**examples**	**why ?**	**stakeholder involvement**		
				difficulty	**structure**	**frequency**
Cancer pagurus	Regional and international	Ireland-Scotland, France-UK	open population structure, fleet is international	Low	international advisory body, fewer stakeholders	annual
Homarus gammarus	Regional within country	NW,W,SW, E coasts of Ireland	coastal distribution, variable biologiy, fleet is regional	Medium	regional management unit, representation from localities	annual
Paleamon serratus	Local within regions within countries	individual bays	closed populations, variable growth and recruitment locally	Medium	management units per Bay	seasonal

Discussion and Conclusions

Management of lobster, crab and shrimp in northern Europe requires a species specific approach because of differences in the biological characteristics, stock structures, effective methods of regulation, scales of management and the issues of optimising socio-economic value which are mainly related to post harvest handling, processing, storage and marketing. Furthermore in order to integrate stakeholders into the management system regionalisation or localisation of management structures and integration of management operations across a hierarchy of geographic scales from local to regional to international is required. This will ensure that the characteristics of the species biology, the spatial structure of the stock and the local preference to the resource are incorporated into the institutional arrangements for management. The emphasis at each level however from local to international, will obviously be different for each species.

Effective management if it means development of sustainable and viable fisheries must incorporate sufficient conservation and control measures, avoid imposing unnecessary costs on the industry and develop policies that will protect viability of the fishing operation for the majority of participants. Given that the catch potential in these fisheries has already been realised or surpassed development needs to be restricted to post-harvest events if economic return is to be maximised. There is significant potential in all 3 species to achieve better economic return without the need to increase catch. Indeed both the stock assessment data, such as there is, combined with the increasing levels of effort and low catch rates suggests that any benefit in economic return resulting from enhanced post-harvest survival and quality should be used an an opportunity to gradually reducte fishing effort. Short term losses may thereby be less severe and management can begin to set objectives for increases in medium term catch rates that can result from reducing effort. The regulatory system to achieve effort control or reduction is not in place however and needs to be strengthened. The management policy, planning and instituational structures that could develop a more strategic and longer term approach are also absent. Management remains generally centralised or devolved to regional bodies between which there is little co-ordination.

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7. A combination of state and market through ITQs in the Tasmanian commercial rock lobster fishery: the tail wagging the dog?

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Abstract

Planning for macro-scale issues such as sustainability is often the responsibility of the state. The market, on the other hand, is the sphere in which rights-based exchanges are coordinated between at times hundreds of agents through the mechanism of price. Few fisheries, however, are entirely state planned or market coordinated, but are a combination of both. In this paper I report on a two year social impact assessment of the introduction of individual transferable quotas (ITQs) in the Tasmanian commercial rock lobster fishery in Australia. This introduction was grafted onto technical conservation measures and input restrictions that stretched back over more than one hundred years. The principal lesson to be learnt from the Tasmanian case is that ownership and transferability of entitlements need to be carefully considered where the social character of the fishery and the state's stake in the fishery are concerned. In managing a fishery using ITQs the state risks giving up too much power to the market. Under ITQs, legally strong individual private access rights-holders can act as an impediment to responsible planning at the fishery-wide scale.

Key words

ITQs, Tasmania, Australia, state, market

Introduction

From the outset, I would like to make three distinctions that are crucial in considering the operation of individual transferable quotas (ITQs) in the Tasmanian commercial rock lobster fishery in Australia.[22] The first is between state and market. Most economies are mixed, "involving both markets and state planning" (Hodgson, 1998, p. 431; see also Sayer, 1995). The challenge is to bring these two spheres together to benefit from the market's ability to coordinate the actions of many different individuals, while at the same time retaining the state's role in affecting the character of an emerging economy.

The second distinction follows from the first, that there is a difference between a mechanism and a plan. If the market, which is made up of mechanisms, is mistaken for a plan then important social objectives risk being left out of consideration.

> [T]he abandonment of any debate about socio-economic goals is both undesirable and impossible. The lack of such an ongoing dialogue creates a void in higher values and aspirations. In the modern, commercial epoch, such a vacuum is likely to be filled

[22] Research informing this paper involved an attempted interview 'census' or universal sample of the Tasmanian commercial rock lobster industry, and took the 12 months from March 2000 to February 2001 to complete. In total, I conducted 247 interviews, involving 312 participants from all sectors of the industry. In other words, the majority of those in the industry were included in the research. Rare in the context of fishery management, these interviews were part of a social impact assessment of quota management funded by the Australian Fisheries Research and Development Corporation.

> instead by a base individualistic ethic of monetary and material gain (Hodgson, 1999, p. 7).

Third, there is a difference between a market and a marketplace.

> While the market denotes the abstract mechanisms whereby supply and demand confront each other and adjust themselves in search of a compromise, the marketplace is far closer to ordinary experience and refers to the place in which exchange occurs (Callon, 1998, p. 1).

"Markets use prices as (imperfect) representations of the interrelated decisions of many agents" (Hodgson, 1998, p. 421). It is in the marketplace, however, that competition between usually unequally positioned individuals occurs; it is the site of exchange regarding a fishery, for example, where boats and licences are leased, sold and bought, profits are made, dreams are realised and hopes are dashed. Market goers are the people who make up the tissue of an industry. By contrast, only buyers and sellers participate in a market, often, in fisheries, through the agency of brokers.

The point here is that in moving to a management system of ITQs the state may give up too much power and responsibility to free market mechanisms. In the case of the Tasmanian commercial rock lobster fishery, the Tasmanian Government has effectively dealt itself out of the fishery as an owner-stakeholder. It owns no quota units itself and finds various social initiatives blocked by legally powerful quota holders who rarely view the fishery as a whole. These individuals profit from their strong access right, free of any responsibility for the biologically and socially sustainable management of the fishery. In some respects, the state body responsible for the management of the fishery finds itself disempowered, whereas those empowered by ITQs seek solely to enhance the value of their holdings.

Two questions arise regarding this situation: first, how did it eventuate; and, second, what might have been done differently to avoid this imbalance between state and market? Following brief introductions of the Tasmanian commercial rock lobster fishery and ITQs, I use the bulk of this paper to address the first question by tracing the emergence of regulatory measures in the Tasmanian commercial rock lobster fishery. I tackle the second question towards the end of the paper, before concluding that the 'Q' in ITQs may deliver biological sustainability, but that conditions associated with the 'T', especially, require careful thought if ownership and control of a fishery are to remain in the hands of both fishers and the state.

Introducing the Tasmanian commercial rock lobster fishery and quota management

The fishery

Tasmania is the island state off the south-east corner of the Australian continent (Figure 1). Tasmania's commercial rock lobster fishery is distributed around the entire coastline of the island, from sub-tidal reefs to deeper reefs on the continental slope (Gardner et al., 2001). Rock lobster were an important source of food for coastal Aboriginal tribes, and also for the first European settlers who founded Tasmania's capital city, Hobart, in 1804.

At present, commercial rock lobster boats make up the majority of Tasmania's fishing fleet. The commercial rock lobster fleet comprises approximately 240 boats, which are licensed to use between 15 and 50 pots. The bulk of the boats in the commercial rock lobster fleet work out of Tasmania's rural coastal towns. The commercial rock lobster industry takes around 1.75 million rock lobsters per fishing year. These have a total landed value of approximately AU$50 million. The majority of the catch comes from waters off the west coast of Tasmania.

Over 80 per cent of commercial rock lobster fishing licences are held by Tasmanians. Just over half the boats in the Tasmanian commercial rock lobster fishing fleet are owner-operated. Additionally, the rock lobster resource supports a recreational fishery, with over 8500 pot and 4500 dive licenses issued annually.

Markets for rock lobster have evolved with changing technology. Only domestic markets existed until after the Second World War when refrigeration enabled expansion into the American frozen tail market. At present, the processing sector uses large tanks to hold rock lobster awaiting live export to Asian markets, primarily in China. The southern rock lobster (Jasus edwardsii) is considered the premium of Australia's rock lobsters and fetches a high price in both domestic and international markets. Approximately 74 per cent of the catch is exported from Tasmania each year, from which fishers average an annual beach price of approximately AU$30 per kilogram.

Since peaking in 1984 at over 2250 tonnes, catch declined to a low of 1440 tonnes in 1994. In response to biomass decline, industry adopted an output control quota management system in March 1998, on top of 'traditional' technical conservation measures and input restrictions such as a shortened fishing season, gear stipulations, size limits and a cap on the number of licences.

Quota management

Different types of quota management system exist, but they have in common the setting of a seasonal total allowable commercial catch (TACC), above which no more fish may commercially be taken (e.g. Copes, 1986; Lanfersieck and Squires, 1992; McCay, 1995; Squires et al., 1995). In terms of stock, if the TACC is set at a biologically sustainable level – reliable fishery assessment being crucial here – then any decline should cease and, ideally, rebuilding should occur. Apart from Australia (e.g. Waitt and Hartig, 2000), ITQs have also been introduced in fisheries in a number of countries around the world including New Zealand (e.g. Batstone and Sharp, 1999; Hersoug, 2002), Europe (e.g. Davidse et al., 1999; Symes, 2001), the US (e.g. Gauvin et al., 1994; Criddle and Macinko, 2000; Holland and Ginter, 2001), Canada (e.g. McCay et al., 1995; Turris, 1999) and Iceland (e.g. Pálsson and Helgason, 1995; Eythórsson, 2000). There appears little doubt that, provided quota management can be adequately policed, a quota management system (QMS) will protect stocks outside a specified catch. If habitat is also conserved, the resource on which the fishery depends long-term is guaranteed. A QMS was favoured in the Tasmanian commercial rock lobster fishery as it operated to cap total catch. Quota management thus put a brake on the 'race' for fish, and promised to succeed in halting stock decline where technical conservation measures and input restrictions had failed. It is to this sequence of events in the history of the regulation of the fishery that I now turn.

Addressing stock decline in the Tasmanian commercial rock lobster fishery

Regulation of most resources is concerned with their use rather than with a particular resource per se. In other words, in the absence of users, a resource does not usually require management. It is use that affects a resource to the point where regulation is considered to be required to manage perceived negative impacts. There are three categories under which regulatory measures to address stock decline in a wild capture fishery are commonly grouped: technical conservation measures; input restrictions; and output controls, of which ITQs are one type. From 1889 to 1998 almost the entire gamut of technical conservation measures and input restrictions were introduced in the Tasmanian commercial rock lobster fishery. These slowed the rate of stock decline but failed effectively to limit effort in the fishery, something only a cap on catch in the form of a TACC achieved in 1998. However, the combination of regulatory measures in the Tasmanian commercial rock lobster fishery has had some undesirable consequences that need to be borne in mind when considering applying quota management to a fishery.

Technical conservation measures

By 1882 as part of a Royal Commission on the Fisheries of Tasmania fishers were expressing concern that "[t]he destruction of crayfish is … so serious in some localities as to threaten extermination at no distant date" (quoted in Winstanley, 1973, p. 3). At this time, the fishery was not subject to regulation of any kind.[23] In 1889, the Crayfish Act introducing size limits and protecting spawning and soft-shelled rock lobster was proclaimed (Williamson, 2001) (Figure 2). It was 1902, however, before regulation of fishing gear was introduced when use of pots was banned in favour of rings. These measures may have ameliorated the threat, in some localities, of extermination of rock lobster, but they did not remove it. Consequently, concern about stock decline was still evident during a second Royal Commission on Tasmanian Fisheries in 1915. Following an enquiry into the use of pots in 1923, the Sea Fisheries Act allowing their use, linked to vessel tonnage, was passed in 1925. This Act also established the Sea Fisheries Board which was to oversee the regulation of sea fisheries as well as issue fishing licences and collect fees.

Thus, between 1889 and 1925 regulations governing legal size, protection of rock lobster in certain conditions at particular times of the year, fishing gear related to vessel tonnage, and licences attracting an annual fee were introduced, this last initiative being principally to raise revenue to contribute to the cost of operating the Sea Fisheries Board. In 1926, closed seasons were added to the range of technical conservation measures, while in 1947 a north-west zone was introduced in the fishery, with the first closed areas following in 1950. Fishers, however, continued to maintain that stocks were in decline despite these measures.

> Concern for the state of the Tasmanian rock lobster fishery prompted investigations by State and Commonwealth authorities and it was generally agreed that drastic measures were necessary to protect this fishery. Licences were restricted to those principally dependent on the sale of rock lobster for a livelihood (Winstanley, 1973, p. 6).

Fishers, however, were themselves part of the problem. More precisely, fishers' gear, including boats, equipment and pots, was both increasing in size (boats) and number (pots) as well as improving in operation (e.g. pot haulers), thus boosting 'fishing power' (Brown et al., 1995; Fernandez et al., 1997) in the fishery. Larger steel diesel-powered boats, depth sounders and the use of up to 40 pots meant that, even without additional fishers, effort in the fishery was increasing.

With a view to quantifying concern about stock decline, detailed catch and effort data were required from fishers by the Sea Fisheries Board from 1962. Before these data could provide a useful time-series, however, pressure began to mount to limit the number of commercial licences in the fishery. This pressure was somewhat independent of concern about stock decline. In the fishery at this time, pressure to limit the number of entitlements "can be seen more as a protection of the incomes of existing fishermen than as a method of conserving the resource" (Storey, 1998, p. 141).

Summarising the state of the fishery before a ceiling was placed on the number of licences, first, stock decline may have been slowed by a number of technical conservation measures, but it was not stopping. Second, two markets existed regarding the fishery, for boats (production) and rock lobster (consumption). Third, members of the 'community' of the

[23] The details associated with the introduction and later changes relating to each regulation are not my concern here (but see Williamson, 2001). My intention is to note the incremental application of different management mechanisms in the Tasmanian commercial rock lobster fishery.

fishery were primarily fishers. Fourth, the components of production in the fishery were the resource (rock lobster), technology (principally boats, fishing gear and equipment) and fishers themselves. Fifth, licences were not limited in number and enabled a financial return only if fished. Sixth, the main asset in the fishery in terms of economic value was boats.

In other words, as it stood at the edge of input restrictions in the form of a cap on licences, the fishery was boat and use centred in terms of value, i.e. boats were the major asset, and licences only made possible an income if directly fished.

Input restrictions

In hindsight post-quota management in the Tasmanian commercial rock lobster fishery, input restrictions were the least thought-through but paradoxically most important of the regulatory measures introduced putatively to address stock decline. By input restrictions in the Tasmanian example I mean limiting the number of commercial rock lobster licences. Limiting the number of licences appeared to be a stock-related measure. If X number of fishers were over-exploiting the biomass then it stood to reason that additional fishers would only worsen the situation. Capping licences in 1967, however, did not reduce the number of operators in the Tasmanian commercial rock lobster fishery, and neither did it limit fishers' effort. It may have obviated existing fishers' additional competition in future. There is little doubt that limiting the number of licences in the fishery was motivated by objectives other than addressing stock decline.

> Following a review of past catches and a study of the economics of fishing, licence limitation [to 420] was introduced [in 1967] to maximise the net economic worth of the fishery. There was no concern over the stocks as a reduction in the legal size for females had boosted catches (Rolden, pers. comm., 2001).[24]

What placing a ceiling on the number of licences did do was affirm the existence of a limited class of owner-stakeholders. Not only were licences granted to individuals and limited in number, they were given in perpetuity, were gratis save for a modest annual licence renewal fee to help pay for the management of the fishery and, most importantly, were fully transferable. In other words, ostensibly in the interest of providing fishers with maximum flexibility regarding their entitlement, licences could be leased, bequeathed or sold by their owners. With ownership, therefore, came value attached to an access right of which there was now a finite number.

In 1967, entitlements were granted with a set number of pots attached, related to vessel length, and a 'one licence only per active skipper' rule (Williamson, 2001). This meant that licences were usually sold, often as part of a boat and licence package, to a fisher. In 1970, however, this rule was abolished and non-fishers as well as owners of multiple licences began to appear in the fishery. In 1972, the number of pots, later under quota management to become the standard units in the fishery, was limited as licence limitation had not stopped stock decline.

> Despite a cap on the number of vessels, however, capital costs and fishing effort continued to rise. Existing boats were replaced by bigger vessels entitled to carry more gear. It was not until 1972 that the government attracted sufficient support from the industry to freeze the total number of pots [at 10,993] (Rolden, pers. comm., 2001).

From 1976, amalgamation of licences was allowed. Again, concern about the poor health of the biomass was cited as the main reason for the introduction of this measure, as well as for

24 'Rolden, pers. comm., 2001' refers to personal communication with a retired Tasmanian rock lobster fishery biologist and manager.

pot rationalisation pursued from 1983. These measures were also put forward as evidence of a responsible partnership between fishers and managers regarding the state of the fishery.

> Although there were claims by industry that the acceptance of limits on fishing gear demonstrated a responsible approach to conservation, such measures were a very weak brake on fishing effort (Rolden, pers. comm., 2001).

Rather than reducing effort, the primary effect of these measures was to reduce the number of entitlements and pots, and thus increase the value of licences.[25]

Limiting the number of fishers, therefore, and turning them into owners failed to arrest stock decline, just as technical conservation measures had failed to do so. Technical conservation measures at least had a direct relationship with stocks, relating to legal size, season, gear and so on. As such, though not capping effort, they were necessary but clearly not sufficient to address over-exploitation. Input restrictions had no such direct relationship with stocks. They related neither to the legal size of rock lobster nor the seasons in which they could be taken. Neither did they directly regulate an individual’s effort or size of boat, only the number of licences and therefore the maximum number of skippers and boats in the fishery. Input restrictions, then, had a strong relationship with ownership and value, but only a weak one with stocks. Like technical conservation measures, input restrictions did not address catch directly. Unlike technical conservation measures, however, input restrictions indirect relationship with stocks raises the question of their necessity regarding the sustainable management of a fishery.

It is important to note that between 1967 and 1992 most boat and licence packages were sold by fishers to fishers and that the value of licences, indexed to the average beach price for rock lobster, remained stable and affordable.[26] This was due mainly to there not yet existing a strong market for the leasing in of pots, chiefly for two reasons. First, pots were not assigned a guaranteed unit of rock lobster, the fishery yet to be quota managed; without quota management there was a question mark over the biological sustainability of the fishery in the eyes of such otherwise strange bedfellows as investors and environmentalists. Second, without a TACC fishers could catch as many rock lobster as they were able and therefore had little reason to lease in additional pots to increase their catch. Moreover, boats were still considered to be the principal asset in the fishery, were worth more with a rock lobster licence and tended to be sold this way. Quota management was still in its infancy in the Tasmanian commercial abalone fishery and few investors were convinced that outlaying money on a licence alone was wise. Not wishing to purchase and deal with a boat as well as a licence, the purchase of licences was left largely to fishers, which kept their value geared around a boat and licence package, the boat not yet being treated as an externality. On the whole, then, the fishery remained owner-operated, but the conditions had been created in 1967 whereby ownership of entitlements and pots could become more valuable than boats. A new market was brought into being in 1967, that for licences, and these could now be exchanged in the fishery for not insignificant amounts of money. In other words, latent in the fishery was the entitlement centrism of quota management, the lead-in to which lasted over ten years and divided the Tasmanian commercial rock lobster fishery.

[25] Given that many fishers routinely ‘overpotted’, i.e. used more pots that they were legally entitled to, reducing the number of pots on paper had little bearing on the number of pots in the water.
[26] For example, in 1980 a pot was valued at approximately AU$1000 and the average beach price was AU$2.50 per kilogram. Ten years later in 1990 a pot was worth AU$4000 while the average beach price was AU$10 per kilogram. With no limit on the amount of rock lobster caught in a fishing year, if he or she so desired a fisher could repay money borrowed to purchase a pot in only a few years. By contrast, in 2002 a pot, or a unit as it became under quota management, had risen in value to approximately AU$50,000, while the average beach price had only increased to AU$35 per kilogram. At 145 kilograms per pot, a fisher would take approximately ten years to gross the amount of money using a pot as he or she had paid for it, repayment most likely taking longer than this period of time.

Output controls

In 1986 a wide-ranging and fisher inclusive seminar was held to discuss ongoing stock decline in the fishery (Bear, 1987). At this seminar both management and fishers agreed that 'something [additional] had to be done' to address stock decline. Despite annual catch in the fishery remaining approximately stable, data were showing that catch per unit effort (CPUE) was falling in the fishery (Figure 3). In other words, fishers were using more potlifts to catch the same amount of rock lobster, i.e. they were working harder to maintain their level of catch. Working harder was facilitated by further investment in equipment such as colour sounders and, from approximately 1990, GPS and plotters, as well as all-weather boats. Such investment was in part made possible, also from approximately 1990, by an increasing average beach price as markets for live rock lobster in Asia developed. Thus, the fishery was considered by fishery managers to be overcapitalising, i.e. for operators to be spending money on ensuring that technology assisted them to increase their effort to maintain their catch. It was less a case that large well-equipped boats were considered not have a place in the fleet by fishery managers than that there was concern that stocks may not take the majority of boats being scaled up. Urgency on the part of fishers was added to their 'gearing up' by a widespread view that they were racing to catch as large an amount as possible of a declining resource. Fishers were of the view that in a catch unlimited fishery individual operators would not cap their own effort. Neither did it appear that the market would act as a break on effort as the average beach price for rock lobster rose to approximately AU$30 per kilogram. The fear was that unless fishery managers capped effort, ultimately the resource would do so in the form of some sort of collapse. It was not until 1991, however, that a Rock Lobster Working Group, comprising both fishery managers and industry representatives, was established to investigate further measures to counter stock decline. The working group reported in 1992 and recommended either the introduction of a TACC or the reduction of the number of pots by 30 per cent. From 1992, then, with quota management mooted regarding the fishery, the value of licences began to climb independent of the average beach price. The commercial fishing industry had witnessed the inflationary impact of the introduction of quota management in the mid-1980s on the value of licences in the Tasmanian abalone fishery. Ownership of tradable units in a biologically sustainable fishery was a potentially lucrative investment both to lease out and in terms of capital gain.

It was another six years, however, before quota management was introduced. Contention concerning its introduction resulted in the emergence of two rival industry representative organisations, and an Act of the Tasmanian Parliament was required to provide the necessary statutory limit on common-law legal challenge. Quota management finally came into operation in the commercial rock lobster fishery in March 1998. It was grafted on to existing regulatory and licensing arrangements without major change to these, i.e. most technical conservation measures remained in place and the rights of entitlement holders were not weakened in any way. Pots became units in the fishery, and all the TACC was allocated to existing entitlement holders.

Quota management had three almost immediate results. First, legal commercial catch was capped in the fishery at 1500 tonnes per fishing year. Though only approximately ten per cent below catches in previous years, a mechanism now existed to adjust catch to a biologically sustainable level. Second, most fishers who had invested in additional licences in case quota management was introduced, recalled these from fishers who had been leasing them. Third, the value of entitlements and quota units kicked further upwards as the market for leasing these was boosted by dispossessed lessees as well as by fishers who had not bought extra licences and were catch-reduced by the equal-per-pot allocation of quota management. Many of these latter fishers wished to lease quota units to maintain their level of catch.

Some lessees who had purchased a boat, long considered the workhorse of the fishery, in the lead-up to quota management, rather than a licence, found that they had purchased an asset depreciated by a glut on the market as a number of operators took a ‘golden handshake’ and retired from the fishery. Young lessees, i.e. in their thirties, the so-called ‘future of the fishery’, had in fact purchased the technology required to compete to lease and catch someone else’s quota units. Neither was this increasingly competitive market a level one as those leasing in quota units additional to their own substantial holdings were, by dint of cross-subsidisation, in a position to out-bid those solely or predominantly leasing.

A quota on the amount of rock lobster that may legally be taken by a commercial fleet in a fishing year is one way to stop stock decline in a fishery. Indeed, ideally stock rebuilding should occur, though supplementary measures such as zoning may be required to ensure that stocks are exploited evenly across a fishery. Quota management is expensive to administer, but it can deliver positive results for the biomass. I should also state that single, inshore and sedentary species fisheries appear better suited to quota management as bycatch and highgrading are less likely. As noted, quota management still requires a number of technical conservation measures to deliver a biologically sustainable outcome (for example, without technical conservation measures spawning rock lobster could be taken). It is on the social side of sustainability, however, linked with the operation of input restrictions, that quota management faces its sternest test in the Tasmanian commercial rock lobster fishery. On the back of individual transferable licences, quota management created a unit and changed the character of the market associated with licences. As catch was limited, the market for units remained unlimited. In a difficult to reverse legal process (e.g. Squires et al., 1995) ITQs moved the fishery from a position of overcapitalisation to one of over-privatisation. Investor syndicates are now in full swing in the Tasmanian commercial rock lobster fishery, and so-called ‘quota catchers’ are beginning to replace owner-operators on the water. A clear capital/labour relation has been created, with possibly serious implications for operator stewardship regarding the resource and compliance with management. In some ways, the market was used as both a mechanism and an incentive for change by fishery managers as they strove to restructure the fishery in as laissez faire and popular manner as possible. Making it possible for one generation of owner-operators to become wealthy through the free market, however, has been at the expense of some longer-term inflexibilities. For example, faced with a dearth of young fishers in the industry, the Tasmanian Government has attempted to create quota units for the short-term use of new entrants only to have this initiative stymied by litigious quota owners, the majority of whom either never did or no longer fish.

Doing ITQs differently

If the introduction of ITQs in the Tasmanian commercial rock lobster fishery is one example of the combination of state and market (cf. Sayer, 1995; Hodgson, 1998, 1999), I see two principal alternative forms of implementation regarding ITQs in fisheries. First, impose conditions on ownership and transferability. This alternative works backwards from a free market position to disallow the leasing of quota units. An individual is entitled to own, fish and sell quota units, as well as to employ a ‘skipper’ for a limited period to work his or her boat in case of illness, etc. To own quota units, an individual is required to own a licensed fishing vessel and to have a ‘skippers ticket’. An owner is required to be aboard for a stipulated proportion of the boat’s sea-time each fishing year. At the end of a specified period of not meeting these criteria, an owner is required to sell his or her entitlement and quota units. These conditions make it both less attractive and more difficult for those not bona fide fishers to own quota units. Such conditions, however, are difficult to introduce, especially retrospectively, and are often subject to lobbying for their relaxation once in place.

Second, retain some degree of state ownership. This alternative works forwards to maintain a role for the state as an owner-stakeholder in the fishery. Again, such a role is difficult to implement retrospectively. A number, possibly all, quota units would be held by the state. The state allocates these as it sees fit, for varying lengths of time and with flexible terms, for example to research institutions or aquaculture interests, to fishers to raise revenue, to new entrants to the fishery, and so on. Rather than try to limit the operation of the market, the state instead ensures that it is an owner-stakeholder in the market and pursues its objectives through its own holding.

Conclusion

> [N]either the market nor the plan can be abolished or marginalised. The problem is to combine and transform them in some way so that human capacities can be developed to face new horizons.
>
> Such a combination may include a substantial role for state intervention – even for a limited form of state planning – as well as for private property and markets (Hodgson, 1998, pp. 429-430).

Without careful consideration, quota management combined with individual and transferable input restrictions run the risk of over-empowering owners at the expense of responsible state management. The tail wagging the dog looms as a distinct possibility. In contrast to this possibility, I consider there to be an important role for the state in planning to ensure that social as well as economic factors are considered in the development of an economy that is part of an industry based on a wild capture fishery. A number of lessons can be learnt from the introduction of ITQs in the Tasmanian commercial rock lobster fishery. First, the 'Q' operated to cap catch, whereas technical conservation measures and input restrictions failed in this regard. In other words, effort continued to increase and stocks continued to decline despite almost the entire raft of technical conservation measures and input restrictions being applied at an early juncture in the fishery. These regulations slowed but did not stop over-exploitation of the resource. A cap on catch, however, acted directly to limit the amount of rock lobster legally taken by the commercial fishery.

Second, the 'Q', then, in ITQ is almost sufficient on its own to ensure that catch is limited to a sustainable level. 'Almost' because some technical conservation measures are also necessary – but on their own not sufficient – to make certain that a resource is exploited sustainably. Obvious examples of necessary technical conservation measures are size limits and protection of spawning stock which relate to the reproduction of the resource. Quota management, therefore, almost certainly needs to operate in conjunction with technical conservation measures, though there may be a degree of latitude regarding some gear-related measures.

Third, less clear is the necessity of combining quota management with input restrictions. There may be good reason for limiting the number of commercial licences, such as to mitigate competition. Individuals may even be granted licences for longer than one fishing year as an incentive to take a longer-term view of their participation in the fishery. However, the link between granting licences to individuals in perpetuity with full transferability rights and ecologically sustainable development appears to be somewhat tenuous. Ownership does not necessarily lead to stewardship. Fishers in the Tasmanian commercial rock lobster fishery arguably had such ownership from 1967, but this ownership acted as a weak break on effort. The addition of the 'Q' to 'IT' does not solve this problem. Many of the second generation of fishers under quota management are likely to lease rather than own an entitlement to the resource. It may be debatable whether ownership contributes to compliance, co-management and sustainable practices – and these may be possible without ownership – but it is undeniably the case in the Tasmanian commercial rock lobster fishery that fewer owners are on the water to exercise any supposed sustainability ethic.

Fourth, the dubious benefits of full transferability rights need to be set against some clear, possibly negative, impacts. ITQs usher in a full-blown market for their exchange which can change the character of the fishery's 'community'. For example, investor syndicates involving individuals with little knowledge of fishing, and fishers who can expect only to work for a wage are two consequences of the introduction of ITQs in the Tasmanian commercial rock lobster fishery. Whether these are positive developments is in some respects for Tasmanian Government fishery managers and industry to decide, but even regarding concern about the replacement of the present generation of fishers, the state's hands are somewhat tied by legally powerful owner-stakeholders interested to increase their returns and add value to their investment. To these participants, the lack of new entrants in the fishery is not an immediate concern. There is a question mark, then, over the ability of the state, attenuated by the existence of private access rights which it created, to act responsibly in the longer-term interests of the fishery.

It is thus salutary to note from the Tasmanian example that markets are places made up of people. A number of traditional fishers were 'caught napping' by the upwards movement in price regarding licences due to the introduction of quota management. Additional licences were not purchased and lease costs now intrude well into their margin. Lessees and the next generation of commercial rock lobster fishers have become labour to investors' capital. The character of the fishery has been changed considerably, as have the focus and the balance of power in the fishery. The focus is no longer on boats and fishers but on entitlements and investors, and it is these last who hold the balance of power in the fishery. A new kind of market has come into being with new types of participants – capital and labour – relating through the mechanism of price. Meanwhile, the architect of this situation, the state, has lost much of its ability to plan for the future of the fishery. The challenge ahead is for the state to reassert its rights in the fishery at the same time as encourage a more responsible outlook from private rights-holders with whom it has to share the fishery. This is a difficult road made not by quota but by it being owned by individuals in perpetuity with full transferability rights.

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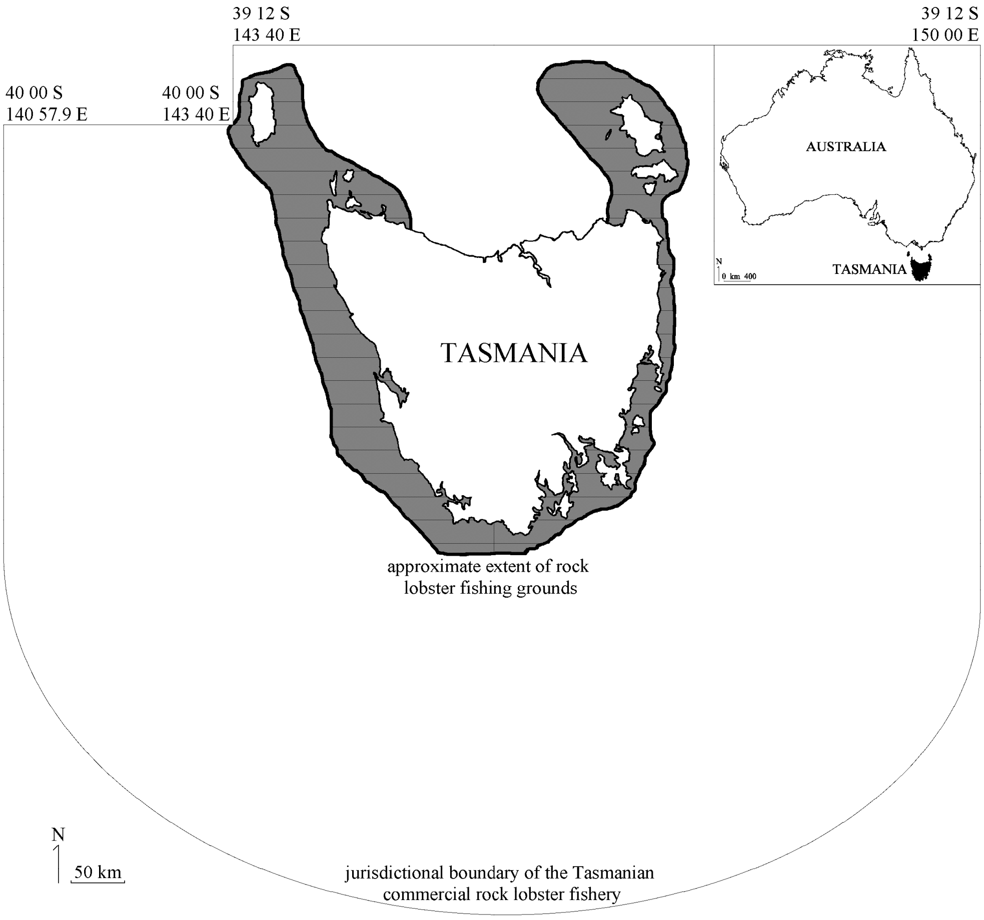

Figure 1 The island state of Tasmania relative to the Australian continent (insert), and the Tasmanian Government jurisdiction of the commercial rock lobster fishery showing the approximate extent of these grounds

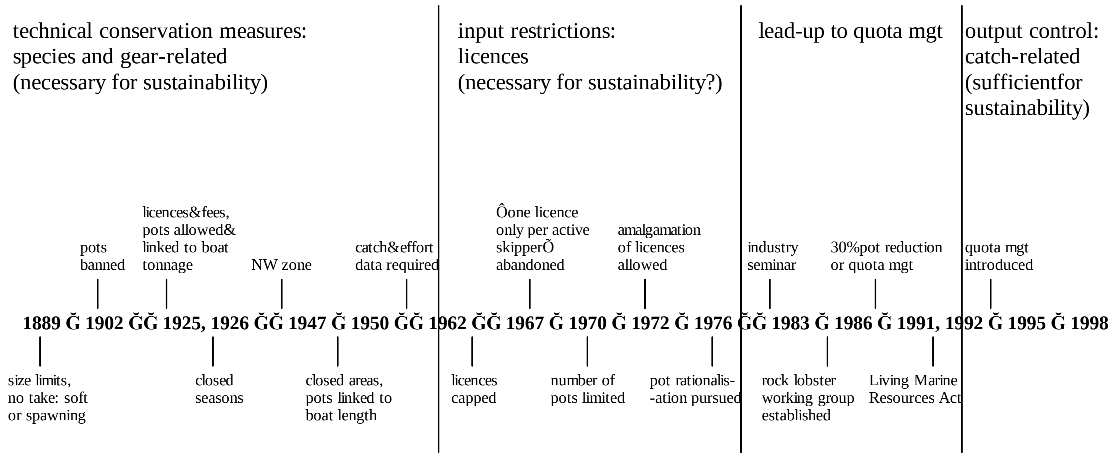

Figure 2. Timeline of regulation of the Tasmanian commercial rock lobster fishery

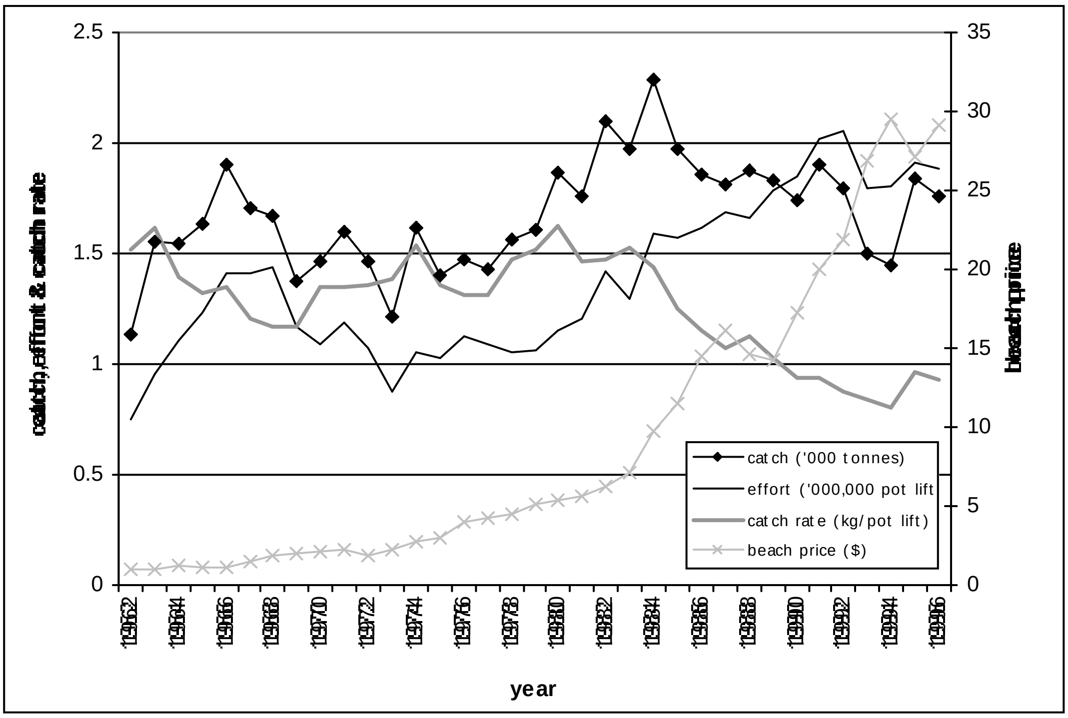

Figure 3. Catch, effort, catch rate and beach price for the Tasmanian commercial rock lobster fishery, 1962-1997. SourceWilliamson, 2001, p. 94.

8. Use Of Private Access Rights In Fisheries: Effective Management Through Public Transferability?

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Abstract

The aim in this paper is to put forward an approach to the issue of access rights that is suitable to Ireland's crustacean and molluscan fisheries. We begin by reviewing proceedings of a recent international conference on the issue of property rights in fisheries. We then pose objectives for fisheries management to be met by our approach. Following this, we outline the present limited entry initiative regarding crustacean and molluscan fisheries in Ireland. We conclude that - for fishers to operate with, but not exchange licences like, owners - a licence should be returned to the issuing authority once it is no longer being fished by its holder.

Keywords: Access rights, Ireland, crustacean and molluscan fisheries

Introduction

… government has no other end but the preservation of property …

(John Locke) [1]

… property is organized robbery …

(George Bernard Shaw) [2]

Search any dictionary of quotations and you will most likely find variants of these two opposing views on private property. In the one view, represented by Locke, private property is a pillar of society necessary to preserve '… lives, liberties and estates …'. In the other, it is a divisive crime.

A similar polarity seems to attend the debate about private 'property' rights in fisheries. For example:

> … property rights are absolutely fundamental … [to] the level of production, productivity and production growth in economies … and, more generally, to almost everything that people usually regard as economic progress [3].

> … the institution of private property … cannot on its own be expected to maintain or improve the condition of the marine habitat, contrary to the tacit assumption of much fisheries economics [4].

According to Symes [5], '[t]he case for rights-based management has been argued with a proselytising zeal by economists and endorsed by fisheries administrators and large-scale fishing interests - and rebutted with equal vigour by the social sciences and the small-boat sector'. He goes on to ask if some middle ground might usefully be explored between these two positions. Such an exploration can be undertaken using an example. The case we present is a change in management underway in Ireland's crustacean and molluscan fisheries.

In this paper, we first consider recent thinking regarding private 'property' rights in fisheries (Section 2). By way of simplifying what is a substantial and complex literature, we centre our consideration on the proceedings of the FishRights99 conference [6]. This conference gathered together many of the world's leading thinkers on property rights in fisheries. Its proceedings capture a wide range of views on this issue. Second, we discuss objectives particular to fisheries management (Section 3). We specify objectives regarding stocks, industry and government, as well as in respect of the management relationship between industry and government. We consider our objectives to be common to many fisheries around the world. Third, we outline the situation regarding fisheries in Ireland (Section 4). This situation is set against the background of the Common Fisheries Policy (CFP). We specifically discuss the management change underway regarding crustacean and molluscan fisheries in Ireland. Fourth, a clear industry preference for licences not to be privately transferable is presented (Section 5). Finally, we ask if it might be possible to construct a middle position in Ireland's crustacean and molluscan fisheries that captures both the public and private benefits of 'ownership' by issuing each licence with a provision that it be returned to the issuing authority once it is no longer being fished by its holder (Section 6). This is a new proposal in Ireland, but we recognise this may not be the case in a number of fisheries in other countries. However, we consider that as private transferability has crept into a number of individual quota (IQ) systems around the world, it is a proposal worth reiterating.

'Fish rights': which way to go?

Is private property a good or a bad thing? This question is easiest to answer at its extremes: if you made it, yes; if you stole it, no. Much property, however, is acquired through a market, i.e., it is purchased. It is here that Shaw's 'organized robbery', quoted above, is relevant. First, governments create licences, determine their conditions *qua* private property and regulate the general operation of markets through which licences are exchanged. Second, free market exchange can be seen to legitimise taking by haves from have nots. Leasing of licences to access a fishery is a case in point.

Private property, however, should not be dismissed out of hand. Ownership of private property can deliver control to an individual of his or her labour. That fishers are secure in their occupation can lead to longer careers and investment horizons as well as to stewardship. There is therefore much to be learnt from both sides of the literature regarding 'property' rights in fisheries. By way of summarizing this literature, we distill points relevant to Ireland's crustacean and molluscan fisheries from proceedings of the FishRights99 conference [6]. Over 45 papers are included in these proceedings. Collectively, they address a wide range of issues, from theory to practice, regarding the role of property rights in fisheries, and include academic, industry and government perspectives, as well as cover institutional arrangements and administrative challenges. In producing this summary we have been mindful of the Irish fishing industry's preference for non-transferable licences (discussed below). Our summary is therefore not disposed to any individual transferable quota (ITQ) orthodoxy. With this said, the main points for management of crustacean and molluscan fisheries in Ireland are as follows:

- In most fisheries, the right in question relates to access rather than to species or areas.
- In some fisheries, privilege (e.g., in Canada) or permit are preferred descriptions to 'right' as they convey a sense of the retention of responsibility to manage on the part of the issuing authority.
- The position of proponents of the use of private access rights in fisheries continues to be underpinned by neo-classical economic theory concerned with efficiencies at the scale of the fleet.
- The link between the use of full private access rights in fisheries and responsible fishing practice is questionable (e.g., quota busting, high grading and discarding are evident in fisheries managed using ITQs).

- Many of the stated benefits of full private access rights (e.g., exclusivity, security and durability) can be obtained with a more partial and flexible 'right'.
- Once introduced, private access rights are difficult to reverse.
- Private access rights systems in fisheries tend, in the first instance, to be biased towards existing boat/licence holders (excluding, e.g., crew).
- Transferability through a market is the major point of contention regarding negative, particularly social, impacts associated with ITQs; in a number of fisheries, IQs seek to avoid these.
- Private access rights can impinge on the ability of public decision-makers to adjust a management system.
- If left solely to the market, distribution of private access rights risks being inequitable (e.g., financially underprivileged fishers and the next generation of fishers may be disadvantaged).
- Under a private access rights system such as ITQs, owners may not be operators.
- It is beholden on government to attend to social justice (e.g., regarding distribution issues) and ecosystem scale objectives, the market will not address these due to it being oriented to narrow efficiency and individualistic profit maximisation parameters.
- Any private access right should be granted with clear obligations (e.g., to comply with and participate in management). Responsibilities beyond the career horizons of licence holders, such as for ecosystem health and stock sustainability, are in the hands of management.
- Concentration of quota into fewer, often non-fishing, hands is a concern in many fisheries managed using ITQs.
- Under full private 'property' rights, operators, co-operative industry bodies, processors, investors and public bodies alike may be required to bid for shares to access a public resource.
- ITQs are static (e.g., allocated in perpetuity) compared with dynamic stocks, fishers, technology, management and government.
- ITQs preclude use-it-or-lose-it licence schemes.
- Private access rights can impede individuals, often with only base levels of formal education, from securing their operation at a price relative to their other sunk costs (e.g., a boat, fishing gear and electronic equipment).
- Private access rights create winners (possession) and losers (dispossession, of often artisanal operators, especially inter-generationally).
- Under a system of limited entry, without licences reverting to the issuing authority (e.g., following cessation of fishing by the holder), *de facto* transfers can occur.
- If *de facto* transfers occur, pressure is likely to be applied to government to make these *de jure*.
- Private access rights tend to create a distinction between capitalists (owners) and labourers (operators).

A number of papers in Shotton [6] rehearse arguments for and against rights-based management (e.g., [5]). The primarily economic case for ITQs emphasises their ability to address overcapacity, at the scale of the fleet, through the market. The operation of Adam Smith's so-called invisible hand of the market means that the state is not seen to be an agent in any rationalisation. Even more attractive to the state, perhaps, is that rationalisation through the market does not directly cost it anything (there may, however, be indirect costs related, for example, to industry polarisation and ecosystem degradation). Also emphasised is the ability of ITQs to weed marginal economic units out of the fleet, meaning that only the most efficient operators remain. A fleet consisting of a small number of large operators should then lead to lower transaction costs. Non-economic benefits of ITQs are argued to be less discarding of catch, greater stewardship and a simplified regulatory system.

The case against ITQs has principally been made on the grounds of natural and social justice. Objections on natural justice grounds centre on the privatisation of access to a public resource. Objections on social justice grounds focus on concentration of ownership and centralisation of operating units. Individuals and localities lacking resources are not favoured by owners and fishers looking to maximise their economic returns and operating efficiencies, respectively. Quota holders can become fewer and larger, as can operators; and operators are increasingly likely to be lessees. Progression to owner-operation can become financially beyond most crew. Small, artisanal and often pluriactive operators may decline in number. It is these who together employ more people and are spread through more local coastal communities than large operators. They also harbour whatever 'traditions' might be associated with the fishery. In short, labourers can end up working big boats and catching quota held by capitalist owners.

Finally, the literature indicates that 'ownership' can lead to more environmentally responsible fishing in the long-term. One caveat here, however, appears to be that owners need to be operators. Before we discuss a possible middle position between private and public ownership, we next specify key objectives to be met in fisheries management as these underpin any specific mechanism such as limited entry. Our proposal relating to the system of rights emerging in Ireland's crustacean and molluscan fisheries can then be considered against this background.

Key fisheries management objectives

By way of simplification, we identify five key management objectives related to four principal components of a fishery (Table 1).

Table 1. Principal components of a fishery and related key management objectives

Principal components	***Key objectives***
Stock	Sustainable exploitation
Industry	Viability & stewardship
Government	Flexibility
Relationship between industry & gov't	Co-operation

We consider similar components and objectives to be common in a number of fisheries around the world. For example, s*ustainable exploitation* of a fish stock is the central objective of many management systems. In the United States, for instance, National Standards for fisheries management have been written into statutory law. National Standard 1 states that:

> Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry [7].

In Australia, on the other hand, the broader framework of Ecologically Sustainable Development (ESD) is used, within which fisheries management, among other kinds of management, is assessed [8].

Standards or criteria in most frameworks tend to be worded generally. Common objectives include:

- that resources be managed sustainably;
- that biodiversity be maintained at the ecosystem scale; and
- that the precautionary principle be applied.

European Union (EU) objectives along these lines apply to Ireland. For example, EU Regulation No. 2371/2002 regarding the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy (CFP) contains the following two objectives:

1. The Common Fisheries Policy shall ensure exploitation of living aquatic resources that provides sustainable economic, environmental and social conditions. For this purpose, the Community shall apply the precautionary approach in taking measures designed to protect and conserve living aquatic resources, to provide for their sustainable exploitation and to minimise the impact of fishing activities on marine eco-systems. It shall aim at a progressive implementation of an eco-system-based approach to fisheries management. It shall aim to contribute to efficient fishing activities within an economically viable and competitive fisheries and aquaculture industry, providing a fair standard of living for those who depend on fishing activities and taking into account the interests of consumers.

2. The Common Fisheries Policy shall be guided by the following principles of good governance:

(a) clear definition of responsibilities at the Community, national and local levels;

(b) a decision-making process based on sound scientific advice which delivers timely results;

(c) broad involvement of stakeholders at all stages of the policy from conception to implementation;

(d) consistency with other Community policies, in particular with environmental, social, regional, development, health and consumer protection policies [9].

These objectives acknowledge that, as well as stock, a fishery is also made up of people, principally fishers. That a stock be fished sustainably is therefore often associated with the objective that operators be assisted to be viable economic units. *Viability* is set within the limit of sustainability, but it is frequently the case that management needs, at the very least, to ensure that any limits placed on fishing reduce the viability of industry as little as possible. More positively, some management authorities are also development agencies that seek to diversify and/or expand industry, to open up new markets, to increase returns to operators and so on. Socio-economic viability of localities associated with commercial fishing can also be a concern of management agencies. For example, in Ireland, Bord Iascaigh Mhara (BIM) is the agency within the Department of Communications, Marine and Natural Resources (DoCMNR) responsible for management of so-called inshore fisheries. Its overarching objective is to increase standards of living in communities connected with commercial inshore fishing. It is required to do so by:

1. Providing additional employment opportunities through diversification into new fisheries, aquaculture and leisure/tourism activities.
2. Managing fisheries to ensure sustainability of the resource.
3. Increasing quality and value of the catch and developing marketing opportunities.
4. Improving infrastructure at piers.
5. Upgrading boats and improving safety standards.
6. Providing a forum for resolution of issues at the local level and consulting between the government and the inshore sector on future policy initiatives and the possibility of devolving powers [10].

This last requirement points to an objective important in many fishery management systems, *stewardship*. Ideally, industry will help government to look after a resource. Certainly, it is an aim in many fishery management systems that industry play a part in co-operative decision-making, or at the very least be consulted about management decisions. Most importantly, any management system will succeed or fail according to degree of industry compliance. The vast majority of industry must abide by fishery regulations. Stewardship is the preferred way to achieve compliance, and is arguably more effective and less expensive than enforcement.

'*Flexibility*' refers to capacity to change a system of fishery management. Bio-social systems are dynamic. Management systems nearly always need to be adjusted, and may not work. Management objectives may also change. Decision-makers need the ability to alter a management system to accommodate bio-social shifts and/or new policy as well as to improve the effectiveness of management. This ability may be constrained by putting in place a management system that uses ITQs. Private access entitlements can sit like stones in a bio-social system in flux all around them. The legal existence in perpetuity of such entitlements ensures that they are difficult to modify.

Finally, '*co-operation*' refers to a key relationship in any fisheries management system, that between industry and government. Much has been written on differences between so-called command and control systems, consultative management and co-operative management [e.g., 11]. In command and control systems, contact between industry and government often occurs through enforcement. Few individuals concerned with Ireland's crustacean and molluscan fisheries prefer 'top-down' management. Instead, co-operative decision-making between government and industry is considered to result in both better informed and more efficacious management.

The challenge, then, is to develop a management mechanism that, at a minimum, does not lead to unsustainable exploitation, reduce industry viability, hamper the development of stewardship, become immutable or work against co-operation. Obviously, however, the aim is to improve on this minimum position. It is stated because it can be important to halt a worsening situation in a fishery before it can be improved. It may be appropriate that management be assessed, at least initially, according to this more modest aim rather than to expect immediate improvements. We next discuss the Irish context, within which our proposal in Section 6 is set.

The inshore segment of the Irish fishing fleet

The Common Fisheries Policy (CFP) is the European Union's (EU) framework for management of fisheries and aquaculture. All aspects of fisheries and aquaculture come under the umbrella of the CFP. As fish are a mobile resource and cannot be delimited to a particular EU Member State, regulations under the CFP apply to all EU Member States. The CFP was introduced in 1983, reviewed in 1992, and again in 2002. The current CFP came into force on January 1st 2003.

The EU's Multi-annual Guidance Programme (MAGP) is the principal means used within the CFP to manage fisheries at the scale of an individual Member State. Current licensing policy regarding the Irish fishing fleet reflects Ireland's obligations under this programme. The purpose of the MAGP is to achieve a sustainable balance between fishing capacity and fish stocks. The MAGP sets fleet capacity/effort objectives which are to be achieved in respect of the Irish fishing fleet by the end of set periods, and provides that Ireland achieves fleet objectives through either reduction in fishing effort or reduction in fleet capacity [10].

The Irish fleet is divided into five segments: polyvalent, pelagic, beam trawl, bi-valve and inshore potting. The polyvalent segment permits access to all but pelagic species. The Irish State has authority, as do other EU Member States, to manage fishing activity within 12 nautical miles of its coast. Fishing activity within 12 nautical miles of the coast and by vessels less than 12 metres in length is considered to be inshore. Inside 12 nautical miles of the Irish coast the important fisheries are in the inshore potting and polyvalent segments of the fleet.

The gross registered tonnage (GRT) of the Irish fishing fleet, set by the EU's MAGP, is approximately 68,000. The inshore segment comprises approximately 80 per cent of the Irish fleet in terms of number of vessels – there are approximately 2000 inshore vessels - but accounts for less than 16 per cent of total fleet GRT. Approximately 50 per cent of these 2000 vessels are open, i.e., they are punts or curraghs without decks, are less than six metres long and have a GRT of less than two. Such vessels mainly use static gear, i.e., pots and fixed nets. A minority of vessels between 6-12 m use dredges to fish for bi-valve molluscs, of which King Scallop is the most important. The average number of pots per vessel is approximately 300, with the majority of these being soft eye creels. There are no quantitative data on the amount of nets being used. Potters fish mainly for brown crab, lobster, shrimp and whelk. Landings from the inshore segment constitute approximately 21 per cent of total landings and are worth approximately €38 million per annum. Over 3,700 people with an estimated 11,800 dependants are employed in the inshore segment, representing almost 50 per cent of total 'onboard' employment in the Irish fishing industry [10, 12].

As GRT is both limited and transferable it has acquired financial value. At present, to purchase one unit of fishing capacity (i.e., one GRT and four kilowatts of engine power) costs between €3000-4000. This is a substantial entry cost relative to the earning capacity of fishing vessels in the Irish fleet, although the majority of vessels with fishing capacity did not purchase it on the open market but had it allocated under various schemes, the first of which was in 1989. Prior to 2003, up to 50 per cent of inshore vessels fished without capacity, either because they had sold it or could not afford to purchase it. A *Scheme for the Licensing of Traditional Pot Fishing Boats in the Irish Inshore Fleet* (i.e., boats less than 12 metres in length and less than 20 GRT) regularized the position of these vessels in 2003.

A further step towards limiting entry to crustacean and molluscan fisheries is now necessary by removing access rights to these fisheries from vessels with no track record in them or from new entrants to the fleet. Access would therefore move from a situation, which was open, in the sense that a high proportion of vessels had very broad licence entitlements, to one restricting access to a species group based on historic activity. The new inshore potting licence emphasised that these licences were not transferable, but licence administration has yet to determine this to be the case. Moreover, *de facto* transfer/leasing *may* occur in future, as occurred in the polyvalent segment of the Irish fleet. If licences are traded, either 'under the table' or *de jure*, there is a risk that small boat, often part time operators will be priced out of the regularised sector. They may then instead attempt to operate outside the licensing system, as occurred between 1989 and 2003. Such an eventuality could undermine the licensing system and/or constitute a significant policing headache. The challenge is to develop an approach to limited entry and transferability that avoids this possibility.

Limited entry and transferability: an industry view

An indication of the view of fishers regarding limited entry was gained in 2000 as part of a conference to discuss the management of the Irish lobster fishery [13]. A paper prepared for the conference reported outcomes of a meeting with representatives of four key fishers' co-operatives, or 'co-ops', regarding management objectives and acceptable measures in respect of the Irish lobster fishery (one 'co-op' from each of the Dingle, East Waterford, South Wexford and West Galway [Clifden area] regions) [14]. Ten critical objectives/measures were agreed, two of which are relevant here:

2. A licensed limited entry system should be established for all crustaceans, excluding shrimp
6. Licence non saleable or transferable [14].

A further indication of the view of fishers regarding limited entry was gained in 2000/2001 through an industry generated initiative that resulted in the document *A Proposal for Licensed Limited Entry Fisheries for Lobster in Ireland* [15]. Voting was organised by members of industry, through fishers' 'co-ops', regarding various aspects related to possible limited commercial entry to Ireland's lobster fishery. A total of 877 people voted, 'representing the majority of lobster fishermen in the country' [15]. (Lobster is taken by more commercial fishers than any other species in Ireland's crustacean and molluscan fisheries.) This exercise resulted in the Irish Lobster Co-operatives issuing a joint proposal for the creation of a limited number of lobster licences, subject to the following two conditions, among others.

- That the licence be renewed annually in order to allow a changing membership
- That the licence be non-transferable except within the immediate family [15].

Industry maintained that access to a licence should be conditional on fishing that licence; in other words, that when a licence holder retired from fishing, his or her licence should be restored to the issuing authority for possible issue to a new holder. The only exception noted was in the case of immediate family being allowed to continue to fish the licence.

A total of 193 pages of the 211 page document is appendices in the form of submissions from lobster co-operatives from around Ireland. The submissions contain statements that flesh out the above two conditions. For example, regarding the licence being based on use, the following statement is typical:

> The recipient should be required to furnish proof at the end of each season that he/she [has] utilised their licence personally, be it in the form of **logbooks or sales receipts**. (No leasing or loaning licence.) This will ensure that people holding a licence will have to fish them or forfeit them thus giving crewmen or others a chance to apply for unused licences in the future [16].

The preference in the submissions is clearly that a licence 'should have no resale value, if not used by [the] licensee then [it] cannot be used by anyone else' [17]. '[T]hat licences do not become a commodity to be traded' [18] was a commonly expressed opinion with a view to licences being held by fishers rather than investors.

With industry's view clear, the requirement is to match it with a management mechanism that will achieve the key objectives in Table 1, discussed next.

Adapting a management mechanism to Ireland's crustacean and molluscan fisheries

As part of the new inshore pot licensing scheme, BIM and the DoCMNR have undertaken to meet the wishes of industry concerning transferability.

> Approval of the scheme by the European Commission was strictly on the basis that the scheme did not lead to increased fishing effort in the existing polyvalent segment of the Irish fleet now or in the future. Boats licensed and registered under this scheme were therefore ring-fenced. The capacity of boats licensed and registered under the new scheme will not be eligible as replacement capacity. This means that neither the boat's capacity or its licence may be traded on, transferred or otherwise used. The licence will attach solely to the licensee, and be valid, in the first instance, for a period of 2 years; the question of renewal of the licence will have to have regard to, inter alia, national and/or EU fleet policy, and the sustainable management and conservation of resources. In the context of the future granting of any new licence to replace a licence granted under the scheme, priority consideration would be given to immediate family members with an active history in inshore pot fishing [19].

Limiting entry with non-transferable licences is one way to ensure that licences are placed and remain in the hands of fishers. Care is required here, however, because markets can be surreptitious. Experience in the polyvalent sector in Ireland, as well as in fisheries internationally, indicates that even when transferability is not allowed, *de facto* transfers can occur. Regarding the above conditions, for example, leasing of licences may still be possible.

We propose therefore that once a licence holder has ceased fishing, i.e., retired, his or her licence should be returned to the issuing authority. By restoring licences to a public body, perhaps for reissue, the possibility of ‘under the table’ transfers would be removed. In this way, the present situation in Ireland regarding polyvalent licences in which ‘[i]t is known that a high percentage of registered vessels no longer fish but retain their licence’ [20] would not be repeated.

How, then, might individual privately non-transferable commercial fishing licences help to achieve the key management objectives in Table 1? Obviously, limiting entry makes it possible to cap the number of operators in a fishery. This is an important part of controlling fishing effort. To be effective at the scale of a fishery, TCMs need to apply to a limited number of operators. For example, limiting the number of pots an operator may use will not cap total number of pots if additional operators can enter the fishery. On the other hand, limiting entry and gear do not limit an individual’s effort in terms of number of pot lifts. This can be addressed, for example, by limiting days at sea. Regarding quota management, setting a total allowable commercial catch (TACC) for a fishery without limiting entry may result in a race for fish that does not produce preferable socio-economic outcomes (e.g., over-capitalisation, so-called derby fishing, and possible temporal and industry concentrations). The point is that, regardless of associated regulations, limited entry is necessary to define the number of operators with a view to wrapping a fishery in a package of limitations aimed at the effective control of individual as well as of total fishing effort. On one hand, overfishing requires that a maximum limit be set regarding total effort. On the other, possible over-competition requires that a minimum viable operating unit be established regarding individual effort.

There are already many substantial and largely unavoidable costs associated with commercial fishing in Ireland, in the forms of vessels, gear and equipment. It is the opinion of many in the industry that an additional cost to access transferable licences is untenable; licences, then, should be made available for use not exchange. Concern is not just that an additional financial hurdle will be put in the way of aspiring ‘owner’-operators, but that a number of insidious effects attend the free market exchange of licences. For example, there is concern about who might buy into the industry. Investors without industry roots are not considered to be desirable. There is concern, too, that transferability will shift the emphasis from the performance of fishing to the management of an investment. This change can be sufficiently powerful to split families, for example, father from son. Industry in Ireland is therefore concerned about the possible divisiveness of limiting entry using privately transferable licences. Alternatively, the introduction of licences that are not transferable privately and are clearly and iteratively assigned to an individual on the basis of he or she having fished in the previous year is supported by industry. Industry is clear that licences should not be commodities but tickets to an occupation, and that licences are privileges, not rights, that should be available to be issued, not sold, to future generations. Licences should be limited, certainly, and should come with obligations (e.g., to pay an annual licence fee, to provide catch records, and to comply with and participate in management). Waiting lists and criteria for qualification may well be required to manage public transfer of licences. But, however onerous this course may be, in the view of industry it is the responsible one in the Irish context, compared with requiring lessees and purchasers to make payments to owners.

But what of the argument that some form of private property right increases the likelihood of licence holders behaving responsibly towards a resource [21]? Recalling the risk that second-generation fishers may be financially pressed lessees rather than owners under, for example, a quota management system using ITQs, might it be possible to encourage resource stewardship without full private access rights? Property is held to have four principal characteristics: transferability; exclusivity; security; and durability [3, 22]. Considering transferability first, we have noted industry’s concern in Ireland that licences not become commodities. Underlying this concern is awareness of the impersonalising propensity of financial gain. In a market, the price of a transaction is paramount. Through a broker, for example, buyer and seller may never meet. In such ways, a licence can be sold out of a family and a community to an investor offering the highest price. Industry is concerned that licences not be transferred out of fishing communities. We propose therefore that transfer be guided by some form of public decision-making committee made up of industry as well as government. Thus, our proposal regarding transferability is not that transferability be disallowed, but that it be public not private.

What of the other characteristics of private property? In short, 'yes' fishers want limited entry, 'yes' they want their own licences, and 'yes' they want these for the duration of their fishing lives. However, they seek to profit by fishing licences, not by leasing or selling them. They consider that a long-term outlook regarding investment in fishing is adequately encouraged by issuing a limited number of individual privately non-transferable fishing licences. Provided fishers operate within the rules of a fishery management plan, their use of a licence would be guaranteed. (Provision would be made for illness, etc.) On a fisher's retirement, the licence would revert to the issuing authority for possible reissue.

'Possible' reissue of licences by a public authority underscores one advantage of flexibility regarding a management system. In this instance, in the interest of sustainable exploitation, decision-makers may undertake to reduce the number of licences in a fishery. With licences linked to holders' fishing lives in terms of duration, decision-makers are in a position gradually to 'drip' effort in the form of maximum number of operators out of the fishery. This is a humane way of adjusting this component of effort downwards, akin to so-called grandfather or sunset arrangements. (If emergency reduction in fishing effort is required, TCMs or perhaps some form of buyback could be used.) Alternatively, should stocks warrant, decision-makers could increase maximum number of operators in a fishery by creating additional licences. The aim is that decision-makers, including both government and industry, retain the ability to adjust or even replace a management system to achieve sustainable exploitation. In the case of quota management systems using ITQs, however, legally intransigent private owner-stakeholders can become impediments to any adjustment.

Finally, co-operative decision-making may well be assisted by operators being regulated using individual privately non-transferable licences that applied for the duration of operators' commercial fishing lives. First, the existing community of operators would be protected. Second, transition to the next generation of operators would then be co-operatively managed by industry and government to ensure that appropriate individuals qualified for any licences being reissued. Operators could therefore both plan to fish in the long-term as well as anticipate that the fishery would remain oriented to operators, which could include their children. They would thus have a long-term interest in participating in co-operative decision-making and complying with management regulations that were oriented both to their own and to the greater good of their fishing community. Embedding obligations in often local fishing communities in this way is preferable to encouraging individuals to comply with management simply to protect an investment or to avoid some form of penalty.

Conclusion

In this paper we have proposed a middle position between private and public ownership of commercial access rights to Ireland's crustacean and molluscan fisheries. Central to our proposal is that transferability of licences be public not private. Supported by the prevailing industry view, we contend that benefits associated with private property other than transferability, namely exclusivity, security and durability, can be gained by orienting a limited number of licences to individuals' fishing lifetimes rather than by allocating licences in perpetuity. On retirement from fishing, an individual's licence would return to a public decision-making authority, made up of representatives from both government and industry, for possible reissue. In this way, Ireland's crustacean and molluscan fisheries would no longer be open access, fishers and their next of kin would be guaranteed use of a licence for their working lives and licences would not become commodities. Thus, co-operative management would have no other end but to organize the preservation of the fishery.

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9. European fisheries inside 12 nm: the role of delegation in effective management

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Introduction

[W]hereas the European Community has assumed responsibility for fisheries management throughout the 'common pond', it has left exposed a vital hole in respect of inshore waters which Member States have been slow to infill. As a result, there is in many European countries a policy vacuum in respect of inshore fisheries (Symes 2002: 113).

The European Commission (EC) has delegated much authority to Member States for the management of fisheries inside 12 nm, often referred to as inshore fisheries. This delegation was made in 1992, and was extended as part of the 2002 review of the Common Fisheries Policy (CFP). A Member State now has responsibility for managing the fishing activity of all vessels within 12 nm of its coast, regardless of nationality. It is also possible for Member States to delegate management to sub-State regions. This scale of delegation is uncommon. There are, however, some notable exceptions. In England and Wales and France for example, inshore fisheries management is principally organized within sub-State geographic units. Thus, in combination there are 12 Sea Fisheries Committee (SFC) areas in England and Wales, and 39 local *Comites des Peches* (CPs) within 10 *Regional Comites* in France. These committees represent significant delegation of authority and operations from central administrations. However, centralised so-called command and control management systems, such as evident in Portugal, Ireland and many other European Union (EU) Member States is still common.

Given extension of the CFP inshore delegation to Member States and an increased awareness of the importance of local sensitivity and inclusiveness of the fishing industry in management, are there lessons to be learnt from the experience of delegated authority for fisheries management in England and Wales and France or indeed from any other parts of the world? In North America and Australasia, for example, management is clearly organised around species and uses advisory committees to provide industry input to multi-annual management plans. Do these management systems work better than the European models in terms of achieving sustainable exploitation, industry viability and integration with other stakeholders in coastal zone management? Answering this question involves exploring the balance between delegation and integration. Just what power is a Member State to delegate, and how will it be ensured that the operations of the delegated authority are consistent with national policy? Is it possible to delegate too much and lose co-ordination? What types of statutory instrument might be involved? What should be the relationship between a responsible Minister, his or her government department and the delegated authority? How is communication among authorities, necessary to deliver integrated management, developed within delegated systems? The aim in this paper is to address such questions with a view to suggesting elements of a management model for inshore fisheries in Europe.

This paper details management that exists at present inside 12 nm regarding crustacean fisheries in EU Member States. Crustacean fisheries are the main type of fishery inside 12 nm of many Member States especially in northern Europe. Two examples of delegation inside 12 nm are discussed, SFCs in England and Wales, and CPs in France. These examples are contrasted with the type of management of Ireland's crustacean fisheries, which is common among Member States. In Ireland, arrangements are centralised, and communication with industry and integration between sectors are *ad hoc*. These European examples are then compared with a management system commonly used in crustacean fisheries outside Europe, species-based management using advisory committees. The example presented is the southern rock lobster fishery in Tasmania, Australia. Lastly, after presenting a definition and rationale for effective management, we compare and analyse the characteristics of each system and present a model that might be capable of delivering more effective fisheries management in coastal waters inside 12 nm of EU Member States.

Description of the systems

Sea Fisheries Committees

Origin and organisation: Sea Fisheries Committees (SFCs) were established in 1888. They are central to the management structure and are empowered to make bye-laws for management and conservation of fisheries in their districts. In 1995, their powers were widened to include control of fisheries for environmental reasons.

SFCs vary in organisational structure. Only one employs less than one full time officer, whereas others employ over 20 full time staff. Most positions are for fisheries officers who are concerned with enforcement both at sea and at the point of landing, but who also collect fisheries data and carry out administrative duties. SFCs may also employ researchers. Research is a statutory function of the Department for Environment, Food and Rural Affairs (DEFRA) and its agency the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), but the SFCs fill some gaps and play an important role in surveying, developing and managing local stocks inshore. Duties and functions of staff vary between districts. Staff of larger SFCs have more specialised duties, e.g., enforcement, research and administration.

Legislation: Basic powers are contained in the *Sea Fisheries Regulation Act 1966*, the *Sea Fisheries (Conservation) Act 1967* and the *Sea Fisheries (Shellfish) Act 1967*; this last Act was reviewed in 1997 to include crustacean fisheries.

Authority: SFCs have scope to make bye-laws and issue regulating orders (ROs) specifically for the management of shellfish out to six miles from the coast and are responsible for enforcement in all fisheries within their boundaries. This responsibility overlaps with DEFRA which has authority out to 200 nm. SFCs tend to undertake shellfish enforcement, and most whitefish enforcement, within their districts. Bye-laws need to be approvide by DEFRA and the EU Commission. SFCs are not involved in quota control or licensing (other than under regulating orders) which are within the jurisdiction of DEFRA. As noted, since the 2002 review of the CFP, there is potential for SFCs to develop and enforce regulations on all vessels fishing within 12 nm, regardless of nationality. All but one SFC have their own patrol vessel that are able to operate in coastal waters. In a limited number of estuarine locations the Environment Agency which deals with inland waters and freshwater fisheries including salmon and eel acts in the capacity of a SFC.

Geography: SFCs have responsibility for coastlines varying from 80 to 800 kilometres in length and regulate the activities of between 150 and 1800 fishing vessels. The main fisheries are potting for crabs, lobsters and whelk, and netting whitefish, although there is extensive netting for shellfish off the south-west of the English coast. There are significant interactions between potters, netters and trawlers in the form of ground use conflict and by-catch mortality in nets and trawls.

Membership: Committee vary in size from eight to 36 people. The average size of an SFC is approximately 20 people. Half the places are reserved for representatives of local authorities which fund the SFC. The remaining places are filled by Ministerial appointees, including representatives from the fishing industry, an officer from the Environment Agency, a representative of marine environmental interests and a normally a recreational fisher. The local DEFRA fisheries inspector will also usually attend the quarterly meetings of the Committee in the capacity of an observer. Representation of commercial fishers may be less than one-third of the committee and representatives may not necessarily be from the inshore sector. In practice DEFRA exercises close control over the list of appointees and the local DEFRA district inspector can be expected to play a key role in the selection of the appointed members. The Chair of the committee is usually a long-standing member of the local fishing industry, but some committees appoint their Chair from among local authority representatives.

Funding: SFCs are funded by local authorities which have discretion as to the level of funding provided. SFCs' budgets vary from greater than €1 million to less that €0.2 million per annum. Level of funding is not related to geographic extent or the number of fishers within SFCs' districts.

Operations: Under the Order that establishes each committee, a committee is required to meet formally four times a year, although extraordinary meetings may be called. A number of SFCs have sub-committees.

The local fishing industry is informed of new proposals through a variety of means. DEFRA representatives are expected to disseminate information through their network of contacts and fishermen's associations, fishery officers are expected to discuss proposals with fishers on an informal basis. Questionnaires may be periodically distributed to the inshore fleet and meetings are held with fishermen's associations. The minutes of SFC meetings are publicly available, and public and the press are invited to attend the quarterly meetings.

The flow of information is two-way, in that proposals for bye-laws are almost invariably initiated by industry. Generally, before a bye-law proposal is finalised by an SFC, industry is informally consulted to gain feedback regarding the likely response to any new measure. Once a bye-law has been finalised by a committee, and before the Minister considers it, a statutory consultation period of 28 days must elapse. The time lag between the submission of thwe proposal to DEFRA and confirmation of the bye-law will normally be several months and may occasionally last for a number of years.

To institute change to inshore management at nationalrather than local level the Fisheries Conservation Group representing all aspects of the industry meets with DEFRA to discuss conservation issues. The group is composed of industry representatives, inshore management, the Shellfish Association of Great Britain (SAGB), CEFAS scientists and the relevant government departments. The group was set up in response to a request from the Fisheries Minister to Seafish to co-ordinate the idnustry's input; SAGB were given responsibility for representing the interests of the shellfish sector within the group. The minuts of the group0 meetings are circulated to the SFCs.

Should central government wish to institute changes to regulations etc a consultation documet is prepared for the industry's consideration. Where the industry is in agreement the process will usually result in legislation although this may take some time. Legislation may also be introduced without consultation.

SAGB may also make, on request from it's members, proposals to the Fisheries Minister to amend existing legislation or enact new regulations.

The SFCs until recently have been poorly co-ordinated at the national level. An Association of Sea Fisheries Committees (ASFC) was formed in 1919 to assist the Committees in their regulatory management and development functions and where appropriate to promote their interests with central government and other relevant organisations. However, until recently, the Association has acted mainly as a trade organisation, serving as an advice and information centre rather than as a fisheries management organisation. As a result SFCs have acted as independent bodies. This situation is now changing with the Association takeing a more active interest in issues of broad policy making but still unwilling to interfere with the autonomy of the individual SFCs. In addition the Chief Fisheries Officers of the 12 SFCs meet on a regular but infrequent basis to discuss technical matters relating to inshore management.

Regulatory system: Fisheries managed by SFCs are open access except that all SFCs have adopted bye-laws restricting the length of vessel permitted to fish in all or parts of the waters under their jurisdication. The principle conservation tools available to SFCs are minimum landing sizes and specifications for the deisgn of fishing gear. Bye-laws regarding minimum landing sizes must be more stringent that in EU legislation. Fishers must have a DEFRA licence, and some SFCs require a permit to target shellfish. These licences and permits, however, do not limit access at the scale of SFC districts or individual fisheries, only at the macro scale defined by the fleet capacity limit imposed on the UK by the EU MAGP as part of the CFP. Coastal fisheries in England and Wales have proved increasingly lucrative in recent years, and much fishing effort has transferred from the whitefish sector to inshore pot fisheries. Pressure on these fisheries is also increasing due to the use of more gear per vessel.

SFCs can regulate fishing activity by two means: bye-laws; and regulating orders (ROs) and/or several orders (SOs). Bye-laws are passed in response to issues that arise in the fishery, i.e., they are reactive rather than proactive. Regulating and several orders give power, in particular, to limit the number of licences in a fishery. An order may be granted for up to 60 years, but 30 years is more common. An order effectively gives a right of access to a specified fishery. Regulating orders can only be applied to molluscan and crustacean fisheries. Inside the time specified, the number of licences can only be reduced naturally, and the nature of the entitlement cannot vary among licence holders. Part time fishers therefore have the same entitlements as full time fishers. Thus, it is difficult to balance fishing effort with stock abundance. Licences under regulating orders cannot be leased or sold. ROs may cover significant areas of coastline. The only existing one that includes crustaceans is the Shetland RO.

Scientific input: Regular inshore stock assessments are not undertaken by SFCs or by other agencies as a matter of course though a number of SFCs have initiated stock assessment projects for their own districts. Scientific advice is given on the impact of change of minimum size legislation regarding yield per recruit optimisation. Surveys and assessments of molluscs, in particular, are more common in areas under regulating orders. Monitoring is undertaken by CEFAS which uses index vessels to estimate catch and effort, although there are difficulties in matching these estimates to SFC boundaries.

Characteristics of the licence: Most DEFRA licences give a right to fish for all species not subject to quota management. SFC permits may give general entitlements or refer specifically to shellfish. There are no species specific licences outside areas controlled by regulatory or several orders. DEFRA licences are transferable but SFC permits are not. The market value of a licence depends on vessel capacity units (VCUs) (overall length x breadth + engine Kilowatts *0.45) as well as on any quota allocated to that licence in the case of vessels over 10 metres in length. In the case of vessels under 10 metres, licence value depends on VCUs only as no individual quotas are allocated to vessels in this sector. Transfer of licences is through the private market, in which no allocation preference rules exist. SFC permits are issued to all comers conditional on vessels being registered and licensed. Licences and permits are issued for one year. Re-issue is a formality provided these conditions are met. Vessels over 10 metres are required to complete an EU logbook. SFC permit schemes require catch and effort reporting.

Comites des Peches

Origin and organisation: Professional fishermen's organisations were established in France in 1938. Prior to 1991 they operated at two scales:

- A national Comité Central des Pêches Maritimes (CCPM); and
- Forty seven local Comités Locaux des Pêches Maritimes (CLPM) distributed along the Channel, Atlantic and Mediterranean coasts.

In 1991 the following changes were made:

- *National scale*: the CCPM was replaced by the Comité National des Pêches Maritimes et des Elevages Marins (CNPMEM hereafter CNPM). The CNPM is composed of a General Assembly (136 members), a Conseil composed of 50 of these 136 members at a more executive level, and a Bureau of 12 of these 50 members which meets to deal with urgent issues.
- *Regional scale*: a new regional level of organisation was created. A Comité Régional des Pêches Maritimes et des Elevages Marins (CRPMEM hereafter CRP) was created in each of France's 10 coastal administrative regions.
- *Local scale*: Some CLPM were merged, reducing their total to 39.

All scales come under central government administration.

Membership: Anyone working in the field of production (i.e., fishers or sea fish farmers), as fishmongers or in processing, must belong to a CLPM.

At the national scale (CNPM) the composition of the General Assembly and Conseil must follow strict rules taking into account the profession and the level at which members work in the fishing industry, e.g., are they a skipper or crew and so on (Table 1).

Table 1. Composition of the General Assembly of the CNPM

Working area	***Members***	***Of which Crew, workers***	***Of which Skippers, owners (heads)***
Crew, skippers and/or boat owners, fish farmers	72	*36*	*36*
First buying industry	10	*5*	*5*
Transformation industry	10	*5*	*5*
Sea weeds	2	*1*	*1*
Maritime cooperation	16		
Regional committees	26		

At the regional scale there is no general assembly. A regional Conseil has a maximum of 70 members elected for 4 years. The Conseil elects a president and two or more vice presidents for the same duration. Rules for membership are similar to those at the national scale.

The local scale largely mirrors the structure of the regional scale, with a maximum of 70 members on any Conseil. At national and regional levels, the Conseil must meet at least four times a year. This is necessary to consider proposals from Special Commissions (see below).

Geography: The present number of local comites in France is 39: 14 along the Channel, 18 along the Atlantic coast and seven along the Mediterranean coast. The length of coast per local comite varies from less than 50 kilometres to more than 100 kilometres. The number of fishers in a local comite's area varies from less than 200 to more than 500. There is also variability at the regional scale. The length of coastline of CRP Bretagne, for instance, is approximately five times that of CRP Haute Normandie. The number of fishers in CRP Bretagne is around 6,900 (1,650 boats) while in Basse Normandie it is 1,800 (650 boats).

Operations: As noted, it is compulsory for all fishers to belong to a CLPM. CLPMs do not undertake management but are organisations focused on local issues relating to the development of fisheries. CLPMs have no decision-making powers. They do, however, have financial autonomy. Prior to 1991, they levied an *ad valorem* tax on landed products. Since 1991, their levy relates to fishers' incomes.

Most of the business of the CNPM and CRPs is done through working groups and Special Commissions. Working groups are composed of scientists or other experts who meet for a limited period to work on a specific technical issue. Special Commissions assess a number of species-based fisheries: crustaceans, clams, white tuna, tropical tuna, red tuna, anchovy and pilchard. A special commission can meet one or several times a year to discuss the regulation of a fishery. Areas of regulation may include size of the fleet, quota management, licensing, gear regulations and closed seasons. The French Research Institute for Exploitation of the Sea (IFREMER) is generally invited to all Special Commission meetings, at both national and regional levels. Special Commissions make proposals to the Conseil of the CNPM or CRP to which it is related. If validated by the Conseil, as is generally the case, a proposal becomes a deliberation. A deliberation, however, only becomes statutory law with the agreement of the Central Government administration. This agreement is through the Ministry if it is a national issue or through the Préfet de Région if the issue is regional.

Regulatory system: Crab and lobster fisheries are regulated by limited entry. Each vessel must be part of the national MAGP fleet, but there is no specification of the type of vessel that can obtain a crustacean licence (a crustacean licence excludes *Nephrops* and *Pollicipes*). Only potters and netters qualify for a crustacean licence. Trawlers may land no more than 10 per cent of the weight of their catch as crustaceans. Minimum size limits apply in all fisheries. Number of pots that can be used per vessel varies according to number of crew and the region in which the vessel is fished.

Scientific input: No regular stock assessment is undertaken in any fishery. Completion of logbooks by licence holders is mandatory. Catch and effort data are used to assess the fishery. Scientific advice is contributed via Special Commissions.

Licence characteristics: Licences are issued for one year and are non-transferable. Skippers are not allowed to nominate another person to fish the licence. After one year the licence reverts back to the CRP. If the characteristics of the operation associated with the licence have not changed, the skipper will, on request, receive the licence for another year. If the vessel or skipper has changed then a decision is made according to priority access rules. In crustacean fisheries, preference is given to applicants who held a licence in the previous year and fished according to logbook and tax returns. Second order priority is given to crew members in the previous year, while third order priority is given to skippers in other fisheries who wish to transfer to crustacean fisheries. Lowest priority is given to new entrants with new boats. An annual licence fee is charged. This is related to the number of pots fished and varies from €140-400.

Ireland

The two examples of delegation of inshore crustacean fisheries management in Europe to regional authorities of SFCs and CPs contrasts with situations in other EU Member States. In this section, the situation in Ireland is presented as an example of largely centralised fisheries management that fails to be effective at sub-national scales.

Authority: Responsibility and authority for management of fisheries in Ireland rests with the Minister and the Department of Communications, Marine and Natural Resources (DoCMNR) under the *Fisheries (Consolidation) Act 1959*. Under the Act, the Minister can pass laws in relation to sea fisheries. The DoCMNR controls licensing policy and enforces EU and national regulations regarding fisheries. Authority is centralised and hierarchic.

Geography: The DoCMNR regulates fishing activity along the entire coast of the Republic of Ireland (4,700 kilometres). Approximately 2500 vessels and over 4000 fishers operate within 12 nm of this coast. The main fisheries within 12 nm are potting for crustaceans and whelks, netting for whitefish and dredging for bi-valve molluscs. Interactions between static and mobile gear does occur, but by-catch of crustaceans in trawls is not significant.

Organisation and operations: Administration and issuing of licences is handled centrally by DoCMNR. It employs enforcement or Fisheries Officers (FOs) to oversee fisheries regulations. FOs are not sea going, and have additional responsibility for food safety and hygiene. Administration transposes EU fisheries legislation into Irish law, and imposes additional restrictions at the request of industry and/or scientific advisors. Agencies of the DoCMNR are the Marine Institute, which is responsible for providing scientific advice, and BIM (the Irish Sea Fisheries Board) which is responsible for sustainable development of fisheries. Both agencies employ staff in coastal regions and BIM, in its development role, maintains regular and close contact with industry.

There are no statutory management or advisory committees overseeing regulation of fisheries in Ireland. Industry co-operatives (‘co-ops’) are consulted by DoCMNR and its agencies prior to enacting legislation. In recent years, some legislation regarding closed areas and seasons has been initiated by industry ‘co-ops’. Such initiatives have been *ad hoc*, however, and there is no authority delegated to ‘co-ops’. Over the past 10 years, ‘co-ops’ have sought a greater input to management. In the case of the lobster fishery, for instance, the introduction of limited entry was formally requested in 2001, without success.

Funding: The Irish Government funds the operations of the DoCMNR. There is no cost recovery from industry. Co-ops are self-funding through annual membership fees. These fees are not used to employ staff but largely to fund lobster v-notching schemes, for example, which are also granted aided by the DoCMNR through BIM.

Communication: Communication between management and industry is *ad hoc*. If sufficient pressure is applied by industry, and there is scientific support for any proposed action, new regulations may be introduced. The process of enacting new regulations is straightforward. The Minister can sign into law new regulations. Any new regulations are usually based on scientific advice and may have been developed in consultation with industry.

Regulatory system: Like the UK and French fleets, the Irish fishing fleet is divided into segments which target different fisheries. The segments in Ireland are pelagic, polyvalent, beam trawl, bi-valve and inshore potters. The capacity of each segment is capped by the MAGP within the EU CFP. Polyvalent licence holders can access bivalve and pot fisheries, and there is no geographic restriction on vessels. In this way, individual crustacean and molluscan fisheries are open access, i.e., any polyvalent vessel or inshore potter can transfer effort to a particular fishery in a particular location. Many of the finfish stocks are quota managed, as is *Nephrops*. Shellfish, however, are regulated almost solely by minimum landing sizes. In some cases, closed seasons and areas are in place and there are additional technical measures regarding the types of fish that can be taken.

Scientific input: No regular stock assessment for crustacean or molluscan fisheries is undertaken in Ireland. Logbooks are not mandatory for vessels under 15 metres in length. BIM initiated voluntary logbook schemes in 2001. Catch and effort data have been compiled for lobster and crab fisheries from skippers' fishing diaries. Egg per recruit and size at maturity data are available for most species and are used to set minimum landing sizes.

Characteristics of the licence: Polyvalent and bivalve fishing licences used to access most of Ireland's marine resources are traded on the private market and have reached a high value (€3-4000 per gross registered tonne of vessel) relative to the earning capacity of vessels. New inshore potting licences may not be transferred, though the system has yet to prove that *de facto* private transfer can not occur. The trading of licences for high prices has developed despite the insecurity of open access and increases in fishing effort in most shell fisheries. Licences are renewed every three years. Renewal is automatic.

Fisheries management using species-based advisory committees

In contrast to crustacean fisheries management in Europe, various types of *advisory* committee are used to assist management of fisheries in North America and Australasia. In Australia, for example, all coastal State and Territory governments use advisory committees regarding fisheries management (Table 2).

Table 2. Comparison of Broad Features of Australian State and Territory Fisheries

State/ Territory	**Stand-alone Government Agency**	**Primary Value of Commercial Production[a] (million)**	**Management Advisory Committees[c]**	**Statewide Cross-sectional Co-management Body**
Queensland	No	$241	Yes	No
New South Wales	Yes	$121	Yes	Yes
Victoria	No	$80	Yes	Yes
Tasmania	No	$214	Yes	No
South Australia	No	$348	Yes	No
Western Australia	Yes	$410[b]	Yes	No
Northern Territory	No	$82	Yes	No
Common-wealth	Yes	$408	Yes	No

[a] Source: Australian Bureau of Agricultural and Resource Economics (2000), *Australian Fisheries Statistics 1999*, Canberra. [b] Excludes pearls. [c] These are mostly single sector, although some are cross sectoral, that is, for example, include both recreational and commercial fishers. From: Parliament of Victoria's Inquiry into Fisheries Management, 2000, http://www.parliament.vic.gov.au/enrc/fisheries/1st_Report/Chapter2-01.htm (accessed 26/9/2003).

The Federal Government's Australian Fisheries Management Authority also uses advisory committees. Most advisory committees are *species-based*. Regarding crustacean fisheries management, an example of the operation of a species-based advisory committee is the Tasmanian commercial southern rock lobster (*Jasus edwardsii*) fishery.

Under the Tasmanian *Living Marine Resources Management Act 1995*:

1. The Minister may establish advisory committees to provide information and advice to the Minister on matters related to the administration of this Act.
2. The Minister may appoint any person as a member of an advisory committee on any terms and conditions the Minister determines.
3. The Minister may abolish an advisory committee at any time (Part 2, Division 2, Section 27).

Clearly, then, a fishery advisory committee (FAC) advises the Minister, but it can also operate as something of a think-tank.

> A FAC is a major source of advice to the Minister … on issues relating to a fishery. The FAC is a forum where issues are discussed and possible solutions developed for consideration by the Minister.
>
> The Minister may seek advice from sources other than the FAC. The advice of the Director, Marine Resources [at the Department of Primary Industries, Water and Environment] will be sought by the Minister as a matter of course.
>
> The FAC is an adviser to the Minister who is responsible for the final management decisions made under the … *Act* …
>
> FACs are expertise based, advisory in nature and make recommendations to the Minister … (DPIWE 2003).

Four FACs have been established in Tasmania, one each for abalone, crustaceans, scalefish and scallop. The Crustacean Fishery Advisory Committee (CFAC) deals principally with two species, rock lobster and giant crab (*Pseudocarcinus gigas*). Its membership is comprised of:

- the executive officer of the Tasmanian Rock Lobster Fishermen's Association (TRLFA);
- three industry members from the TRLFA;
- one industry member nominated by the Tasmanian Fishing Industry Council;
- one rock lobster fisher not aligned with the TRLFA;
- one industry representative of the giant crab fishing industry;
- one giant crab fisher with more than 15 quota units;
- one processing sector representative;
- one fishery manager from the Department of Primary Industries, Water and Environment (DPIWE);
- two scientists from the Tasmanian Aquaculture and Fisheries Institute;
- one Marine Police representative;
- the DPIWE Chief Fisheries Investigations Officer;
- one representative from the Tasmanian Conservation Trust;
- an independent Chair; and
- an executive officer provided by DPIWE.

In total, therefore, 17 people sit on the committee. Additional individuals may address the committee concerning specific issues. The Minister may request advice regarding a specific issue, or the committee may initiate advice to the Minister. In terms of the production of formal documentation by the committee, it may develop a draft code of practice for consideration by the Minister. This code, if approved, acts as a non-mandatory guide to employers aimed at ensuring that operators fulfil their duty of care regarding workplace health and safety. Management plans for the fishery are devised by DPIWE. These are reviewed in draft by the CFAC so that it can advise the Minister. It is rare that a decision is made by the Minister relating to the fishery without the advice of the CFAC.

In effect, then, the CFAC operates to bring regulators (DPIWE), scientists, police, industry and environmental interests together to provide joint advice and proposals to the Minister. A separate Marine Recreational Fishing Council advises the Minister regarding the recreational sector. The committee is a forum for brokering compromise and focusing advice to the Minister. Largely, the TRLFA is relied on to furnish industry representation on the committee. The procedure of the TRLFA for selecting its representatives is assumed to be democratic. Officers of DPIWE and any individual can, of course, make separate representations to the Minister.

The CFAC was closely involved in the most recent change in management system in the Tasmanian commercial rock lobster fishery. ITQs were introduced in the fishery in 1998. According to DPIWE, "[t]he CFAC played an important role in the development of the new Fishery Management Plan that embodies the quota system" (http://www.dpiwe.tas.gov.au/inter.nsf/Attachments/ECAL-5L629T/$FILE/Tasmania's%20Rock%20Lobster%20Industry.pdf, accessed 29/9/2003). The CFAC continues to be central to adjustments to this quota management system.

Advantages of Ministerial advisory committees are that they:

- facilitate informed decision-making by the Minister;
- do not diminish the Minister's responsibility to manage on the public's behalf;
- do not require any unwieldy structures of delegation;
- they are co-operative bodies;
- they are capable of responding quickly to a request for advice;
- the link between committee (advice) and Minister (decision) is direct;
- they provide a forum in which different perspectives can be brought together;
- they aim to reach compromise;
- they are low cost compared with many delegated authorities;
- they add legitimacy to management decisions; and
- that by involving industry they may make compliance more likely.

Disadvantages of advisory committees include that:

- representation of industry may only be partial in coverage;
- industry representation may not be generated democratically;
- a committee has no power either of decision or action;
- a committee's advice may be ignored by the Minister;
- a committee may not be able to reach compromise;
- deliberations of a committee may be slow;
- a committee may become personality rather than issue driven; and
- industry representatives may become 'stale', 'burned out' or disillusioned with serving on the committee.

In summary, an advisory committee steers a fine line between being perceived by industry as simply another layer of 'toothless' and dilatory bureaucracy, and operating as a nuanced, legitimate and valued voice for relaying fishery perspectives to the Minister. Realising the advantages of an advisory committee is largely a matter of the maintenance of goodwill among its members and with the Minister, as well as the development of confidence in its role among industry.

Analysis

Defining Effective Fisheries Management

What is fisheries management meant to achieve? Two goals are common: sustainable exploitation of the target biological resource; and viability of the operations fishing it (Table 3).

Sustainable exploitation requires that fishing activity does not have harmful ecosystem effects, i.e., that impacts on non-target species and the reproductive capacity of target species do not involve changes that are irreversible, or induce significant changes to ecosystem structure or function. Developing and maintaining fishing practices to guarantee such sustainability is a fundamental priority for fisheries managers. The activity of fishers is a crucial control point, and fisheries management is largely about designing rules and persuading licence holders to abide by them. Tension exists between the desire for short-term gain and the need to sustain an activity in the long-term. This tension is likely to be greater in an environment that is unpredictable and multi-user.

Viability of the fishing operation is often expressed in terms of economic efficiency. Economic efficiency can be optimised at high stock levels and high catch rates relative to the cost incurred in catching fish. This guarantees that target stock is held within safe biological limits as the point of maximum resource rent occurs below the point of recruitment failure. However, the legitimate social objective to distribute widely the benefits of natural resources to the community can result in pressure to increase participation at the expense of individual economic efficiency. This is particularly likely in coastal fisheries where only low levels of capital are required to enter fisheries and benefits are traditionally of a depth and breadth that a community may be dependent on the resource.

The difficult requirement to combine biological, economic and social objectives suggests that a management system needs to be consultative in developing regulations. A management system also needs to be adaptable. Decision-makers need to be informed of the uncertainty inherent in predicting biological processes. Acknowledging this uncertainty, however, clear policies, objectives, targets and systems to manage multiple user groups are necessary.

Table 3. Aspects of sustainable and viable fishing in management of fisheries

Sustainable fishing	Viability of fishing
Environmental Protection	**Control participation**
- Gear design, MPAs	- Control entry
- Codes of conduct	- Agree access rules
- Interagency communication	- Adjust and adapt to conditions
Spawning stock conservation	**Optimise value**
- Size limits, seasonal and area closures	- Yield per recruit
- Regulation of effort	- Optimise fish quality
- Quota	- Marketing of product
	- Added value
Activity of fishers	**Minimise costs**
- Codes of conduct	- Entry costs
- Communication and education	- Management costs
- Stewardship and enforcement	- Operating costs

Strengths and weaknesses of each system

Characteristics of the systems described are summarised in Table 4.

Policy and species: The basic unit of management in fisheries is the stock of a single species. This is the reproductive unit and the unit of biological production. Of the systems described here only management in Tasmania focuses on individual stocks of a single species. Multi-annual management plans contain explicit policy for control of single species/stocks.

Although technical conservation measures in Europe, such as minimum landing sizes, focus on species, licensing policy does not. CPs issue licences that include crustaceans among other fisheries, SFCs issue general fishing permits, and the Irish system issues polyvalent fishing licences. Administration therefore does not usually know how many fishing vessels are targeting which species.

In Tasmania, input and output controls operate at species level, and objectives and performance indicators in fishery management plans allow performance to be evaluated.

Management structures and stakeholder involvement: The Irish system is centralised and 'top down'. There are no advisory bodies for crustacean or molluscan fisheries. In Tasmania, advisory committees exist for particular species. These provide management the opportunity to focus on species and consult with stakeholders. Approximately half the advisory committee is comprised of licence holders. Although fishers are represented on advisory committees, however, this does not guarantee that issues raised represent the views of industry. Democratic procedure is best pursued through representative structures within industry. Where these do not exist, they need to be developed. In Tasmania, there is a possibly low level of communication between some licence holders and their putative representatives. DPIWE therefore communicates with every licence holder by post regarding draft management issues. DPIWE also conducts annual port meetings with industry.

There is no regional management in Tasmania. Stocks and fishers are managed at a single Tasmania-wide scale. By contrast, SFCs in England and Wales are regionally organised, with the result that the national fishery for a given species is overseen by 12 committees. Regional and local management structures increase the scope for inclusion of industry. In effect, however, in SFCs industry does not always have strong representation (less than one-third of seats may be filled by industry) and appointment of representatives is by the Minister. There is no industry organisation at local level to receive feedback from SFCs. SFCs are also weakly integrated at a national level. Although an Association of SFCs exists, its inclusion in the management system is weaker than the CNPM in France.

There is significant integration in the French system. The hierarchy of organisation ensures industry involvement. To obtain a licence a fisher must be a member of one of the 39 CLPMs. Special Commissions and working groups propose changes in regulations and these pass through local and regional levels before ratification. The Comites delegate functions to their Conseils and Bureaus. Many proposals arise from CLPMs. Horizontal integration is facilitated by inclusion of individuals from all relevant industry sectors at local, regional and national scales. CRPs differ regarding the areal extent and diversity of fisheries they are required to administer. Regions are not designed with fisheries in mind, however, but map onto existing administrative government areas.

Management focuses on species in Tasmania. Advisory committees deal with a single or limited number of species, and species-based management plans are central to their discussions. In France, stronger emphasis is placed on achieving input from industry. Comites, however, deal with more than one species; they are management comites for all fisheries in their locality or region. There is less focus therefore on individual species and no management plans to orient discussions. SFCs are also concerned with all fisheries in their districts. In Ireland, management may take the form of a dictate from central administration or be developed through *ad hoc* consultation with industry. No formal procedures exist for including industry in decision-making.

Regulations: Neither Ireland nor SFCs comprehensively control either inputs (effort) or outputs (quota). They rely instead on technical conservation measures such as minimum landing sizes or on operational restrictions such as seasons or closed areas. Switching between fisheries is common in what are essentially open access systems, within the constraints of national fleet capacity set by the EC MAGP. CPs limit entry and effort at a generic (crustacean) rather than a species level. Control of exploitation on species therefore depends on total generic effort and on technical conservation measures. In Tasmania, both limited entry and quota management are used at the species level. These enable control of the rate of exploitation.

Stewardship and policing: Policing is the responsibility of the central authority in Ireland, France and Tasmania, but is delegated to SFCs in England and Wales. Stewardship by industry in Ireland is only weakly developed. Lobster co-operatives operate v-notch schemes and, during the 1990s, were a voice for conservation of lobster stocks. This resulted in increased awareness of the need for additional regulation and introduction of limited entry was proposed. Lobster ‘co-ops’, however, had no delegated authority and were powerless to change licensing policy. Stewardship and goodwill were eroded as a result, and lower levels of lobster v-notching, and a sense of frustration with central administration, ensued.

SFCs have an effective policing programme. Officers are provided with a vessel from which to monitor regulations at sea. In this way, compliance regarding minimum landing sizes and mesh sizes is largely ensured. The *Sea Fisheries Regulation Act 1966*, however, does not allow SFCs to enforce local regulations if their breach is within national or neighbouring SFCs’ limits. Enforcement of local technical measures can therefore be problematic. Regarding CPs in France, compliance with trap limits is the most difficult aspect of enforcement. Though they must be tagged, traps are not inspected at sea. Ineffectiveness of enforcement is a significant and recurrent problem for CRPs as it discourages stewardship. Some CRPs are pressuring central government regarding enforcement and the situation is improving. For instance, the Basse Normandie CRP informs central government on fisheries regulations that should receive enforcement priority at different times of the year, or as issues arise. Some inspections are now being carried out, but control of limits on fishing gear remains difficult.

In Tasmania, marine police enforce fisheries regulations. This is achieved both at sea as well as in concert with central administration. Up-to-date catch records ensure that a paper trail exists that can be policed on land.

Property rights and licences: Open access fisheries in Ireland provide little exclusivity of access to licence holders. Switching between fisheries is not restricted by present licensing policy. In particular, the catchall polyvalent segment has access to a wide range of fisheries. Most inshore operators are diversified and seasonal, something acknowledged by polyvalent licences. Insecurity exists due to the threat of effort transfer from the large boat sector to coastal pot and static net fisheries. This is less of a threat in England and Wales where, although DEFRA licences give entitlement to fish in particular fleet segments, SFC permits geographically restrict which species vessels can fish within SFC districts. DEFRA licences are generally able to be transferred from one International Council for the Exploration of the Sea (ICES) (and SFC) area to another, except for beam trawl licences which are restricted geographically according to conditions attached to each licence.

In England and Wales, VCUs for vessels under 10 metres sell for £120-£130 per unit (September 2003). SFC permits are not transferable, but DEFRA licences are sold on the private market. Exclusivity and security regarding licences are provided by CPs in France.

Vessel capacity (tonnage and kilowatts) represents about 50 per cent of the entry cost to the fishery. Access to crustacean fisheries is limited, as is individual effort. The group of licence holders entitled to access crustacean fisheries is limited and no transfer or nomination is allowed. There is also a set of access priority criteria.

Licence security and exclusivity are greatest in Tasmania. The number of licences is limited. Consequently, the cost of accessing a licence is high. Quota is allocated to individual licence holders. Quota is privately transferable. Market forces therefore determine the costs of entering a fishery. Initial allocation lead to windfall gains to the first generation of licence holders, at the expense of subsequent entrants. Today these entrants are often lessees due to high purchase prices. Increasingly, therefore, the fishery is non-owner operated. Licence holders constitute a strong lobby group and are consulted intensively regarding any management change. The situation is also co-operative in France where CPs, comprised of fishers, take a lead role in the development of regulations. Central administration does not dominate the system. In SFCs, although licence holders are represented, actions of the committee are restricted by DEFRA and existing legislation. SFCs are not free to institute any major change in management without negotiating with DEFRA. Powers of SFCs, beyond enforcement, are limited.

In Ireland, strength of title is weakest. Regulations can be introduced *ex cathedra* by central administration. As an EU Member State, management is further constrained and accountable to the EC and the CFP, even within 12 nm. Fleet capacity of Member States is capped based on historic activity. New technical measures can be introduced for particular species and apply to all EU Member States. Polyvalent, pelagic and bi-valve fishing capacity (without which a licence can not be obtained) is also privately transferable in Ireland, and cost is determined by supply and demand. This has not resulted in leasing on a large scale. However, much capacity is inactive and is transferred without being attached to a fishing vessel. The high cost of capacity has increased the amount of illegal fishing in Ireland. This fishing necessitated the introduction of a new segment of inshore potters to the Irish fleet in 2003. These potting licences are not privately transferable.

Trends in fishing and the fishery: The main goals of management are to ensure sustainable levels of exploitation and viability of operators. Trends in standardised catch per unit effort (CPUE) indicate the effectiveness of management. Environmental effects on recruitment, however, can play a role in the performance of fisheries independent of management. Strong positive or negative environmental impacts on recruitment should result in adjustments to effort or landings. Declining catch indicates that the level of activity is not sustainable irrespective of whether the cause is environment or fishery related.

Although there are few long-term catch and effort data sets available in Ireland, England, France or Wales, available data indicate different trends and catch rates. Egg per recruit in lobster (*Homarus gammarus*) fisheries in Ireland is below safe levels. In other Irish fisheries, there are trends showing decline in shrimp, *Palaemon serratus*, some crab fisheries, *Maja brachydactyla*, lobster, and *Palinurus elephas*. In France, strong recruitment of spider crab (*Maja brachydactyla*) and, to some extent, edible crab (*Cancer pagurus*) pre-dates the introduction of limited entry and cannot be said to be due to management. However, the current positive trend in catch rates may not have occurred if a cap had not been placed on effort. SFCs' catch rates of lobster are probably stable, but at a low level. The status of lobster stocks in England and Wales may be similar to that in Ireland. In Tasmania, catch rates of rock lobster and abalone are stable and high compared with those in Europe. Fishing effort is also stable as entry is limited and individual quotas apply. Quota can be taken efficiently with a low number of traps compared with Europe. A maximum of 50 traps can be used per vessel compared with 100s used by vessels in Europe.

Although crustacean fisheries in England, Ireland, Wales and, until recently, France are effectively open access, they have remained viable. Why, then, should further regulation be considered? Recent changes mean that viability is increasingly threatened. Traditionally, inshore vessels have been small (i.e., less than six metres in length), seasonally active and weather dependent. Recently, however, access has been gained to offshore stocks of crab and lobster. This constitutes new pressure on crustacean stocks. At the same time, decline in finfish stocks may have reduced predation pressure on or opened up new niches for crustaceans. Lately, recruitment has been increasing. The absence of management, however, is the major threat to the sustainability of current activity. Fishing effort continues to increase which means that, at some point, stock decline will recommence.

Viability of fishing in Ireland is reduced by high entry costs associated with purchasing fishing capacity on the private market and by low or unstable catches in some fisheries. Fishing costs have also increased as more gear is purchased to maintain volume of landings. Increased competition to access fishing grounds in static gear fisheries occurs as there is no control of inputs. Similar trends are occurring in SFC districts as there are no limits on entry or effort. This situation, however, may soon change. A national shellfish licensing scheme has been proposed for England and Wales. Cost of fishing capacity in the private market are lower than in Ireland. In France, purchasing vessel capacity (tonnage) doubles the economic cost of fishing. In Tasmania, fishing is profitable due to high catch rates. The costs for new entrants, however, are higher than in Ireland, which has the highest entry costs of the European systems. In Tasmania, one quota unit (145 kilograms of rock lobster) costs up to $50,000 on the private market. Despite high catch rates, the cost of quota is such that new owner-operators are few. The majority of new fishers enter the fishery as employees or lessees.

Table 4. Characteristics of fisheries management in four different systems

Characteristic	**SFCs**	**CPs**	**Advisory committees**	**Ireland (Centralised)**
Fisheries	All species	All species	Single species	All fisheries
High level policy	Non-specific	Non-specific	Explicit	Non-specific
Management plans	No	No	Yes	No
Statutory bodies	Yes	Yes	Yes	No
Regional structure	Yes	Yes	No	No
Local structures	No	Yes	No	No
Access to fisheries	Open	Limited	Limited	Open
Property right :				
Exclusivity	*Low*	*Medium*	*High*	*Low*
Quality of title	*Medium*	*Medium*	*High*	*Low*
Transferability	*Medium*	*Low*	*Private*	*High*
Duration	*High*	*Medium*	*High*	*High*
Policing	SFCs	Government	Government	Government
Trend in effort	Increasing	Stabilising	Stable	Increasing
Actual effort	High	High	Low	High
Communication	Informal	Formal	Formal	Ad hoc
Quota	None	None	ITQ	None
TCMs	Yes	Yes	Yes	Yes
Main gear	Traps/Nets	Traps/Nets	Traps	Traps
Main species	Crab, lobster, whelk	Crab, lobster	Lobster, ormer, crab	Crab, lobster, whelk, shrimp
Fisheries interactions	Strong	Strong	Few	Weak

Discussion and Conclusions

Fisheries within 12 nm of the European coast are characteristically artisanal, although there are advancements in technology and an increasing size of operating unit. Many thousands of people are directly employed in the inshore catching sector. This sector, for example, accounts for the majority of employment in fisheries in Ireland.

If it is to be considered effective, management must achieve sustainable and viable fisheries. None of the European management systems described here, either delegated or centralised, orient regulations, other than TCMs, to species. Thus, they cannot control inputs to or outputs from the basic unit of biological production, i.e., the species or population of a species. Without it being possible to do so, fisheries management cannot claim to be effective regarding sustainability and viability.

Finfish trawl fisheries in Europe are managed on a species basis through ICES/Advisory Committee on Fishery Management (ACFM). Annual quotas are set for particular stocks, despite there being significant biological and fishery interactions and discard mortality being high and only partly known. Some inshore fisheries, such as pot fisheries for crustaceans or dredge fisheries for bivalves, are suited to being managed on a species basis. By-catch is not significant, discard mortality is low in pot fisheries, and effort is readily quantifiable. Admittedly, there are fisheries interactions in both French and English waters, which increase the difficulty of species-based management. For example, in France incidental mortality of spider crab in trawl fisheries is an issue. In addition, a species-based approach may seem contrary to recent emphases on multi-species assessment, ecosystem based management and integrated coastal zone management. An ecosystem based approach to management, however, must begin by addressing its fundamental units of composition, i.e. its component species.

Species, then, should fundamentally define the purview of management. Any regional boundaries created by government and industry need to be treated as transparent layers above this fundamental level. The SFC CP boundaries, however, are related to administrative units rather than to fisheries. Regionalising the operations of the catching sector within a Member State should only be justified by differences in species biology, stock structure and distribution. There may be sound reasons for regionalising onshore activities. Whatever these reasons, effective communication is needed across fiat boundaries, especially if these do not match the boundaries of stock distribution. SFCs' and CPs' boundaries are not coextensive with stock distributions. If communication across such boundaries is ineffective, stock management may be ineffective. For example, different types of regulation (TCMs and effort control) are applied to the same stocks straddling SFC and CP boundaries.

Many species of crustaceans in Europe's inshore fisheries have spatially persistent local or regional distributions, and biological variability between regions is strong. In such cases, for management to be successful it is necessary to consider both local biology and local industry. Delegation of management to levels below central government is not a formula in itself for effective management of fisheries. However, delegation, as seen from the systems described here and compared with central management in Ireland, tends to promote increased industry involvement, without which effective management is unlikely. Industry stewardship will only develop if industry participates in management decisions and is given cause, such as an appropriate private property right, to consider long- as well as short-term time frames. Delegation has advantages such as increased awareness of the importance of sustainable practices, increased stewardship, inclusiveness in decision-making and better informed management. Many of the weaknesses of the delegated systems tend to derive from tensions between the delegating authority, the delegated authority, and industry. Roles and responsibilities of state and industry need to be made clear. New legislation should accompany the establishment of any delegated authority. Development of effective relationships between a central authority and the delegated authority, and between the delegated authority and industry, is crucial. In the public interest, a state role needs to be maintained, as well as due to the state's responsibilities under international treaties and directives.

Integration of the main stakeholders (from the individual operator to the industry organisation, and from central administration to the delegated authority) receives increased emphasis where management is delegated to a sub-State level. The functioning of the delegated authority is, then, an important issue to consider. The functioning of SFCs is reactive rather than proactive mainly due to the way in which DEFRA's guidelines for bye-law making are written. Decisions that have only local effect need to go through a central bureaucracy. The ability of delegated authorities to be pro-active is therefore reduced. To be considered by industry to be effective, delegated authorities need scope to act, within national policy guidelines. Appointment of fishery managers in North America and Australasia clearly designates the task of day-to-day management to an accountable individual. A fishery manager's full time role is to facilitate making and implementing decisions regarding regulation of a fishery. In other words, a fishery manager maintains the machinery of management while other members of a delegated authority are conducting their full time business as fishers, processors or scientists. It is important that someone be dedicated to making whatever management machinery is put in place work. Without such an individual, a system can lack attention to seeing that management gets done. In other words, fishery management needs a manager or it risks lacking a full time focus. In the European systems described, there is little of the required focus. Apart from fishers, scientists are the only participants in the management system that are species oriented. None of the committee structures of SFCs or CPs focuses on particular fisheries or species. In SFCs and CPs, moreover, there is also a need for integration across management regions.

Viability of fisheries in each of the management systems described is made more difficult by the imposition of costs attributable to licensing policy. Transfer of licences through the private market has inflated access costs in each case discussed. The licence component of access costs appears greatest in Tasmania where many fishers now lease fishing entitlements from owners. In Ireland, UK and France, access costs are approximately double the real economic costs of purchasing fishing vessels. These experiences suggest that management of inshore fisheries in Europe should adopt a careful approach to the issue of property rights. On the one hand, allocation of a level of private property right can help to extend the outlook of licence holders beyond the short-term. On the other hand, the public's stake needs to be protected. It is also important, given likely variability in stock recruitment and changes in economic and social circumstances, that an adaptable management system is developed. Strength of private property right is negatively correlated with management flexibility.

A possible alternative to individual transferable licences is individual privately non-transferable licences that applied for the duration of operators' commercial fishing lives. The existing community of operators would still be protected with such licences. But, transition to the next generation of operators would be co-operatively managed by industry and government to ensure that appropriate individuals qualified for any licences being reissued, such as is possible in France. Operators could therefore both plan to fish in the long-term as well as anticipate that the fishery would remain oriented to operators, who could include their children. They would thus have a long-term interest in participating in co-operative decision-making and complying with management regulations that were oriented both to their own welfare as well as to that of their fishing community. Embedding obligations in often local fishing communities in this way is preferable to encouraging individuals to comply with management to protect an investment or to avoid some form of penalty.

A species-based management or advisory committee, including a fishery manager, is a common model in North America and Australasia. It is uncommon in Europe, where inshore fisheries have thus far largely fallen between the stools of the CFP, industrialised offshore fisheries, the ICES/ACFM assessment/management system and weakly developed national policies. Following the review of the CFP and the EC's confirmation of authority for management of fisheries out to 12 nm by Member States, Europe must re-think how management of inshore fisheries is to proceed. Observations in this paper regarding species-based management and advisory committees are, of course, well understood outside Europe's inshore crustacean fisheries. This paper indicates that careful attention to a number of issues such as property rights, a species based approach, delegation of responsibility and adopting scales of management consistent with the biological structure of stocks is required.

References

10. Fishery interactions in The Normand-Breton Gulf : management options

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Introduction

Located in the western part of the English Channel (ICES VIIe), the Normand-Breton Gulf (or Gulf of St-Malo) is entirely within the 12 nm zone of France and the UK Channel Islands (mainly Jersey and Guernsey)[27]. It is a rich and complex fishery. Fisheries conflicts in the area are primarily related to ground use and the use of static and mobile fishing gear. Mobile and static gear cannot be used in the same place at the same time. In addition the use of poorly selective gears (trawls) results in a high level of discarding (Morizur et al., 1996) which are a cause of economic losses for the fishery as a whole but impacting more particularly (although not exclusively) fishermen using more selective gears. The problem gets especially acute when low selectivity gears are used in nursery areas, a phenomenon which is not uncommon in the Normand-Breton Gulf (Berthou et al., 1996).

This situation obviously calls for management measures preventing the use of the least selective gears in the most sensitive areas. Some of these issues are discussed by the Bay of Granville Committee, a consultative body where government representatives and fishermen organisations of both France and Jersey Island elaborate proposals concerning the management of fishing activities in the south-eastern part of the Normand-Breton Gulf.

The study presented here focuses on a scenario of a seasonal trawl ban within the Gulf. This is intended to prevent discarding by trawlers of by-catches of juveniles belonging to various species but mainly black sea- bream and spider-crab. The case study is presented as follows :

1. Description of fishing activities within the Normand-Breton Gulf
2. Analysis of the problem of discards by trawlers operating in the Gulf
3. Modelling of a seasonal trawl-ban scenario

Fishing activities inside the Normand-Breton Gulf

Diversity of fisheries

The fishery of the Normand-Breton Gulf is complex. Despite a deficit of comprehensive and reliable data, various elements suggest that there is overcapacity in the fishery as a whole. Some knowledge of the economic performance of the French fleets operating the fishery was obtained through the results of a survey of skippers.

The area is complex in terms of biodiversity in the area, range of fishing activities and the arrangements for fisheries management.

As a consequence of hydrological and sedimentary characteristics, biodiversity is higher in the Normand-Breton Gulf than in other parts of the Western Channel (Berthou et al., 1996). Benthic populations are very important. Fishing is also diverse. In the last century, dredging of flat oyster *Ostrea edulis* was the basis for fishing activity of many boats. Warty venus

[27] For the sake of the present analysis, the Normand-Breton Gulf is understood as the interior and territorial waters of UK Channel Islands and France, between the *cap de la Hague* (Lower-Normandy) and the *sillon de Talbert* (Brittany).

Venus verrucosa and scallop *Pecten maximus* have been heavily exploited since 1950. Queen scallops *Chlamys opercularis* also support fishing activity. Biomass of the clams *Glycymeris glycymeris*, *Ruditapes rhomboïdes* and *Spisula ovalis* are very high. In addition to these suspension feeders, others molluscs such as the whelk *Buccinum undatum* (most of French landings come from the Normand-Breton Gulf) and the cuttle fish *Sepia oficinalis* which is abundant support important fisheries.

The mixture of soft and rocky grounds is also favourable to crustaceans and the Normand-Breton Gulf is the most important area for lobster *Homarus gammarus* and spider crab *Maja squinado* in France. Although they are of lesser importance, velvet crab *Necora puber*, edible crab *Cancer pagurus* and common prawn *Palaemon serratus* are fished by many potters.

Many species of finfish also find favourable nursery grounds in the Gulf. The most important species in the landings are the rays *Raja clavata* and *R. naevus*, common sole *Solea solea*, red gurnard *Aspitrigla cuculus*, sea bream *Spondyliosoma cantharus*, sea bass *Dicentrarchus labrax*.

Landings data are not complete. There are a lot of landings points, and the majority of fishing boats in the fishery are too small to be obliged to fill log-books under current regulations. French fishermen have a legal obligation to weigh and declare their landings, but the enforcement of this rule is variable. The statistical knowledge of the landings is variable as regards species and fishing activities. The landings of molluscs, as well as the landings of finfish by trawlers, are generally well known because most of them are sold through auction markets. In the case of crustaceans and, more generally, in the case of products of potting and netting activities, landings are mainly sold directly by the fishermen. As a consequence and because of the lack of declarations, official statistics are often underestimated with a year-to-year variable degree of uncertainty. It is also difficult to determine which landings come from inside or outside of the Gulf area.

Fishing activity

The Normand-Breton Gulf is fished by Channel-Islands and French boats. At the beginning of the 90', the Channel-Islands fishing fleet was composed of approximately 670 inshore and 35 offshore boats (Tétard, Boon et al, 1995). The inshore boats operate only inside the Gulf. Most of these are potters and handliners, small-sized (4 to 11 metres), and many are operated by non-professional fishermen on a seasonal basis. The offshore fleet is composed of potters, trawlers and longliners. These boats range from 9 to 21 metres and operate mainly outside of the Gulf.

In 1994 there were about 650 French professional[28] fishing boats operating inside the Gulf (Berthou et al., 1996). Though the majority come from harbours bordering the area, some boats from ports beyond the Gulf area fish in the area seasonally for scallop, cuttle fish or spider crab. Most of the boats operating inside the Gulf are strongly dependent on this area : 50 % operate in the Gulf all the year round, and 35% between 6-10 months per year.

The French fleet operating inside the Gulf is basically small scale (average length 10.8 m) but the number of boats over 16 m is increasing. Boats under 13 m operate mainly in the coastal parts of the Gulf. Boats between 13-18 m are less in the Gulf and, with a few exceptions, the largest boats (18-25 m) operate only part time this area.

More than 20 *métiers*[29] were observed in 1994, and each French boat operating inside the Gulf was involved in 2.1 *métiers* per year on average. There are 3 main *métiers* : crustaceans

[28] Unlike UK non-professional fishermen, French recreational fishermen are not allowed to sell their landings. Their activity, which is in principle strictly non-commercial, is out of the scope of the present survey.
[29] Combination of gear, targeted species and fishing area (Tétard, Boon et al., 1995).

potting, scallop dredging and bottom trawling each comprising one-third of the fleet. Their activity represents 60% of the total fishing activity of the French fleet in the Gulf. Five secondary *métiers* (whelk potting, small mesh netting, warty venus dredging, spider crab netting, cuttle fish potting) represents a further 30 % of the total activity. The total French fleet may be split into 7 subsets (Table 1).

Table 1. Description of the French fleet operating the Normand-Breton Gulf in 1994 (Berthou et al., 1996)

Type of boat	**Number of boats**	**Mean length (m)**	**Mean HP (kw)**	**Remarks**
Trawlers	76	19.4	372	Mainly bottom trawlers, but also a few midwater trawlers.Boats operating only part time inside the Gulf. 24 boats coming from outside the Gulf (district of Caen)
Trawlers-dredgers	118	12.3	174	Boats involved both in dredging (scallops, warty venus) and inshore trawling.
Dredgers	63	9.4	102	Boats specialised in dredging *métiers* all the year.
Dredgers + fixed gears	110	10.0	118	Dredgers completing their activity with various activities, mainly crustacean *métiers* and bass longlining.
Crustacean potters	150	8.5	79	Some of these boats complete their activity with other fixed gears (nets or lines).
Whelkers	65	8.5	100	Full-time whelk potters.
Miscellaneous	70			Spider-crab netters (11), finfish netters (22), shellfish-farming / fishing boats (9), handliners and longliners (28).

The numerous *métiers* operating in the Normand-Breton Gulf are strongly interactive. They interact in three different ways. Firstly the same boat can operate in several metiers. Spatial (ground use) conflicts are most important between towed and fixed gears (Table 2).

Table 2. Main space interactions between métiers (Berthou et al., 1996)

	1	2	3	4	5	6	7	8	9
1. Crab and lobster potting	**X**			**X**				**X**	
2. Whelk potting		**X**					**X**	**X**	**X**
3. Small mesh netting			**X**				**X**	**X**	
4. Spider-crab netting				**X**				**X**	
5. Cuttlefish potting					**X**			**X**	
6. Bottom longlining							**X**	**X**	**X**
7. Scallop dredging									
8. Otter trawling									
9. Warty venus dredging									

Resource interactions (Table 3) occur because different *métiers* may target the same species or they may discard species which are targeted by others. Few resource interactions are generated by the *métiers* using fixed gears (with the exception of small mesh finfish netting). Bottom trawling has the most interaction with other metiers in the area (Table 3). Discarding of spider crab, bream, rays, gurnards and red mullets is important. Mid-water trawling interacts with sea bass and bream (the latter being partly discarded).

Table 3. Main resource interactions between métiers (Berthou et al., 1996)

Species caught / Activity	Spider-crab	Scallop	Sea-bream	Sea-bass	Sole	Skates	Gurnard	Red mullet
crab and lobster potting	L							

whelk potting	d							
cuttlefish potting								
small mesh netting	l d		l	L	L			L
spider-crab netting	L							
bottom longlining				L				
scallop dredging	L d	L						
warty venus dredging								
otter trawling	l D	L	l D	L	L d	L D	l D	L D
midwater trawling			L D	L				
recreational fishing	L			L				

Key : L or l = landing ; D or d = discarding ; upper or lower case letter refers to major or minor interaction.
Notes : 1) in the table above, midwater trawling and recreational fishing were added to the 9 main *métiers* in the Gulf, because the interactions which they generate are substantial for certain species ; 2) The by-catches of some species used as baits for other activities were classed as discards.

Institutional complexity of the fishery

The complexity of the fishery also stems from the impressive variety and overlapping character of the legal rules concerning its management (Prat, 1996 ; Curtil, 1996 ; Prat and Curtil, 1997). The remarkable complexity of the legal status of the Normand-Breton fishery has several origins: the variety of species targeted and of *métiers*, but also the coexistence of different national jurisdictions and, within each one, the multiplicity of competencies that are implied in the management of the fishery.

The Normand-Breton Gulf is entirely within the 12 NM zone, but it is characterised by the cohabitation of two different State jurisdictions : France and the UK, who has the sovereignty over the Channel Islands (however, these islands do not belong to the EU). The intricacy of the maritime zones under the jurisdiction of the States bordering the Gulf has for long necessitated the setting up of mechanisms of international co-operation. Though both Jersey and Guernsey are under UK sovereignty, the relations between France and each of these two islands are different (Prat, 1996).

The coexistence of two different State jurisdictions within the Gulf is not the only factor complicating the legal status of its fishery. The multiplicity of administrative competencies creates a very intricate legal situation (Curtil, 1996).

Being inside the EU fishing zone (even for the part bordering the Channel Islands), the Gulf fishery is subject to the general CFP regulations, which apply to this zone (legal sizes of catches, European quotas, etc.). But since it is entirely inside the 12 nm zone access to the fishery may, under current CFP arrangements, be reserved for vessels belonging to the home state. The management of stocks distributed wholly within this zone is largely, but not entirely, delegated to the state.

In France, the Regional Prefects are responsible for administration in their region. As the Normand-Breton Gulf is bordered by two different regions (Brittany and Lower-Normandy), there are 2 Prefects administering the fishery. Two Comites Regional (CPs, see Tully et al. page 90 this document) are also involved in the management of the Normand-Breton Gulf fishery. These Comites can at regional level make proposals for regulation that are implemented by the Central Administration. On a local scale, fishermen themselves create cohabitation agreements between *métiers*, the status of which is informal (Prat and Curtil, 1997).

The fishing activities of the Gulf are thus exposed to different norms of management from various authorities. The resulting confusion certainly does not help the implementation of the rules. However, several arguments indicate that the Gulf may be an interesting zone for new approaches to management :

- it is an ecological entity, relatively isolated from the rest of the Western Channel by the currents ;
- the zone is entirely within the 12 nm of either France or Channel Islands ;
- several stocks are totally included in the Gulf, some of which are sedentary or with low mobility ;
- a majority of boats operating the fishery are local and depend strongly on the fish stocks of the area ;
- there are many important interactions between the various fishing activities inside the Gulf ;
- notwithstanding the frequent conflicts within the fishery, local fishermen have some significant common interests, concerning conservation and limiting access to the fish resources of the area.

A first step towards the creation of a common management system for the Gulf fishery was taken in 1996 with the creation of a joint consultative committee for the management of fishing activities inside the Bay of Granville (Southeastern part of the Normand Breton Gulf). More specifically, this committee is in charge of developing proposals for the management of fishing activities within the so-called ‘common sea’ between France and Jersey Island. It is composed of representatives of government authorities of both countries, regional fisheries committees of Brittany and Lower-Normandy, the Jersey Fishermen’s Association, and scientists (who do not have voting rights).

The equilibrium between fishing capacities and resources

Excess fishing capacity in the Gulf may further exacerbates conflicts between fisheries (Boncoeur et al., 1998) although there is insufficient data to test this hypothesis. For some species (mainly crustaceans), landings data are poor. For other species (mainly finfish), the geographic origin of the catches is not known with sufficient accuracy. There are time series of data on the number of boats registered in the maritime districts bordering the Gulf, but this data set does not fully corresponds to the fleet operating in the fishery. It is therefore unavoidable to rely on partial, approximate and indirect indications (the data which are used in the three tables below come from French governement statistics).

Table 4. Changes in landings and fishing fleet in the 4 maritime districts bordering the Normand-Breton Gulf between the mid 70’ and the mid 90’ (Boncoeur et al., 1998)*

Value of landings (constant francs)**	+ 3 %
Number of boats registered***	- 48 %
Average HP***	+ 119 %
Cumulated HP***	+ 27 %

* Districts of Paimpol, St-Brieuc, St-Malo and Cherbourg. ** Average 1991-95 compared to average 1974-78. Products of far-away fishing, mussels and sea-weeds excluded. ***1993 compared to 1976. Vessels under 25 meter long.

The above table shows an overall stability in the global value of landings in the harbours bordering the Gulf[30] over two decades. During the same period the number of boats halved but there was 25% increase in total engine power i.e. the average power per boat more than doubled during the period. This suggests that, irrespective of the sharp diminution in the number of boats, the fishing capacity around the Gulf significantly increased during the period. Technological advances in fishing may have further increased effective capacity. The available data allow a more precise description of landings for the period starting in the mid 80’ :

[30] In this table, data that could clearly be regarded as having no connection with the Gulf fishery have been excluded.

Table 5. Main species targeted in the Normand-Breton Gulf. Changes in landings in the 4 bordering maritime districts, 1986-94 (Boncoeur et al., 1998)*

	1986	1991	1994
[1] Number of tons landed	100	115	134
[2] Value of landings (constant francs)	100	87	82
[3] Average price of landings (constant francs)	100	75	61
[4] Synthetic index (Laspeyres) of the prices of the landings (constant francs)	100	90	85
[5] Effect of the change of the structure of landings. [5] = 100.[3] / [4]	100	83	72
[6] Synthetic index (Paasche) of the volume of landings. [6] = 100.[2] / [4]	100	106	97

* By decreasing order of landed value (in 1991) : common scallop, spider-crab, whelk, warty venus, cuttle, sea-bass, sole, rays, pollack, lobster, sea-bream, red gurnard (the total amounts to 60% of the value landed in 1991 in the 4 districts bordering the Gulf, boats over 25 meters excluded).

Table 5 shows the landings for the 12 main species targeted in the Gulf. For shellfish, landings generally correspond to catches from the Gulf. The situation is not as clear for finfish but species that are poorly represented in the Gulf are not included in Table 5.

The table shows a growth of approximately 33% in the weight of the landings during the period 1986-94 although their global value decreased by 20%. This 40% drop in value may be due to a change in individual species prices and a change in the composition of the landings. To separate these two factors, a Laspeyres price index has been calculated. This indicates that the drop in value was mainly due to changes in the species composition of the landings. High value species were replaced by lower value species as the former species got progressively exhausted (replacement of warty venus by whelk for instance). The Laspeyres synthetic price index allows a synthetic (Paasche) volume index of the landings to be calculated. This depicts the change in the value of the landings assuming stable individual prices. The result shows a global stability in the volume of the landings during the period 1986-94 although the fleet composition changed significantly during the same period (Table 6).

Table 6. French fishing fleet registered in the 4 maritime districts bordering the Normand-Breton Gulf Evolution 1986-94 (Boncoeur et al., 1998)*

	1986	1990	1994
Number of boats	100	92	77
Average GRT	100	128	148
Average HP	100	141	160
Cumulated GRT	100	118	114
Cumulated HP	100	130	123

* Cherbourg, St-Malo, St-Brieuc, Paimpol.

To sum up, the historical data suggests the following trends :

- a sharp decrease in the number of boats registered in the districts surrounding the Gulf ;
- significant increase in total fishing capacity ;
- stability in the global volume of the landings ;
- reduced unit weight value due to change in species composition of the landings
-

Economic survey of the French fleets operating the Normand-Breton Gulf fishery

In 1997, an economic survey of the French commercial fleets operating the Normand-Breton Gulf fishery was undertaken by CEDEM (Boncoeur and Le Gallic, 1997). The main population which served as a basis for sampling was given by Berthou *et al.*, 1996. With 66 boats in the sample, the sampling rate was slightly over 10%. The quota method was used for selecting the sample, according to a simplified fleet typology[31]. Table 7-9 compare the

[31] For the purpose of the sampling, 5 fleets were distinguished : trawlers (pure trawlers and trawlers-dredgers), dredgers (pure dredgers and dredgers also using fixed gears), crustacean potters (including potters also using other fixed gears), whelk potters, miscellaneous.

characteristics of the main population and of the sample, and their respective structures by fleet and by maritime district.

Table 7. Economic survey : compared characteristics of the main population and sample (Boncoeur and Le Gallic, 1997)

Boat characteristics	Main population	Sample		
	Mean value	Mean value	Relative standard error(a)	Confidence limits, 5% risk (b)
Length (metres)	10,8	11,4	3 %	10,7 - 12,1
GRT	18,6	16,3	11 %	12,7 - 19,9
HP (Kw)	142	156	7 %	134 - 178
Age (years)(c)	15	17	7 %	14,6 - 19,4
Crew size (number of persons)	2,8	3,0	5 %	2,7 - 3,3

(a) Standard error / sample mean. (b) assuming conditions of a random sampling. (c) sample : 1997 ; main population : 1994.

Table 8. Economic survey : compared fleet structures of the main population and sample (Boncoeur and Le Gallic, 1997)

Fleets	Main population	Sample
Trawlers and trawlers-dredgers	30%	35%
Dredgers and dredgers + fixed gears	26%	32%
Crustacean potters	23%	18%
Whelk potters	10%	12%
Miscellaneous	11%	3%
Total	100%	100%

Table 9. Economic survey : compared geographical structures of the main population and sample (Boncoeur and Le Gallic, 1997)

Maritime districts	Main population	Sample
Cherbourg*	39%	41%
Saint-Malo**	12%	18%
Saint-Brieuc**	27%	35%
Paimpol**	14%	6%
Others (districts not bordering the Gulf)***	8%	-
Total	100%	100%

* Lower-Normandy. ** Brittany. *** Mainly Caen (Lower-Normandy)

The survey was limited to the French harbours bordering the Normand-Breton Gulf (8 harbours were surveyed) and to boats with a significant part (>40%) of their activity inside the Gulf. Trawlers were thereby underrepresented. Skipper/owners were interviewed directly. The questionnaire was composed of four parts: type of activity, fixed capital, fishing and marketing behaviour, revenues and costs. Table 10-14 present the main results. Purely trawlers and boats belonging to 'miscellaneous' group have been excluded because of low numbers. The crustacean potters were split into potters-netters and other crustacean potters.

Table 10. Economic survey results : fixed capital and crew (Boncoeur and Le Gallic, 1997)

Fleet	Boat age (years)		Insured value (1000 FF)		Crew size (fishers)*	
	mean	std. dev.	mean	std. dev.	mean	std. dev.
Trawlers-dredgers	20,1	8,2	1394	933	3,2	0,9
Other dredgers	20,8	9,1	652	465	2,5	1,0
Potters-netters	10,4	7,6	1796	689	3,7	1,1
Other crustacean potters	12,0	5,7	708	791	2,8	1,6
Whelkers	12,6	6,0	571	242	2,6	0,7

* including skipper.

Table 11. Economic survey results : fishing behaviour (Boncoeur and Le Gallic, 1997)

	Time at sea (days / year)	% of total fishing time inside the Gulf

Fleet	mean	std. dev.	mean	std. dev.
Trawlers-dredgers	224	22	74%	22%
Other dredgers	213	25	88%	22%
Potters-netters	204	29	100%	0%
Other crustacean potters	198	11	97%	5%
Whelkers	240	31	100%	0%

Table 12. Economic survey results : landings and sales (Boncoeur and Le Gallic, 1997)

Fleet	Main landed species	Yearly turnover (1000 FF)		% of sales through auction markets
		mean	std. dev.	
Trawlers-dredgers	scallop, warty venus, sole, cuttle fish	1350	598	81 %
Other dredgers	scallop, warty venus, spider crab, lobster, bass	812	466	36 %
Potters-netters	spider crab, lobster, rays and other finfish	1900	783	0 %
Other crustacean potters	lobster, spider crab, edible crab	1046	847	4 %
Whelkers	whelk	1094	426	53 %

Table 13. Economic survey results : yearly costs (1000 FF) (Boncoeur and Le Gallic, 1997)

	Variable costs*		Wage costs**		Fixed economic costs***	
Fleet	mean	std. dev.	mean	std. dev.	mean	std. dev.
Trawlers-dredgers	334	166	651	246	160	85
Other dredgers	171	94	443	255	80	48
Potters-netters	430	252	878	287	140	60
Other crustacean potters	226	228	580	465	75	72
Whelkers	288	133	511	165	63	21

* non durable goods (including fishing gears replacement and repairs), 75% of boat maintenance and repairs, landing taxes. ** net wages (including skipper owner's wage) + national insurance contributions. *** 25% of boat maintenance and repairs, insurance and management costs, yearly fishing licences costs, economic depreciation of fixed capital..

Table 14. Economic survey results : economic performance indicators (Boncoeur and Le Gallic, 1997)

	Yearly gross margin* (1000 FF)		Profit rate**		Skipper-owner's yearly net activity income*** (1000 FF)	
Fleet	mean	std. dev.	mean	std. dev.	mean	std. dev.
Trawlers-dredgers	1017	489	15%	10%	335	209
Other dredgers	641	396	18%	20%	231	174
Potters-netters	1470	625	25%	25%	625	445
Other crustacean potters	820	662	23%	41%	296	248
Whelkers	805	303	41%	17%	413	194

* Turnover - variable cost (1000 FF). ** (Gross margin - wage cost - fixed economic cost) / Boat insured value. *** Full equity profit + skipper-owner's net wage - opportunity cost of capital (5.7% of boat insured value) (1000 FF).

Analysis of the problem of discards by trawlers inside the Normand-Breton Gulf

Discards in the coastal fisheries of the Western part of the English Channel originate from a number of gear types (Morizur et al., 1996). Discards are highest in trawl fisheries because fo poor selectiveity and because 30% of all boats use trawls on a full time or part-time basis (Berthou et al., 1996). This is of concern in relation to the status of nurseries in the Gulf area.

Trawling inside the Normand-Breton Gulf results in various types of discards. These occur for commercial (species with low commercial value, such as spotted dogfish, red gurnard, pout whiting) or legal reasons (undersized fish, such as juveniles of black sea bream, sole, red mullet), or because of the physical condition of the individuals that are caught (soft-shell spider-crabs). The two last types of discards were surveyed by Fifas (1998), who focused on the three following species : black sea bream (*Spondyliosoma cantharus*), sole (*Solea vulgaris*) and spider crab (*Maja squinado*).

Sole

This species is mainly targeted by inshore bottom-trawlers from the ports of Granville, St-Malo and around St-Brieuc, operating in the bay of Mont-St-Michel or in the bay of St-Brieuc. Some offshore bottom-trawlers occasionally catch sole, either as bycatches, or as targeted species. Most of the sole landed in the harbours bordering the Normand-Breton Gulf were fished inside the Gulf. Average annual landings during the 1990s were 300-400 tonnes.
Sole is a highly valued species. Small (individual portion) soles are particularly sought-after, and this promotes the catching and marketing soles under legal size. According to data collected by Morizur et al. (1996), the critical length for hand-sorting of individuals onboard inshore trawlers of St-Malo and St-Brieuc is around 18-20 cm., while the mimimum legal length is 24 cm. Approximately 10% of sole on the market is under the legal size.

Not all undersized soles are landed. Trawling in the nurseries of the bays of St-Brieuc and Mont-St-Michel generates important discards of juveniles (under 18 cm.), with a high rate of mortality (larger individuals are stronger, and their rate of survival is higher when they are discarded). This phenomenon is linked to the use of trawls with undersized mesh (50-60 mm., instead of 80 mm.), and is responsible for some 25% of the total fishing mortality of sole in the Normand-Breton Gulf.

Enforcing legal mesh size would result in a 50% reduction in discarding. A Beverton-Holt type structural analysis suggests that the average yield per recruit would then rise by 18%, even with a slightly higher effort level. The spawning stock biomass per recruit would increase significantly, shifting from 14% to 20% of the unexploited biomass equilibrium level. The maximum increase in yield per recruit would be obtained with an increase in mesh size to 105 mm: the average yield per recruit would then increase by 32%, and the spawning stock biomass per recruit could reach 37% of the unexploited biomass equilibrium level.

Black sea bream

Black sea bream is targeted mainly by pelagic trawlers from the harbour of Granville. It is also a bycatch for inshore bottom-trawlers of St-Brieuc and St-Malo. The resource is characterised by high fluctuations in recruitment (at the end of the 90', the abundance was high, resulting in landings of 1000 tons per year). Juveniles up to 20 cm in length stay close to the shore and then move to deeper waters as they grow. During this first phase of their life cycle, they are accessible to inshore bottom-trawlers, especially at the end of summer, when concentrations of juveniles in nurseries are highest. Adults are accessible mainly to pelagic trawlers, except in spring when they reach the coastal spawning areas.

The critical length for hand-sorting of individuals on pelagic trawlers is around 18 cm., while the mimimum legal length is 23 cm. As a result, around 5 to 8% of all marketed individuals are undersized.

Though the legal mesh size of 80 mm is usually enforced onboard pelagic trawlers, these boats discard approximately 10% of all the individuals they catch. The rate of discarding is 90% on inshore bottom-trawlers who use mesh sizes of 50-60 mm. At the end of summer in fact the rate of discarding approaches 100%. The rate of mortality of discarded individuals may itself be considered as 100%. The estimated mortality of sea bream due to discarding of juveniles is presented in Table 15.

Table 15. Estimation of fishing mortality of black sea-bream by French trawlers operating the Normand-Breton Gulf fishery (Fifas, 1998)

	Catches (10^6 individuals)	Discards (10^6 individuals)	discards / catches
Pelagic trawlers (whole year)	2.49	0.27	11 %
Inshore bottom trawlers (August-September)	1.58	1.57	99 %

The analysis conducted by Fifas suggests that a seasonal bottom-trawl ban during the months of August and September, combined with the enforcement of the legal mesh size, could increase the total landed weight by nearly 20%, as compared to the situation prevailing at the end of the 90s'. However, this policy would benefit pelagic trawlers but not inshore bottom trawlers where landings would decrease.

Spider-crab

Spider-crab is targeted by some 300 netters and potters of the Normand-Breton Gulf. This fleet takes approximately 70% of the natioanl landings of this species. Fishing takes place in winter and spring. Each year, around 80% of the newly recruited individuals are fished, which makes this fishery highly dependent on recruitment.

During August and September, juveniles concentrate in the nurseries of West-Cotentin and in the bay of St-Brieuc where they undergo their terminal molt[32], before migrating to deeper waters. Bottom trawlers catch very large numbers of crab at this time when they are in poor condition and do not have any commercial value. Some 90% of the catch is discarded. Discard mortality is high and as a result around 25% of the individuals to be recruited each year are destroyed by trawlers in two months. This represents, on average, a loss of potential catch of 1100 tons per year compared with average landings ranging between 3000 and 4000 tons per year in the 1990s.

Modelling a seasonal trawl-ban scenario

The level of discarding described above indicates that new management measures are necessary. Enforcement of mesh size regualtions for sole and seasonal restrictions on trawling to avoid concentrations of juvenile sea bream and spider crab would have significant benefits.

The impact of a seasonal bottom-trawl ban[33] within the Gulf was studied by Boncoeur, Fifas and Le Gallic (2000). The survey was conducted for spider crab but also applies to sea bream as the concentration of discarding for both species coincides in August and September. The ban would need to apply only to bottom-trawling, since midwater trawling has no impact on spider crab discarding only a marginal impact on sea bream. The survey considered a bottom-trawl ban over the whole Normand-Breton fishery.

In order to evaluate effect of a 2 month bottom-trawl ban a bioeconomic model was developed. Its purpose is to estimate, from a cost-benefit perspective, the impact of the trawl-

[32] Unlike other crabs, spider crabs perform their successive molts during the 2 first years of their life cycle. The diversity of size at the age of the terminal molt is important.
[33] According to French rules, trawling is forbidden within the 3 miles line, and, in Brittany, an additional rule bans pelagic trawling within the 12 nm (this rule applies to the Brittany part of the Normand-Breton Gulf). However, numerous impairments result in significantly weakening of this restriction.

ban on three categories of stake-holders : trawlers, crustacean potters and netters, and consumers. The data used in the model were as follows:

- biological data provided by stock assessments and discards by IFREMER using 11 years of survey data, plus data on the biology of *Maja squinado* (Le Foll, 1993) ;
- boat cost and revenue data provided by the above mentioned economic field survey of the fleets operating in the Normand-Breton Gulf (Boncoeur and Le Gallic, 1997), complemented by another broader scale survey (Boncoeur and Le Gallic, 1998)[34] ;
- price and landings data (*Affaires maritimes* statistics)[35].

Figure 1 depicts the general structure of the model. The biological and economic components of the model[36] and the results of simulations are presented below.

Biological component

Bycatch of spider crabs by trawlers in August and September depend mainly on two parameters : recruitment (most of the bycatches concern 2 years old pre-recruit juveniles) and activity of bottom-trawlers in the area during the two critical months.

The model uses the average level of activity during the 1990s'. This results in catching approximately 10% of the stock of juveniles per week, during August and September. Three possibilities are considered for the recruitment parameter:

- average recruitment (the probability of a higher recruitment is 0.5) ;
- high recruitment (the probability of a higher recruitment is 0.05) ;
- low recruitment (the probability of a higher recruitment is 0.95).

These values were calculated by adjusting a log-normal law of probability to the stock assessment data obtained from 11 years of survey data.

Around 95% of the spider crabs caught by trawlers during August and September are discarded. The resulting mortality depends on the condition of these individuals. While 80 to 90% of the soft shell crabs are killed (the model assumes a rate of 80%), the rate of mortality of discarded hard shell crabs varies according to their size (larger individuals are more fragile than smaller ones). Discard mortality of hard-shelled crab is taken to be 12%. Moulting frequency is higher in smaller crabs (Le Foll, 1993). The probability of molting according to size was simulated using a decreasing logistic curve, parameterised so that 95% of the cohort had molted by the end of September, when no trawling occurs. In all, it is estimated that 20 to 25% of the population concentrated in coastal nurseries at the end of the summer is destroyed by trawling.

This mortality reduces the stock biomass available to potters and netters during the following fishing season (November to April). To estimate the deficit, it is necessary to take into account the increase in size of individuals at the moment of their terminal molt[37] (for the part of the cohort which is destroyed before achieving its molt), and the natural mortality between the end of summer and the fishing season[38] (part of the individuals which are destroyed by trawling would have died anyway before being targeted by potters and netters).

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[34] For practical reasons, these data are restricted to French commercial fishing boats : due to lack of data, Channel-Islands fishing boats and recreative fishing boats could not be included in the model.
[35] The quality of these statistics is questionable, because most landings of spider-crabs are not sold through public auction markets.
[36] This component is presented with more detail in Fifas, 1998.
[37] The increase in size at the moment of the terminal molt represents between 25% and 40% of the pre-molting size, and is usually more important with small individuals thab with larger ones (Le Foll, 1993).
[38] The model relies on a 0.3 instantaneous coefficient of natural mortality.

The biomass deficit resulting from discard mortality generates a deficit in catches, for any given level of fishing effort. This reduction is estimated by applying, for the duration of the fishing season, an instantaneous rate of fishing mortality equal to 3.7, an estimate which is consistent with the observed 80% exploitation rate[39].

Economic component

The reduced catch of spider crabs causes a loss of income for potters and netters[40]. But the two effects are not necessarily proportional, as the deficit in catches due to summer discards may influence the price of spider-crabs. The Normand-Breton Gulf is responsible for 70 to 80% of the national supply of this species, for which imports are marginal (contrasting with edible crab). The hypothesis of a price effect is confirmed by an examination of landings statistics over 2 decades for the maritime districts bordering the Gulf (Paimpol, St-Brieuc, St-Malo and Cherbourg). This examination displays a significant sensitivity of landing prices (expressed in constant francs) to landed quantities (tons). The use of a log-linear model for the testing of the price-quantity relation gives the following results :

$$\ln P = -0.414 . \ln Q + 5.924$$

where :

P = average yearly landing price (4 districts), in constant francs (1995) per kg.

Q = yearly landed quantity (same districts), in tons.

with :

number of observations : 20

determination coefficient (r^2) : 0.66

residual standard deviation : 0.110

Regression coefficients	Student *T*	Confidence limits, 5% risk
a = - 0.414	- 5.922	[- 0.562 ; - 0.267]
b = 5.924	10.897	[4.782 ; 7.066]

While it reduces the economic loss for fishers, the price-effect induces a decrease in the consumer's surplus. This is the social cost of discarding. This decrease is calculated on the basis of the above log-linear price-quantity equation. This makes two assumptions (1) no distinction is made between Hicksian and Marshallian demand, and (2) no distinction is made between landing price and retail price. The first assumption is of no consequence, due to the very low importance of the commodity in the consumers budget. The second simplification is more questionable, as the *level* of retail price is usually very different from the landing price, and it is not proven that the *change* in landing price corresponding to a decrease in discards would result in an equivalent change in retail price. In fact, the variation in the 'consumer surplus' concerns both consumers and marketing activities (wholesalers and fishmongers).

In order to assess the economic value of a seasonal bottom-trawl ban in the Normand-Breton Gulf, it is also necessary to estimate the impact of this measure on trawlers operating inside the Gulf. These boats belong to two distinct fleets (Berthou et al., 1996) :

- inshore trawlers-netters (118 units, with an average length of 12.3 metres in 1994), which may be considered as entirely dependent on the Gulf fishery ;

[39] Let m be the instantaneous rate of natural mortality, f the instantaneous rate of fishing mortality, and Δt the duration of the fishing season. The rate of exploitation, i.e. the percentage of the recruited cohort which is fished during its first year, may be written as :

$$[\, f / (m + f)].[1 - e^{-(m+f).\Delta t}]$$

With $m = 0.3$, $f = 3.7$ and $\Delta t = 0.5$, the rate of exploitation is 0.8.

[40] Because of the so-called « share system » characterising the remuneration of the crew in artisanal fisheries, this loss affects both skipper-owner and the members of his crew (if any).

- offshore 'pure' trawlers (76 boats with an average length of 19.4 metres in 1994), most of them operating mainly out of the Gulf (and for a large part coming from harbours located outside the Gulf).

For the first fleet, the main database was provided by the economic field survey undertaken in 1997 (see above). For the second fleet, the results of this survey had to be complemented by additional data. These were obtained from a broader field survey, undertaken in the same year and according to the same methodology, at the scale of the whole French side of the English Channel (Boncoeur and Le Gallic, 1998). The impact of the trawling ban on a sample of 21 trawlers-dredgers and 9 offshore trawlers[41] was estimated as follows :

1. Isolating, inside the annual total turnover and variable cost of each boat, the share due to bottom-trawling. This was based on the field questionnaire which included a question concerning the distribution of annual turnover according to *métiers*. The split of total variable costs was based on an analysis of costs relative to each *métier* (for specific costs), and of the yearly activity calendar, which indicates the allocation of total fishing time betwee *métiers* (for non-specific costs)[42].
2. For trawlers operating only part-time in the Gulf, identifying the share of the bottom-trawling activity which occurs inside the area again using the field questionnaire which included a question concerning the spatial distribution of yearly fishing time.
3. Determining the shares of annual turnover and variable costs related to bottom-trawling inside the Gulf that may be imput to the two months of August and September. This third step was realised with the help of monthly landings statistics (showing good reliability in this case, since most landings of trawlers are sold through auction marlets), and boat activity calendars.
4. Calculating, for each fleet, the gross margin due to bottom-trawling inside the Gulf during the period corresponding to the trawl-ban scenario.

Variation in consumer's surplus may be neglected as regards trawling. This is due to the fact that, contrasting with spider-crabs targeted by netters and potters, most species targeted by trawlers in the Gulf (finfish and cephalopods) are also fished in large quantities in other places. As a consequence, when yearly data are considered, no significant price-quantity relation may be established at the local scale for trawler landings.

The global economic value of the seasonal trawl-ban scenario is established by comparing :

- the producers surplus generated by bottom-trawling inside the Gulf during August and September,
- and the social cost of discards (deficit in producers and consumers surplus) that would be prevented by a trawl ban during these two months.

The time-interval between discards of juveniles by trawlers and the exploitation of the stock by potters and netters must be considered when estimating the social cost of discards. However, this interval is very short (6 months on average), because the stock is basically reduced to the last recruited cohort. This is therefore unimportant considering other assumptions in the model.

As mentioned above, the social cost of discarding was calculated for spider-crab only[43], a calculation which in reality underestimates the effect since it does not account for discarding

[41] Some of these boats combine bottom-trawling and midwater-trawling.
[42] For these costs, it was assumed that the share of each *métier* was proportional to fishing time. Wage costs were not included, a choice which is consistent with the « share-system » characterising the remuneration of the crew in artisanal fisheries.
[43] excluding landings in the Channel-Islands and by French recreative fishers.

of black bream for instance. It must also be stressed that the calculation is limited to the direct impact of the scenario, i.e. it does not integrate indirect effects due to reallocation of effort by fleets affected by the trawl-ban (for an analysis of this question, see Le Gallic, 2001, chapter 7, section 2).

Simulation results

The results of the simulation are shown in Table 16-19. Table 16 gives results for the biological component and Tables 17-19 for the economic component. The actual situation is compared to a hypothetical situation incorporating a simulated seasonal bottom-trawl ban, under three assumptions concerning recruitment (as described above).

Table 16. Simulated seasonal bottom-trawl ban . Estimation of consequences on biomass and catches of spider-crabs (Boncoeur, Fifas and Le Gallic, 2000)*

	Recruitment hypothesis		
	normal	high	low
1. Actual situation			
End of summer biomass of juveniles	2613	5782	1181
End of summer discards by trawlers	1190	2634	538
Exploitable biomass in November	4264	9436	1927
Winter catches by potters and netters	2871	6353	1298
2. Trawl ban scenario			
End of summer biomass of juveniles	2613	5782	1181
End of summer discards by trawlers	0	0	0
Exploitable biomass in November	5906	13067	2669
Winter catches by potters and netters	4015	8885	1815
3. Impact of shift from 1 to 2			
End of summer biomass of juveniles	0	0	0
End of summer discards by trawlers	- 1190	- 2634	- 538
Exploitable biomass in November	+ 1642	+ 3631	+ 742
Winter catches by potters and netters	+ 1144	+ 2532	+ 517

* Unit : metric ton.

Table 17. Simulated seasonal bottom-trawl ban . Estimation of social cost of discards (Boncoeur, Fifas and Le Gallic, 2000)

	Recruitment hypothesis		
	normal	high	low
1. Actual situation			
Winter catches of spider-crabs by potters and netters (tons)	2871	6353	1298
Yearly average landing price of spider-crabs (kf / ton)	13,84	9,96	19,22
Yearly revenue of potters and netters due to spider-crabs (kf)	39734	63286	24954
2. Trawl ban scenario			
Winter catches of spider-crabs by potters and netters (tons)	4015	8885	1815
Yearly average landing price of spider-crabs (kf / ton)	12,05	8,67	16,73
Yearly revenue of potters and netters due to spider-crabs (kf)	48364	77032	30371
3. Impact of shift from 1 to 2			
Winter catches of spider-crabs by potters and netters (tons)	+ 1144	+ 2532	+ 517
Yearly average landing price of spider-crabs (kf / ton)	- 1,80	- 1,30	- 2,50
Yearly revenue of potters and netters due to spider-crabs (kf)	+ 8629	+ 13747	+ 5417
Consumers surplus (kf)	+ 6085	+ 9692	+ 3821
Social cost of discards (kf)	14714	23439	9238

Table 18. . Simulated seasonal bottom-trawl ban . Estimation of gross margin generated by bottom-trawling inside the Gulf during the months of August and September (Boncoeur, Fifas and Le Gallic, 2000)*

	Trawlers-dredgers			Pure trawlers		
	Mean	Standard deviation	Total fleet**	Mean	Standard deviation	Total fleet***
Turnover						
Yearly total	1350	598	159300	4704	888	357500
among which : bottom-trawling	564	510	66552	3647	1456	277160
among which : Normand-Breton Gulf	564	510	66552	388	509	29480
among which : August-September	113	102	13334	65	85	4913
Variable cost						
Yearly total	338	162	39884	1835	416	139449
among which : bottom-trawling	156	97	18408	1469	630	111649
among which : Normand-Breton Gulf	156	97	18408	143	169	10900
among which : August-September	36	22	4248	24	28	1817
Gross margin						
Yearly total	1012	489	119416	2869	626	218051
among which : bottom-trawling	408	395	48144	2178	847	165551
among which : Normand-Breton Gulf	408	395	48144	244	356	18580
among which : August-September	77	91	9086	41	59	3097

* 1997 survey data. Unit : kf. ** 118 boats. *** 76 boats.

Table 19. Simulated seasonal bottom-trawl ban . Estimation of the economic value of the trawl-ban (Boncoeur, Fifas and Le Gallic, 2000)*

	Spider-crab recruitment hypothesis		
	normal	high	low
[1] Increase in yearly revenue of potters and netters	8629	13747	5417
[2] Increase in consumer surplus	6085	9692	3821
[3] Trawlers-netters gross margin	9086	9086	9086
[4] Pure trawlers gross margin	3097	3097	3097
Overal balance ([1] + [2] - [3] - [4])	2531	11256	- 2945

* Unit : kf.

Comments :

- End-of-summer discards of spider-crabs amount to 1200 tons per year based on average fishing activity during the 1990s. For potters and netters targeting this species, the resulting mortality generates a landing deficit of close to 40% of actual landings.
- The price-effect resulting from this deficit represents 13% of the actual landing price; it limits the economic loss for potters and netters to 22% of their actual revenue, ie. approximately €1.3 million for an average recruitment year.

- An additional loss of consumers surplus, representing €0.93 million per year of average recruitment. Therefore the social cost of discarding of spider-crabs represents €2.2 million per year of average recruitment. In years of high and low recruitment, this cost is €3.6 million and €1.4 million respectively.
- The gross margin generated by bottom-trawling in the Gulf during the months of August and September is estimated at €1.4 million for trawlers-dredgers and €0.5 million for pure trawlers at the end of the 1990s'. These figures may be overestimates however. As a result, under normal circumstances this activity may be profitable only because it does not bear the social cost of the discards it generates: with an average recruitment, the overall balance between the gross margin generated by trawling and the social cost of discards gives a positive value to the seasonal trawl-ban, amounting to approximately €0.4 million per year.

It seems reasonable to regard that the estimated economic value of the trawl-ban is underestimated for the following reasons

1. Spider-crab mortality is not the only negative effect of bottom-trawling in the Gulf (and particularly in its coastal areas) during the months of August and September. As noted above this activity also generates a considerable amount of discards of juvenile sea-bream, with an associated mortality approximating 100%. According to Fifas (1998), a seasonal trawl-ban and enforcement of the legal mesh size could improve the annual harvest of adult sea-bream in the Gulf by an average of 190 tons. Assuming a landing price of 12 €1.83 euro / kg[44], this would generate an additional income of approximately €0.35 million for fishers.
2. Considering other species, the annual loss of income borne by trawlers as a consequence of the seasonal trawl-ban would not actually be the gross margin for this period because part of the corresponding catches would simply be posponed to the following months.
3. The cost of the measure for trawlers would vary according to fleet. For trawlers-dredgers, which are almost entirely dependent on the Gulf fishery, the seasonal trawl-ban could impose a temporary stop in their activity. But for pure trawlers, which are larger offshore units operating only occasionally inside the Gulf (with a few exceptions)[45], the seasonal bottom-trawl ban would simply mean a limited change in the geographic distribution of their fishing effort during two months of the year[46]. It is likely that the cost of this reallocation would be significantly smaller than the gross margin realised in the Gulf.
4. The positive effect of the seasonal trawl ban on the landings in the Channel Islands and on the activity of French recreational fishers is not taken into account in the above scenario.

These points strengthen the case for a seasonal bottom trawl-ban in the Normand-Breton Gulf (or part of it). However, the overall benefits that may be expected from a trawl-ban are challenged by its distributional effects, which, if not properly addressed, may hinder the adoption of a globally efficient management measure. Moreover the impact of the measure if implemented will not be wholly realised if it is taken as a substitute for the treatment of the problem of overcapacity in the fishery.

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[44] Average price in 2000 and 2001 at the auction market of Granville, which is the main landing harbour in the Gulf for this species.

[45] These exceptions apply to midwater trawlers, rather than to bottom-trawlers.

[46] For the trawlers combining midwater and bottom-trawling, the ban would concern only their bottom-trawling activity.

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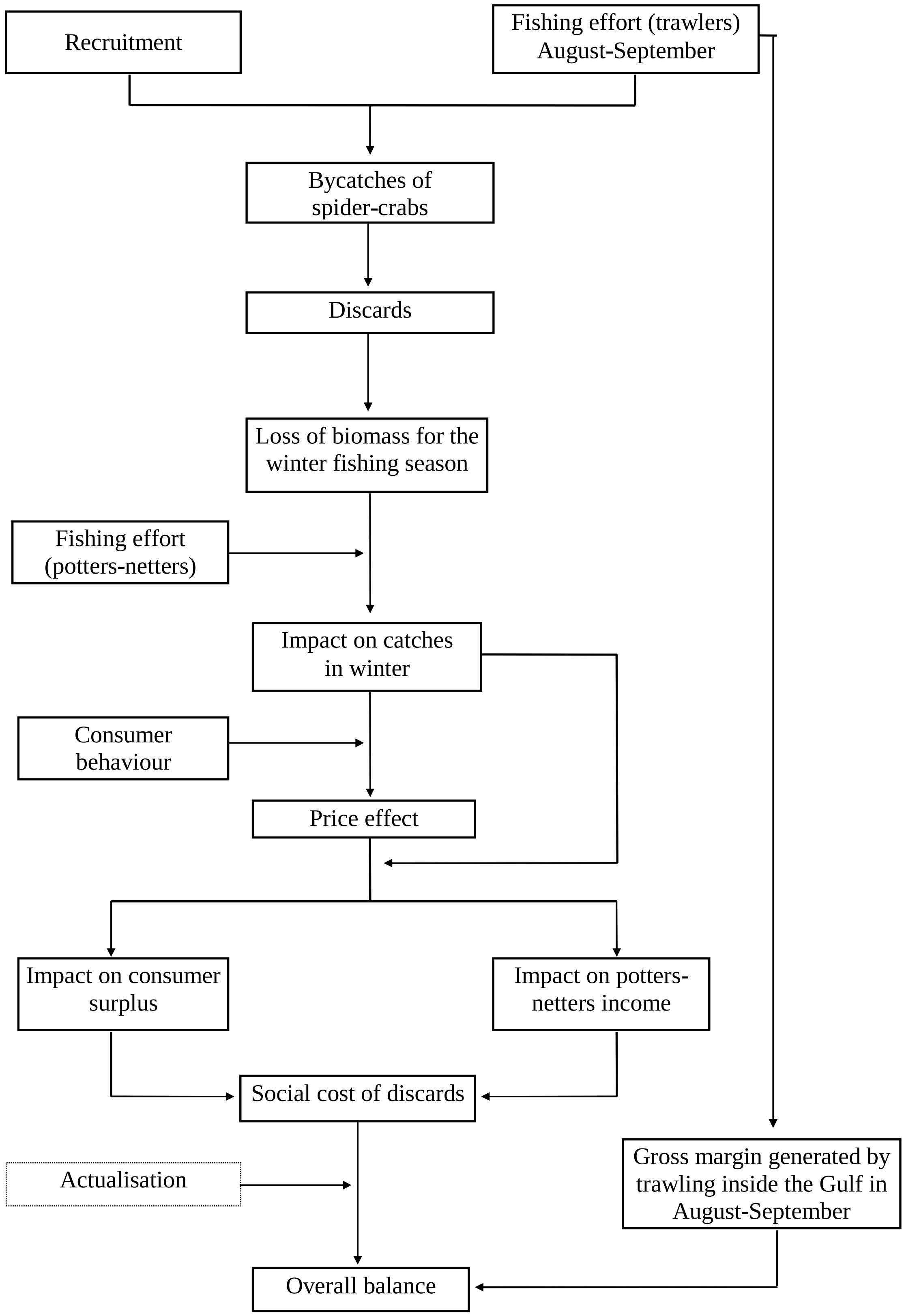
Fig.1 Structure of the Normand-Breton Gulf spider-crab model



11. Description Of The Social And Economic Dimension Of The Greek Fishery Of The Shrimp *Penaeus* (*Melicertus*) Kerathurus (Forskål 1775)

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Introduction

The shrimp *Penaeus (Melicertus) kerathurus* is a shrimp species with high commercial value in the North Mediterranean region and mainly in Italy and Greece. Despite the excellent climatic conditions, coastal fish and shrimp are considered to be poor in condition and largely affected by over-fishing, fishing with illegal methods and pollution in both areas. In addition, the species population in most Italian lagoons has been mixed with the Penaeus japonicus species for restocking thus, a man-made ecological pressure has been applied on the species.
In Greece the species can be found in Amvrakikos Gulf (Western Greece). Smaller populations inadequate to support a target fishery can be found along the Ionion Sea coast of Greece and the North Aegean Sea (from the Gulf of Thermaikos to Alexandroupolis). It is commonly accepted that scientific knowledge of the coastal ecosystems is still limited. Additionally, there are no reliable data regarding the fish and shrimp yields in most lagoons, especially in the case of multi-species fisheries. A matter of similar importance is the fisheries and environmental data collection process applied in these areas today. In the case of a closed Gulf, such as the Amvrakikos Gulf, the pollution and the other coastal human activities apply significant stress on the population of the native shrimp, Penaeus kerathurus. The isolation of the species population in the Gulf combined with the facts that this population has never been studied before and that it is considered as the most valuable commercial product of the whole region, makes the need for a thorough study imperative.

Materials and Methods

The Greek research team of the National Centre for Marine Research (N.C.M.R.) attempted to conduct experimental fishing first time in August 1999. However, the resulting catch was less than 4 individuals indicating that it is not cost-effective to conduct experimental fishery for the collection of shrimps from the area. After consultation with the local fishermen, it became obvious that the daily catch of the commercial fishermen is between 1 and 5 kg of shrimps. Therefore, the research team could not collect the required amount of more than 15 kg from every region around Amvrakikos Gulf and it would not be cost-efficient (daily boat rentals etc.). For this reason, a close collaboration was formed with the local fishermen and in particular, the professional fishermen of Amfilohia city, Vonitsa city and Preveza city. The fishermen collected samples every day of the month during their normal operation and kept them in freezers (<-4°C) until the team collected them once monthly. The fishermen kept a special protocol, which described the date of the catch, the total catch, the depth and the nets used. The frozen shrimps were transferred to the laboratory in portable polyurethane freezers and on ice to prevent thawing. Once in the laboratory, the shrimps were stocked in a large freezers (-20°C) until measurement.

In addition, the research team of N.C.M.R. conducted experimental fishery once per month (during night-time and day-time) with the objective to:

- estimate the C.P.U.E. of the shrimp fishery in the various regions of the Amvrakikos Gulf area,
- make observations on the methodology of the net operations

- take water samples for the analysis of the basic environmental parameters required for population dynamics (on site measurement of temperature, salinity, conductivity, pH, transparency, dissolved oxygen as well as receive samples for nutrient analysis in the laboratory)
- record various information on the feasibility of the fishing activity

The collection of social and economic information related to shrimp fisheries, market and products as well as the local fishermen social group, was based on the distribution and completion of questionnaires which lasted 20 months.

Results

1. Area Description

The Amvrakikos Gulf is located on the west coast of Central Greece between 38°55' and 39°05' N and 20°45' and 21°10' E. It covers an area of 530 km² with a maximum length of 35 km and maximum width 20 km. The maximum depth of the Gulf is approximately 63 m at the centre according to the maps but bathymetric study during this project showed a maximum depth of 58 m indicating a 30 cm decrease of depth per year, approximately. The Gulf is connected with the open sea (Ionion Sea) through a narrow channel located at the west side. The width of the channel is about 600 m and the maximum depth is 7 m. There are 2 rivers: the Louros and Arachthos rivers that flow into the Gulf from the North side creating a multiple habitat that sustains aquatic ecosystems locally. The flow of the rivers is continuous at 32.9 and 15.5 m³/sec respectively.

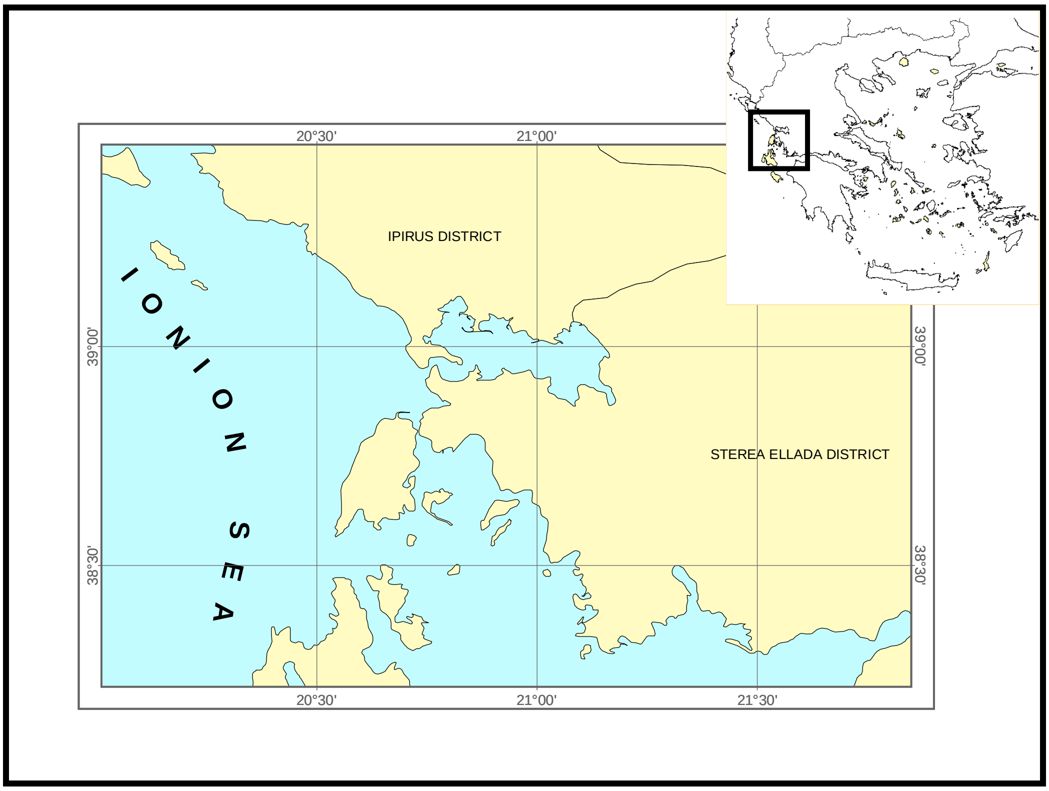

Figure 1. G.I.S. map of the Amvrakikos Gulf area (Central-Western Greece)

The rivers have created over the years, a series of lagoons at the North side. These 4 lagoons are named Rodia, Tsoukalio, Avleri and Logarou. These lagoons can be organized in two distinct areas - the Tsoukalio complex (composed of the lagoons of Tsoukalio, Avleri and Rodia, which are interconnected with canals) with an area of 6,000 Ha and the Logarou lagoon with an area of 4,000 Ha. The Tsoukalio complex is connected with Amvrakikos Gulf through one main canal located at the south side of the Avleri lagoon. From this canal, the seawater is transferred to the Rodia lagoon through the Tsoukalio lagoon and therefore, the isolation of both Rodia and Tsoukalio lagoons. The Logarou lagoon is interconnected with the Gulf through four openings on its southern levees. Most of the fisheries production of Amvrakikos area originated from these lagoons but the pollution (agriculture chemicals) and the management of freshwater flows for irrigation, has caused the dramatic decrease of water quality and lowering of the landings.

2. Uses and sources of conflict

The area of Amvrakikos Gulf is characterised by intensive uses along the coastal zone as well as the surrounding land. North shoreline exhibits 2 groups of large lagoons which are exploited for lagoon fisheries with traps. Further to the north (a distance of 1-2 km from north shoreline bordering the lagoons), an extensive irrigation and drainage system for agriculture is operation (around 100 km²). The system outflows at the north shoreline through 2 rivers (Louros and Arachthos) and a few special channels (*Fig. 2. Red boxes*). Livestock is greatly developed in the surrounding lands. Also there exist 3 major commercial harbours and 7 small fishing vessel refuges (*Fig. 2. Boat icon*). The commercial harbours are used for transportation of agriculture materials (mainly chemicals) and fuel. In a few areas organised campings can be found and small scale tourist activities take place. However, most tourist activity is transferred to the Ionion Islands and especially Lefkada (15 minutes from the Gulf on average). On the east shoreline, 2 fuel depots can be found (SHELL and MAMIDAKIS) and on the south-west shoreline, one air force fuel depot can be found. Finally, 21 cage fish farms, 3 ell farms (land based) and 2 hatcheries operate in the area (*Fig.2. yellow arrow-boxes*).

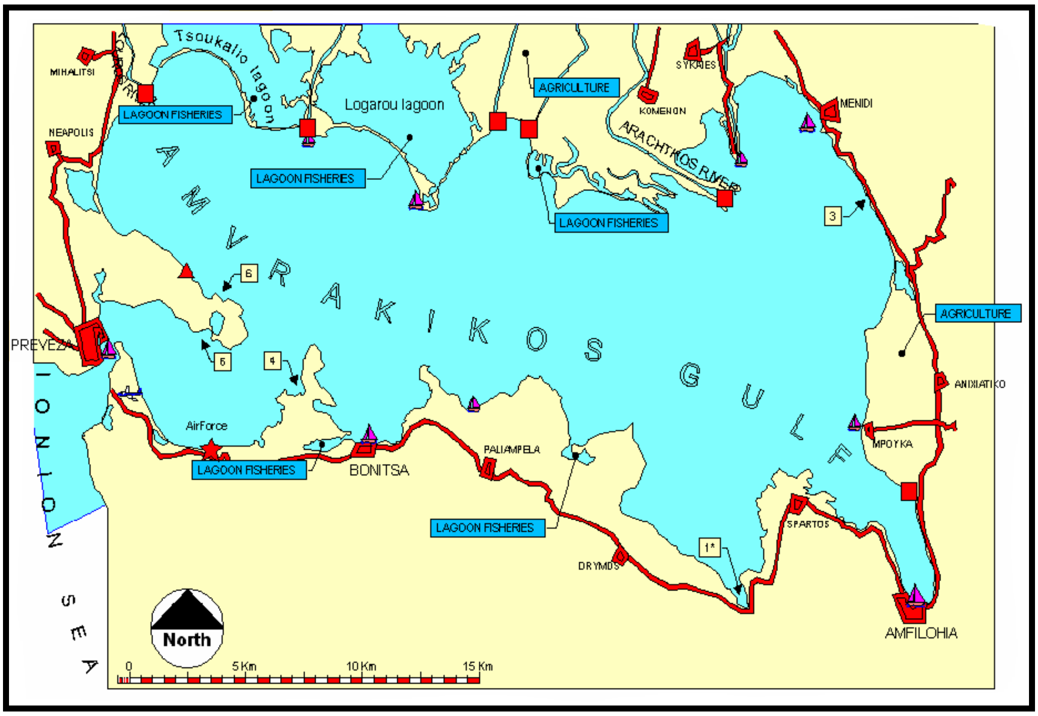

Figure 2. Distribution and location of the major coastal zone uses in Amvrakikos Gulf

3. Fleet and professional fishermen

Due to major discrepancies between the Ministry of Agriculture records of professional fishermen and vessels and the initial observations of the research group in the area of Amvrakikos Gulf, forced the group to undertake an extended campaign to count all vessels and fishermen based on the local Unions and actual observations in harbours and refuges.
The results showed that there are:

- 12 official and registered cooperatives of professional fishermen

- 604 fishermen with professional licenses issued by the local Coast Guard Authority
- 435 fishing vessels operating in the Gulf

Most fishermen and Unions are located on the north parts. Harbours located on the western shoreline also exhibit high numbers of registered vessels and fishermen but care should be taken to distinguish the fleet segment which operates out of the Gulf (Ionion Sea coasts). Those vessels are purse and beach seiners mainly which are not allowed to operate these gears in the Gulf.

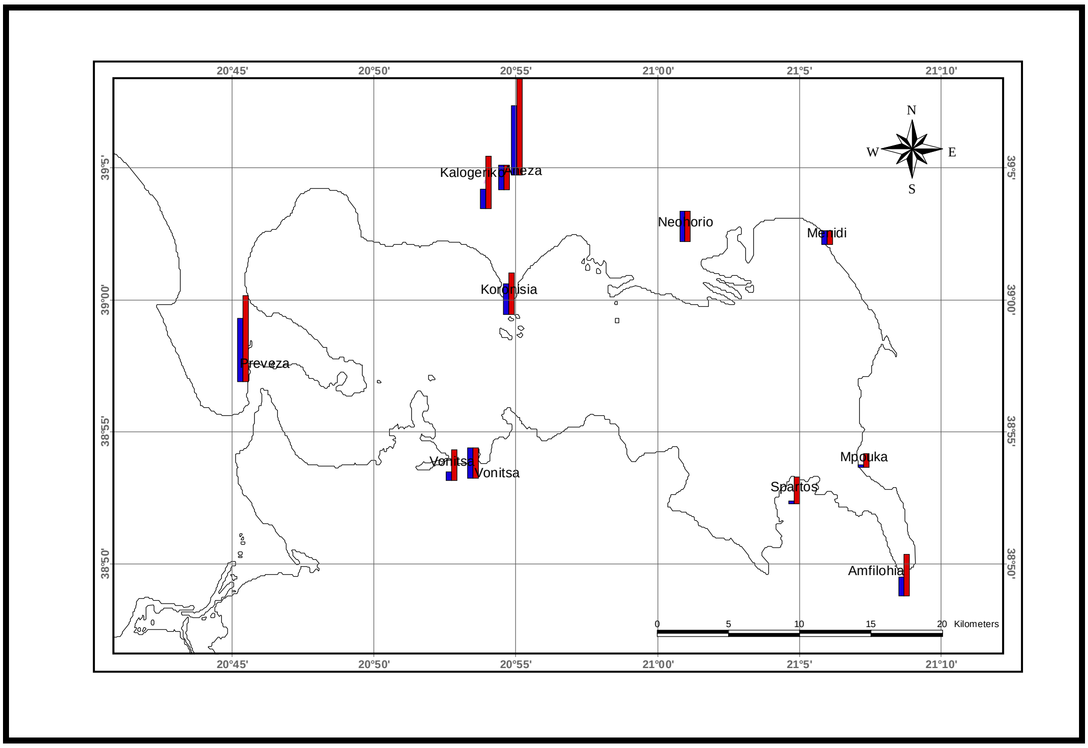

Figure 3. Distribution of fleet and professional fishermen

4. Vessels and fishing operations

Fishing of shrimps is carried out using trammel nets with a mesh of 22 mm and external net mesh, 110 mm. Today this is the only allowed gear in Amvrakikos Gulf according to the legislation in effect. The nets are deployed usually at depths between 5 and 16 m in various areas of Amvrakikos Gulf. The nets that are used in the area, in general, have a length of 500-600 m and a height of 1.5-4 m. The traditional net that was used in this study exhibits a height of 1-1.5 m and a length of 600m. The nets are deployed either parallel or perpendicular to the coastline depending from the coast morphology and previous experience. The nets remain in the water for 2 to 12 hours depending to the season and the existence of large schools of other non-commercial species as anchovies and sardines or large animals (dolphins and turtles) that may destroy the net.

The boat used locally is called "priari" and is a small wooden craft with a length between 4-8 m and a small inboard petrol engine (5-15 HP in most cases).

- Size 6-9 m, average 7 m
- No keel, wooden, traditional ship building technique unique in the region
- facilities for net lifting are rarely installed as in the picture on the left; hand lifting of nets limits the depth of deployment at depths above 10 m
- Engine: inboard, petrol, 5-25 HP, average: 15 HP
- Trammel nets and long lines only
- One or two (2) fishermen per boat (owner-worker)

5. Fishing grounds

Previous studies undertaken in the area of Amvrakikos Gulf, have shown that there has been a dramatic change in the distribution and migration patterns of the species in Amvrakikos Gulf.

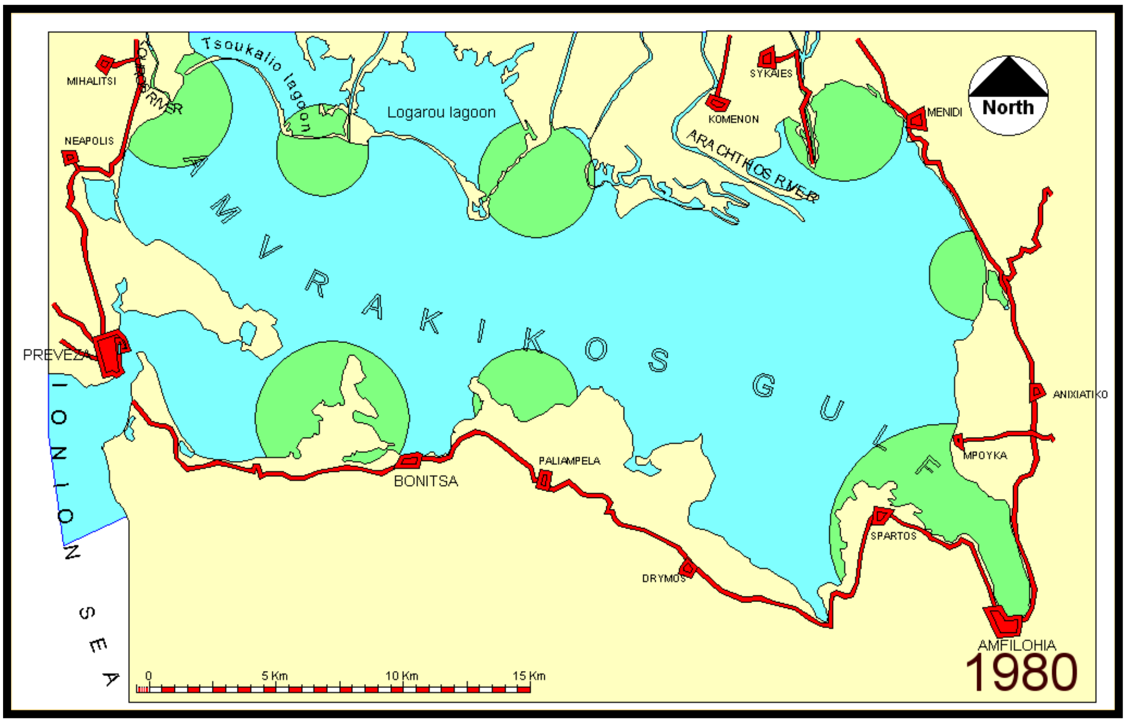

Figure 4. Distribution of the main shrimp fishing grounds in Amvrakikos Gulf (1980-1984)

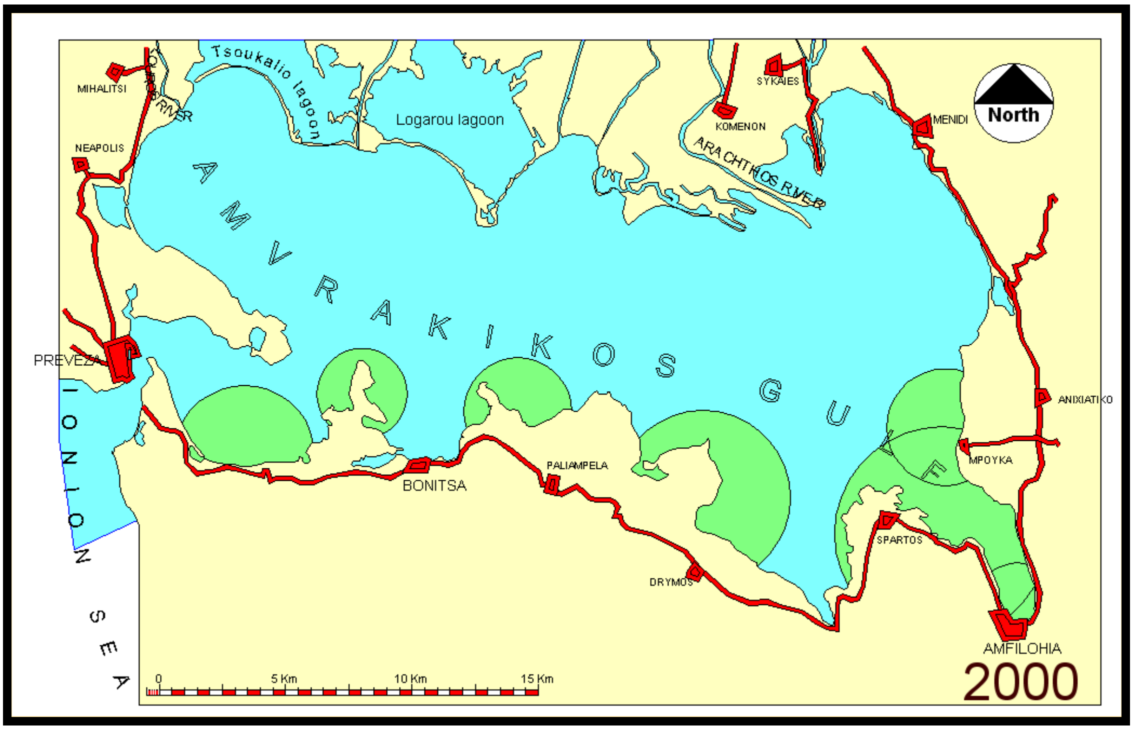

Figure 5. Distribution of the main shrimp fishing grounds in Amvrakikos Gulf (1999-2002)

The results have shown that the fishing grounds have been reduced almost to 50% and are today located along the south shoreline only. Traditional fishing grounds (and also reproduction grounds where adult shrimps gather) around the river deltas have been eliminated due to agro-chemical pollution (Louros river; north-west shoreline) and water management for upstream hydro-electric power production (Arachthos river; north-east shoreline).

6. Relationship between fishing trips and fishing grounds

The use of old and traditional fishing vessels in the Gulf as well as the extremely low financial strength of fishermen – which hinders their ability to modernise the vessels or buy more nets - does not allow them to operate far from their home ports. The average fishing trip is 2-3 hours (one way) until the selected area for net deployment and is highly affected by the weather (especially the winds coming from the west).

Fishermen from the north shoreline need to cover long distances in order to reach the rich south fishing grounds. Fishermen from Amfilohia city (south-east area) usually operate within the Amfilohia Gulf. The low financial strength of the fishermen does not allow them to invest in nets and on average each fishermen owns 800-1200 m of trammel nets. Because of this, the fishermen cannot exploit more than one fishing ground per day (only one location). Only a few fishermen with large vessels (coastal vessels, 8-10 m in total length, 30-60 HP) which are registered in west harbours (Preveza city) exhibit the appropriate power to cover within one day all the area of Amvrakikos Gulf and therefore, these vessels can exploit more than one fishing grounds simultaneously.

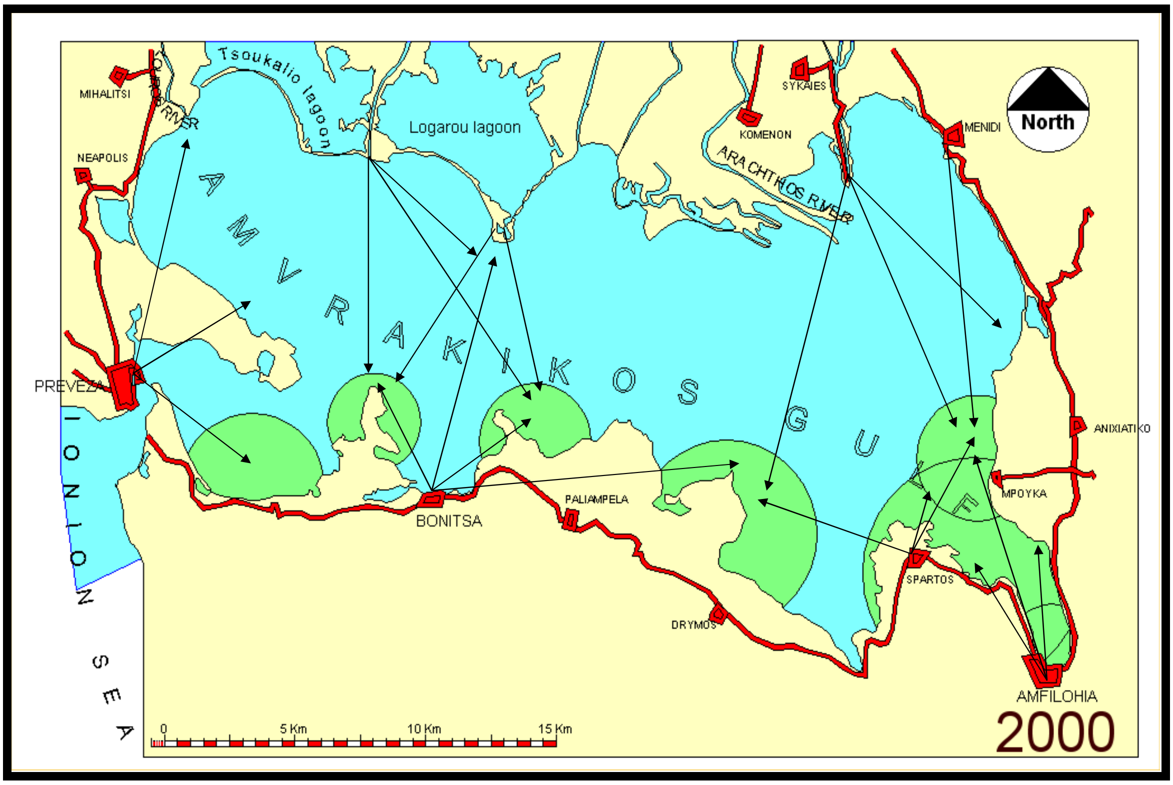

Figure 6. Relationship between fishing grounds and fishing harbours/refuges in Amvrakikos Gulf (arrows: daily fishing trips)

7. Products types

The main fishing products in the area of Amvrakikos Gulf and their average prices (period 1999-2002) is the following:

• Shrimps (*Penaeus kerathurus) **	26 €/kg
• Sea-bass	9 €/kg
• Sea-breams (4 species)	15 €/kg
• Eels	7.5 €/kg
• Mullets (4 species)	5.9 €/kg
• Red mullets (2 species)	11.8 €/kg
• Cuttlefish *	4.5 €/kg
• Sardines, Anchovies**	2 €/kg
• Sardinella**	2 €/kg

** Target fishery, seasonal*

*** Spatial interest, from no interest to full target fishery*

The products are sold whole fresh, directly to consumers on dock or through retail shops. There is no possibility for any kind of processing or packaging and in more than a few areas, there is lack of freshly produced ice to preserve the products temporarily.

8. Spatial interest in pelagics

The collection of market and product data around the Gulf, indicated that there is a diversity of perception among fishermen of the market value- and thus, fishermen preference – regarding the small pelagics. The eutrophication of the Gulf due to agriculture pollution is very high and the environment is beneficial for small pelagic fish feeding on plankton (sardines, anchovies).

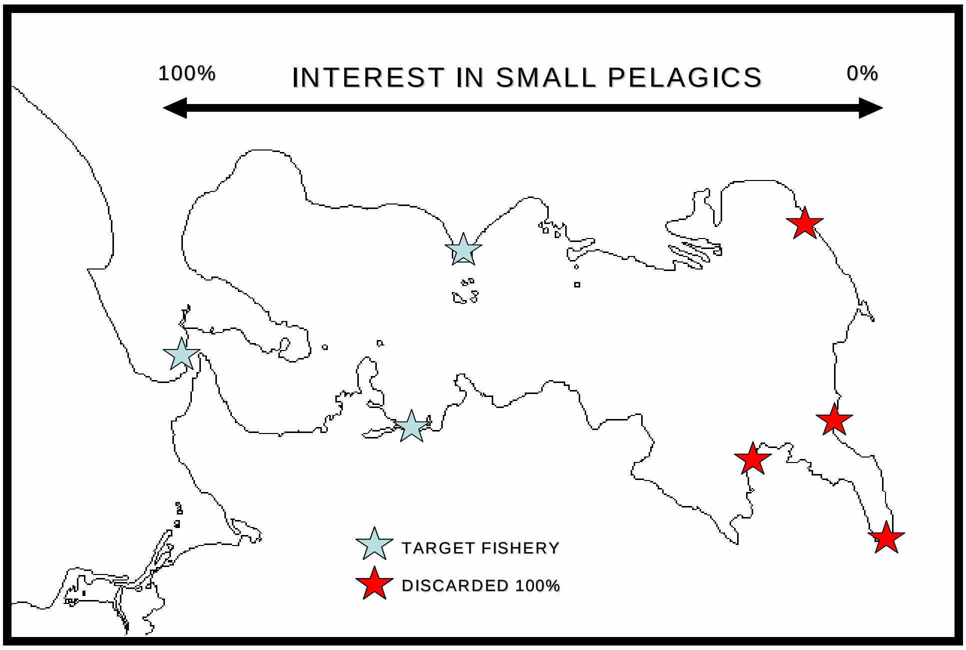

Figure 7. Spatial interest in small pelagic species

Fishermen operating at the east parts of the Gulf discard 100% the small pelagics that they catch on their nets and actually, during several periods of the year, they deploy the trammel nets only for 2-3 hours per day because the amounts of small pelagics caught do not allow the nets to be easily lifted by hand. However, in the rest of the Gulf, small pelagics and especially sardines are very well received by the fishermen and in the northern parts is considered as a local delicacy (locally called "papalina") and there exists a target fishery for these species.

9. C.P.U.E. and spatial distribution of C.P.U.E.

The results from the experimental fishery organised during the projects showed that high C.P.U.E. values can be obtained from the south fishing grounds, hence the fishermen preference for these areas and very low or 0 values, from the north grounds. This result is explained by the distribution patterns of the shrimps: abundance is higher in the south ground and very low in the north grounds due to agriculture pollution.

The results were:

- Average fishing days per year = 225
- Average C.P.U.E. per day (g 1000m of net^{-1} day^{-1}) = 3421 ± 354 g
- Average income (€ year^{-1} fisherman^{-1}) = 7500
- Comparison with average income in Greece = ~ 50%

C.P.U.E. values also fluctuate on a monthly basis significantly with higher values in winter and lower values in summer. At this point, however, the effects of sport fishing on the lowering of C.P.U.E. during summer cannot be assessed because sport fishing in Greece is completely uncontrolled by all authorities and the fact that this fishery is "open access" without any limitation at all limits the capacity and the benefits from the further analysis of C.P.U.E,

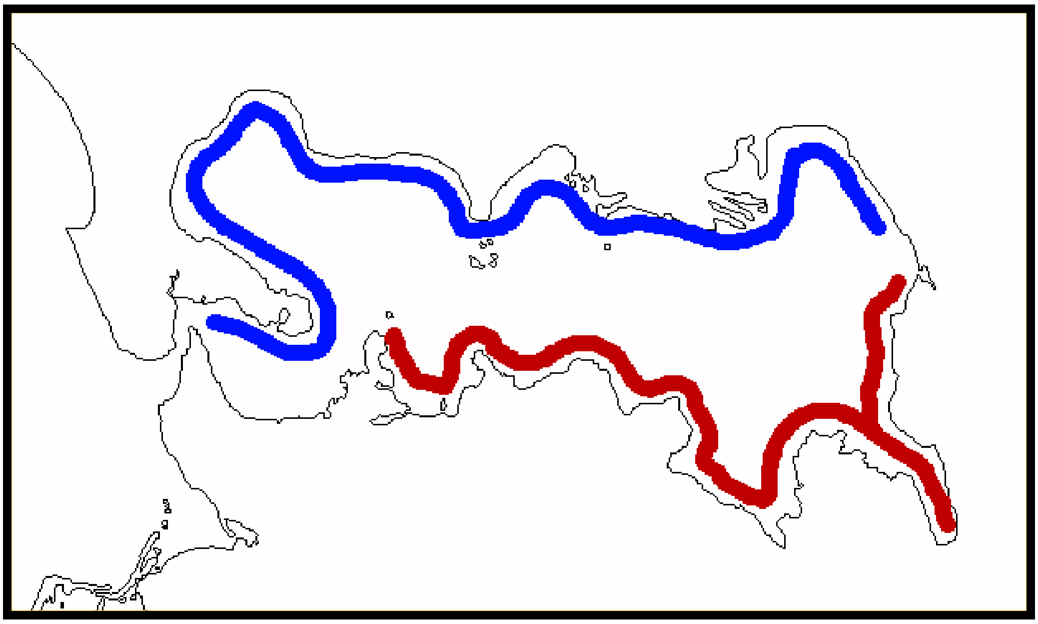
Figure 8. Spatial distribution of C.P.U.E. values (red: high values; blue: low values)

10. Fishing costs

Based on the questionnaire survey and visits to the local retail fishing gear supply shops showed the following, regards fishing costs (recalculated to depict daily values):

Boat maintenance	1.4 €
Boat painting	2.0 €
Other costs (replacements, minor service etc.)	1.0 €
Fuel, Oil	15.0 €
Wages (one worker)	35.0 €
Engine overhaul (once annually)	2.0 €
TOTAL DAILY COST	**56.4 €**

The overall analysis of costs and revenues showed:

- Daily Costs = 21.4-56.4 € (with or without worker respectively)
- Daily Production = 33 €
- Theoretical Overall Income = -23.4 € to 11.6 € per day
- Usual Income = 0 to 11.6 €

11. Other sources of income

Based on the family questionnaires completed by the professional fishermen, the following major categories of income supplementation were recognised ranked according to significance:

1. Ownership of retail fishery product stores
2. Ownership and exploitation of agriculture plots and/or livestock herds permitted by Law 1361
3. Occupation as seasonal workers in public works of regional authorities (fire dept etc.)
4. Members of the families (wives) work also
5. Ownership of taverns (rare)

6. Tourism (very rare)

More than 80% of the fishermen have another source of income and this further justifies the extremely low financial strength and consuming capacities of this social group.

12. Social concepts and their application in the case

In the social science, there exist several social concepts which help to understand and categorise social groups and in particular, understand the effects of management (centralised-decentralised). These concepts, important for the shrimp fishing sector are: alienation, specialisation, interdependence and individuality, tradition and modernisation and public goods.

Alienation: the concept of *alienation* is that extreme specialisation can cause the separation of a sector or a group of people from the surrounding society in both ways: the society cannot approach or aid this group of professionals and support them in their work due to differences in aims and other general issues and in the same time, the group cannot follow the society trends since they are mostly unable to change the ways the carry out their profession.

Specialization: the various sectors of fishing industry require a high degree of *specialization* in order to achieve the expected results. High degree is required due to the scarcity of the resources.

Interdependence/Individuality: The economic concept of *interdependence* is based on the fact that specialisation and labour division may lead eventually to the interdependence between social groups in order to achieve the same goal of prosperity. The 'individuality' of fishing profession may not help the fisherman to gain monetary value from distributing his overheads over a greater chain of production unless he has a second occupation (part-time in most cases) and/or own a fish retail shop.

Traditionality/Modernization: fishing in the area has been carried out using traditional methods, which were taught by the older fishermen, and little or no advances were observed during the on-site surveys. The use of fish finders with speed-meter and thermometer attached was used in one case and the preliminary results showed a dramatic lowering of the effort (less time in the sea) and increase success in fishing larger amounts of fish by at least 40%. This technical upgrade would be favourable for the local fishermen BUT ONLY when limitation in the catch will be enforced.

Public Goods: eventhough the fishermen are not liable to taxes, they benefit from *public goods*. In this case, these public goods (apart from the usual ones such as schools, roads, hospitals etc.) are mainly ports and fishing refuges for the protection of their vessels and gears. However, the intention of the Ministry for the Environment, Planning and Public Works (YPEHODE) which is responsible for these works, is not to support the fishermen only since these structures aid also tourism (yachts, sport fishing etc.) activities in the area and in general, these works contribute to the welfare of the community. Again, in this case we may find that there are no actions from the central government directed to the fishermen alone unless there is a specific program from the E.U. with funds for fisheries and which is exploited for the benefit of the government first and secondly for the fishermen.

13. Other Social Issues:

Based on the family questionnaires completed by the professional fishermen, the following information was also derived:

- Family sizes: *3-4 persons plus elderly members; 1-2 children on average*
- Number of working persons per family: *1-2; extremely rarely 3*

- Fishermen are considered as an important part of the local society as "*customers*" (services, fuel/oil, bank loans, debts to fishing gear stores)
- Average debts to fishing gear supplies retail shops: *~150 € (range: 0 – 500 €)*

14. Legislation in effect

Management of shrimp fishing in Amvrakikos Gulf is governed by National Laws and Presidential Decrees with nation-wide application as well as by two Presidential decrees of local interest and application. These are the following:

General use legislation

- P.D. 666/1966 (J 160A/1966) concerning professional fishing licences
- P.D. 373/1985 (j. 131A/1985) concerning sport-fishing
- P.D. 917/1966 (J. 248A/1966) concerning the operation of trawlers
- R.L. 26-1-1954 (J. 25A/1954) concerning size of landed fish
- Market regulation 10/1995 (J. 1012B/1995) concerning the minimum size of landed fish
- Market regulation 71/14-10-1986 concerning the minimum size of landed fish
- Law 1740/1987 (J. 221A/1987) concerning the protection of corals, fish farming and others
- Law 1361/1985 (J. 66A/1983) concerning the agricultural unions
- Law 420/1970 (J. 27A/1970) concerning the code of conduct of fisheries
- P.D. 1094/1977 (J. 356A) concerning the full prohibition of the use of monofilament nets from July 1, 1978 in whole Greek territory

Legislation for the Amvrakikos Gulf fishery

- P.D. 234/1979 (J. 65A/1979) concerning the prohibition of trawling in Amvrakikos Gulf
- P.D. 3-12-1952 (J. 339A/1952) concerning the shrimp fishing ban during July (1-31 July every year) in Amvrakikos Gulf

The most important observation from the above legislation list is the fact that those laws and decrees were issued a long time ago and without any scientific advice or research. Unfortunately, the fact that legislation is NOT based on scientific advice or any research activity is a common practice for Greece and in particular, the Ministry of Agriculture.

15. Other management schemes

To make things more complicated, anarchic application of other types of management schemes occurs in the area of Amvrakikos Gulf. One of the main results from the application of these schemes is the increased pressure on the fishermen by (a) increased cost for gear repair/replacement due to damages caused from endangered and protected species. These damages ARE NOT reimbursed by the Ministries of Agriculture (MINAGRIC) and Environment (YPEHODE) and therefore, fishermen are aggressive against these species; (b) further limitation of fishing grounds.

In the area, there are 3 main management schemes recognised during the study: (a) LIFE Nature project focused on the north lagoons; (b) numerous RAMSAR areas with various designations (a,b,c etc.) and (c) numerous areas included in the NATURA/CORINE lists (lagoons, land strips between lagoons and open sea, river deltas, salt and mud marshes etc.).

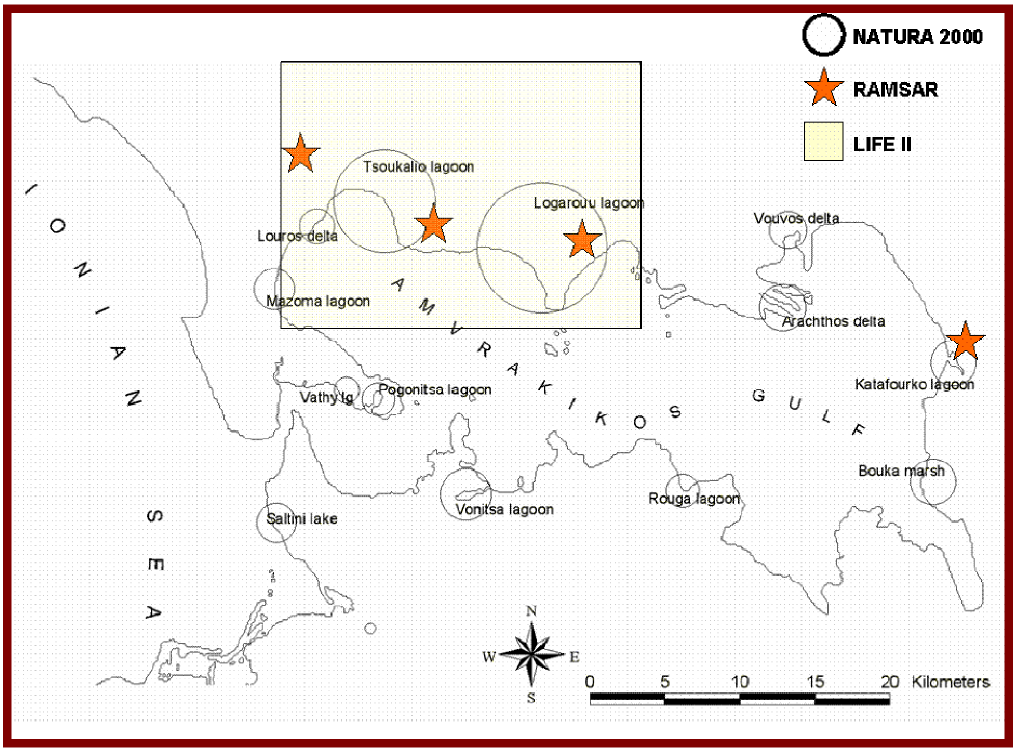

Figure 9. Specific management and protection schemes in Amvrakikos Gulf

16. Management requirements

From the results of the research study on the fishery of *Penaeus kerathurus* in Amvrakikos Gulf and the difficulties encountered during the study, the following information are fundamental for shrimp fishery management in the area and which do not exist today:

- ***Detailed study of the environment*** – the state of pollution, existence of endangered species, monitoring and detailed databases
- ***Fisheries assessment studies*** – to assess the status of the resources
- ***Detailed study of the economic sector*** (all economic activities) to reveal the importance of the various sectors (including fisheries) for the local economy – description of market, prices and elasticities of prices, demand and supply of products, fishing cost. Also include Infrastructure – fleet, distribution of fleet, age of fleet, processing sector, fishing routes and distances plus built new; Legislation and environmental protection schemes – the balance between the natural and human environments has to be maintained.

In order to support any shrimp fishing management plan, the following actions are required:

- ***Establish a basic monitoring system*** – Production time series, Fleet, Fishermen, Data Bases
- ***Enforce a basic management framework*** – size limitation, gear, licenses, TAC/QUOTA
- ***Support fisheries by development of Infrastructure*** – Processing and packaging, whole sale and retail markets
- ***Funds for reimbursement of damages*** – Special Bank loan schemes
- ***Legislation enforcement***

17. Simple bio-economic analysis of fishery data

In order to include social, economic and biological parameters in the analysis of the shrimp fishery of *Penaeus kerathurus* in Amvrakikos Gulf, a simple bio-economic model was used (Lleonard, Franquesa and Maynou; ECON 1.2 model). ECON is a simple bio-economic fisheries model with main purpose to illustrate the dynamics of a fish stock subject to fishing by an economic agent. The fishing fleet has certain economic and technical characteristics

(Capital, fishing power, effort, etc.) which inflict a fishing mortality (F) to the fish stock. The fishing process results in catches which are then sold and tranformed in revenues. A fraction of these revenues will directly be used to increase or diminish the Capital or the effort of the fleet. The fishing mortality is dynamically changed at each time step, by virtue of the relationship of F with q (catchability) and E (Effort). MECON can be used to study the changes produced in the fishing system by technical or economic measures imposed by the user, either as startup conditions or at given periods of the simulation horizon (events).

Since from the existing data on *Penaeus kerathurus* in Amvrakikos Gulf, Biomass and Biomass∞ values cannot be estimated or "guesstimated", only the part of the model relating catch evolution with fleet characteristics was used.

17.1. Model data
The model was fed with the following data which were estimated during the process of the analysis of the shrimp population dynamics and the study of questionnaires:

- Catchability (q = F/effort; constant) = 0.0024 (from dynamics)
- Effort = 465 vessels (from questionnaire surveys)
- Fleet capital = 5.000.000 € (from questionnaire surveys)
- Cost of unit of effort = 56.4 €/day (from questionnaire surveys)
- Price of catch unit = 28.8 €/kg (from questionnaire surveys)

The initial values which were used to run the model showed that the annual catch can be maximised at an effort of 600-650 vessels and which confirms previous results derived from the carrying capacity analysis (Fig. 10).

At the same time, the annual catch is shown to maximise at fishing mortality (F, year^{-1}) values around 1.25-1.3. This confirms the results from Beverton-Holt Y/R analysis. Overall Y/R analysis showed that the current fishing mortality ($F_{CURRENT}$=1.11 year^{-1}) and which was lower than F_{MAX}. Since the model showed that it behaves well in comparison with data derived using other methods, three year-cycle scenarios were studied:

A. No investment
In this scenario, the fishermen will not use any part of their revenues from fishing activities in order to buy more fishing effort (gears or boats). Such a strategy does not affect the catchabiltiy of the fleet which remains constant nor the effort. We assume that the rate of damages and fishing costs as well as the state of the population remain stable.

B. Investment of 10% of revenues to fishing effort
In this scenario, the fishermen will use 10% of their revenues from fishing activities in order to buy more fishing effort (gears or boats). Such a strategy affects the catchability of the fleet. We assume that the rate of damages and fishing costs as well as the state of the population remain stable.

C. Investment of 90% of revenues to fishing effort
In this scenario, the fishermen will use 90% of their revenues from fishing activities in order to buy more fishing effort (gears or boats). Such a strategy affects the catchability of the fleet. We assume that the rate of damages and fishing costs as well as the state of the population remain stable.

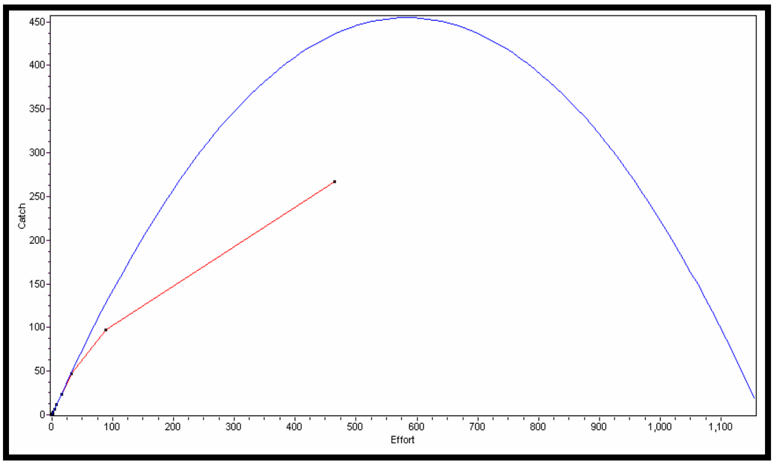

Figure 10. Expected development of annual catches in relation to fishing effort (vessels)

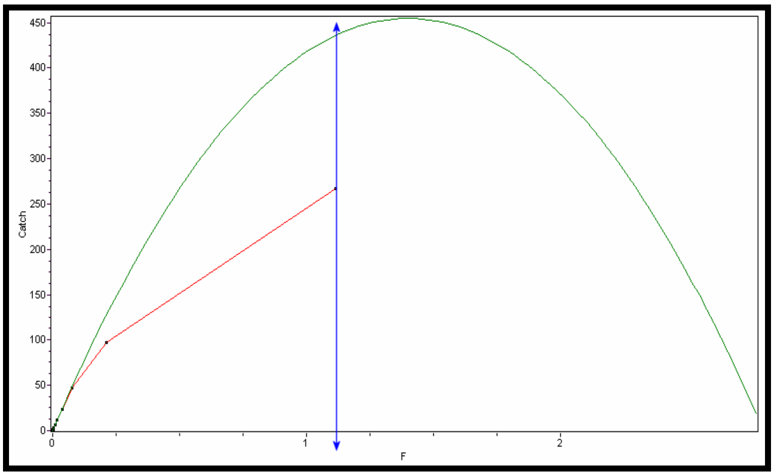

Figure 11. Expected development of annual catches in relation to fishing effort
(blue arrow-line: current levels of F in Amvrakikos Gulf)

17.2. Model results-Scenarios on expected annual catches

Scenario A: No investment to fishing effort

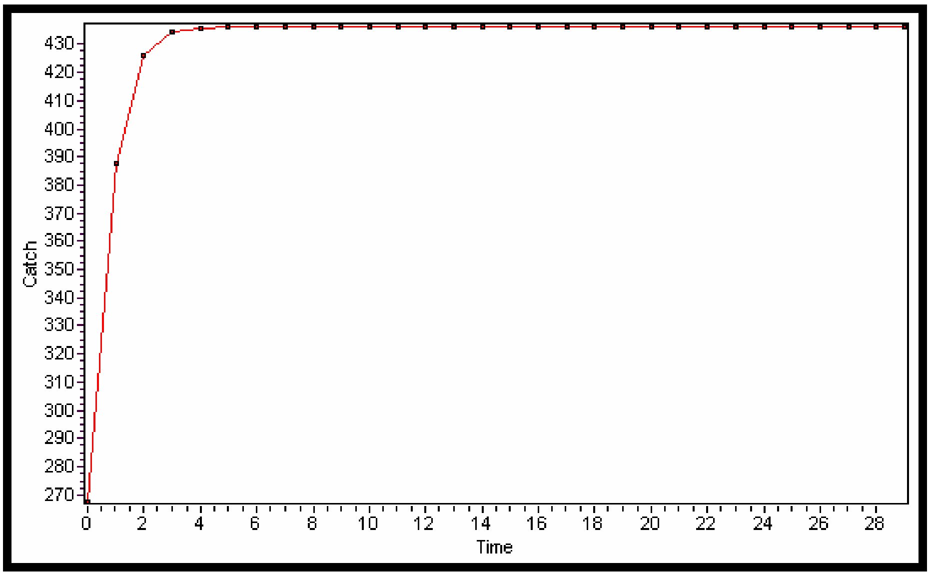

Figure 12. Expected levels of annual catches

From Figure 12, it is obvious that the catches will keep increasing and will eventually stabilise at a certain level which will be the product of effort and shrimp population growth.

Scenario B: 10% of revenues investment to fishing effort

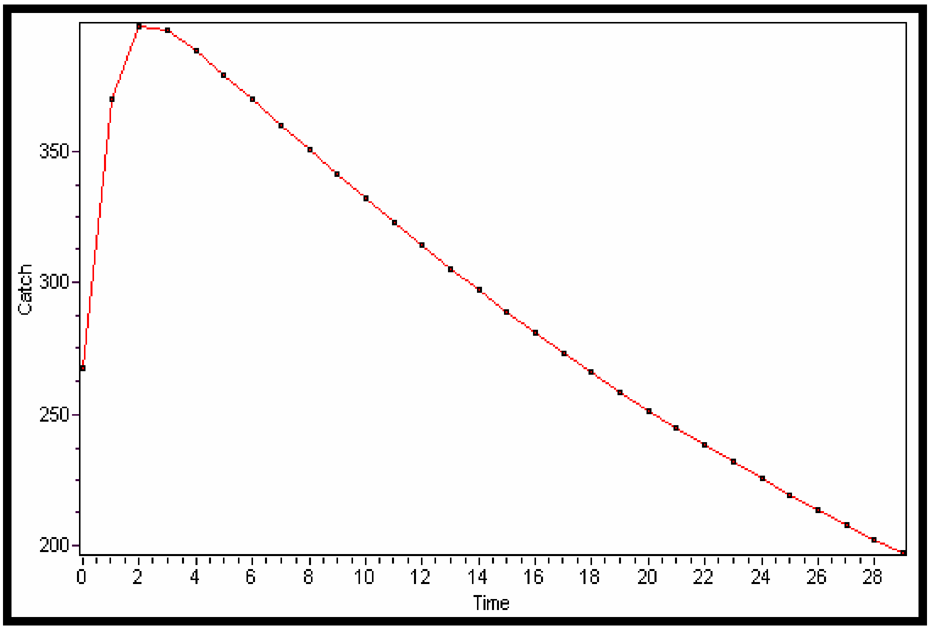

Figure 13. Expected levels of annual catches

From Figure 13, it is obvious that the catches will increase for a small period. Since the current fishing mortality at point 0 is lower than the F_{MAX} at the carrying capacity level, the catch will increase for a short period but afterwards, even a level of 10% investment will increase F values above carrying capacity levels and thus, the catches will start declining. The rate of decline is very slow due to the low increase of effort (bought with the 10% of the revenues).

Scenario C: 90% of revenues invested to fishing effort

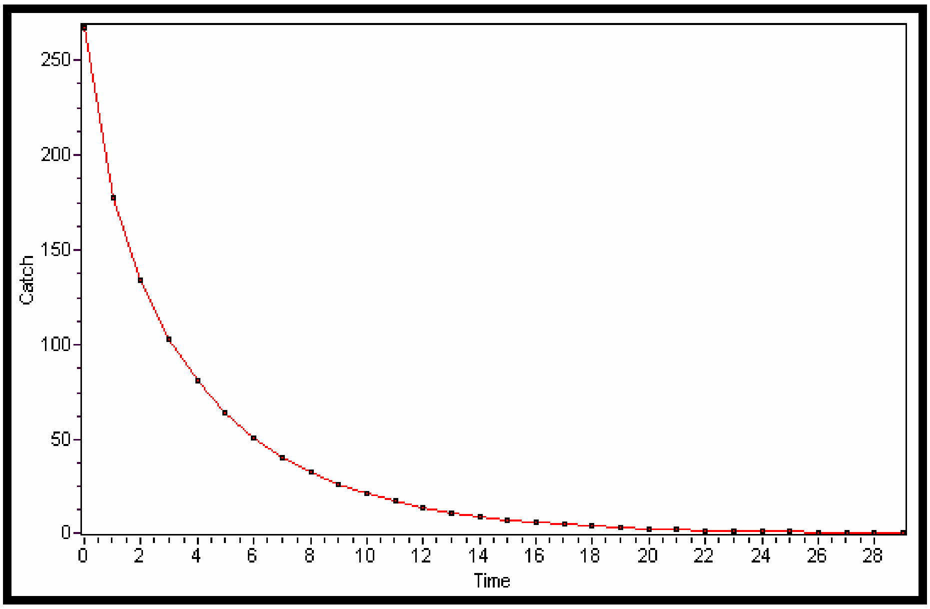

Figure 14. Expected levels of annual catches

From Figure 14, it is obvious that the catches will decrease from year-cycle 0. Since the current fishing mortality at point 0 is very close to the F_{MAX} at the carrying capacity level, a level of 90% of investment will increase F carrying capacity levels immediately and thus, the catches will start declining. The availability of the shrimps at sea also changes over the next year-cycles and therefore, the catches decline exponentially.

Acknowledgements

The findings reported herein were derived during the research project # **0037/98** entitled “Comparative study on the current state of fishery of the native prawn *Penaeus kerathurus* populations in North Mediterranean” approved and funded by the DG XIV-Fisheries within the framework of the “Biological Studies for the Support of the Common Fishery Policy” programme. Analysis and modeling were undertaken for the EDFAM project.

European Decapod Fisheries: Assessment and Management (EDFAM)

Concerted Action Project number QLK5 1999 01272

Workpackage 5: Draft Final Report

II. Management of European Crustacean Fisheries : A case study of the European lobster

(Proceedings from a meeting in Galway, Ireland, November 2000)

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Workpackage 5 of EDFAM

The draft final report of work package 5 of EDFAM is comprised of two main deliverables

1. A series of papers on the management of crustacean fisheries. The international legal context, institutional arrangements, property rights, delegation from central government, integrating biology and management and bio-economics are discussed in some detail (Report of WP5 Part I).

2. In a separate second report (this document) of WP5 a detailed discussion on the assessment and management of the European lobster is presented. This resulted from a meeting with the Irish industry and lead to discussions on the feasibility of a fundamental change from open access to limited entry to these fisheries. Interestingly the workshop subsequently lead to a submission to the Irish authorities from industry arguing for the introduction of limited entry complete with documentary evidence of support from industry groups. It remains a useful example of the feasibility and importance of integrating stakeholders in the development of policy for management of crustacean fisheries

Preface

During the 1990s the lobster fishing industry in Ireland organized itself into co-operatives and took on various local conservation and fishing control initiatives. These actions were largely unilateral by individual co-ops and there was no attempt to develop a regional or national management policy either from the central management authorities or from the industry groups themselves. Nevertheless the establishment of the co-ops and the conservation measures they adopted represented real progress and increased awareness of the need for conservation in lobster trap fisheries at that time.

A meeting in Galway, Ireland, the proceedings of which are in this report, was organized by the EDFAM project as a forum for the Irish industry groups in which they could express their opinion on management of lobster fisheries (both the structures and the fishing controls). This discussion was facilitated by the presentation of results of recent stock assessment, v-notching, local management plans and voluntary fishing controls in Ireland and of management systems and policies that had developed in other countries that gave a European wide perspective on this species. Contributions on American lobster were also included.

This meeting was in fact a first step in a process which subsequently saw the industry proactively seeking the establishment of limited entry to lobster fisheries in Ireland. This culminated in May 2001 with a formal submission to the Irish Minister for the Marine by the co-ops for the introduction of limited entry.

Herein are presented short papers from the meeting complete with minutes of the open discussion that ensued after the formal presentations.

Acknowledgements : Additional sponsorship for this workshop was provided by Taighde Mara Teoranta, Carna, Co. Galway, Ireland, The Irish Sea Fisheries Board (BIM), Dublin, Ireland and The Marine Institute, Dublin, Ireland.

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BIM/TCD

Integration of Biology and Management in Irish Lobster Fisheries

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Introduction

The biological characteristics of exploited fish species determine how they should be regulated and managed. Fisheries managers can also use biological information to judge the likely response of stocks to management actions based on biological characteristics. This integration of biology and management is valid and important in cases where there is insufficient quantitative data that would allow quantitative stock assessment to be undertaken. Lobster stocks in Ireland and elsewhere in Europe are one such case. Stock assessments are not routinely carried out and there is insufficient quantitative information available to identify the population structure or the stock recruitment relationship for instance.

In this paper two points are emphasized:

1. Various biological characteristics of lobsters and lobster stocks are important in
   - deciding on the appropriate scales of the management for these fisheries and
   - informing management of the effects of various conservation measures and their relationship with catch rates
2. That because the scientific knowledge on lobster stocks is imperfect and increases incrementally as new research is carried out that management needs to be sufficiently responsive and adaptive to respond to new information.

The effects of various conservation measures or management actions will be determined by the biological characteristics (Table 1). Variable growth rate smoothes the effect of variable recruitment on catch rate. There is a significant delay between introduction of measures to protect spawning and any expected effect on catch rates. The expected return will be affected by local environmental conditions and therefore will not be the same in all areas. Even if spawning potential is increased there will not necessarily be a beneficial effect in all years. Discarding of undersized lobsters will lead to increased yield per recruit as natural mortality and discard mortality are low. Conservation of large female lobsters is an effective way to increase egg production because of higher individual fecundity, higher frequency of spawning, low natural mortality and long life span. Dispersal of larvae and especially of adults is restricted probably to a regional scale thereby identifying the appropriate geographic scale along which this species should be managed and regulated.

Table 1 . Biological characteristics of lobster particularly relevant to expectations of management and management structure

Characteristic	**Implication**
Growth rate is variable	A good year class will last many years in the fishery. All individuals born on a given year will not all recruit to the fishery at the same time but may reach the minimum size over a period of 10 years.
	After introduction of new conservation measures recovery of catch rates will take at least 5 years and possibly between 5 and 10 years
	Variable growth tends to stabilise catch rates as a number of both strong and weak cohorts may be in the fished stock at any given time.
	Because of the 5-10 year delay between egg production and recruitment to the fishery overfishing of spawning stock would go unnoticed for 5 – 10 years. Monitoring of catch and effort is therefore important

The environment affects recruitment	Probably depending on weather conditions during summer larval survival and settlement to the sea bed will be good or bad. Even with healthy spawning stock, therefore, recruitment may not be good in all years. However, spawning stock needs to be high in order to get good recruitment when the environmental conditions are favourable
	Similar conservation measures may not have the same benefit in all areas. Because the environment (the tidal conditions, temperature, wind directions, sea bed) is different in all regions the relationship between spawning stock and recruitment may also be different in each region
Recruitment will not continue to increase at higher levels of spawning	At a certain level of spawning stock recruitment will be sufficient to fill all the available habitat in an area. Further increases in spawning will not be beneficial without habitat enhancement. In Irish stocks it is unlikely that spawning levels are this high (see paper 2 below)
Natural mortality is low	Yields will usually benefit from allowing lobsters to grow to a larger size because there is only a small chance of lobsters dying from natural causes from one season to the next
Lobsters have a long life span	It is worth conserving large individuals that have already got over the phase of their lives where mortality is highest and that are now producing many more eggs than smaller animals. These lobsters will remain in the fishery for many years
There is a larval dispersal phase	Although adult lobsters do not travel great distances the larvae have the potential to travel 10s if not 100s of kilometers. The stocks are probably not isolated locally but there may be regional stocks within the country.
	Management structures should be regional rather than local in scale (see below)
	If local co-ops want to manage their area of coastline independently of neighbouring co-ops then the activity of neighbouring co-ops will still affect them. Neighbouring co-ops that have no conservation programme in place will benefit. The direction of larval drift will determine who will benefit from whom.

The co-operatives in Ireland

Lobster co-operatives in Ireland have membership along relatively small areas of coastline (mostly between 20-70 km). Figure 1 shows this local rather than regional structure. These co-ops are unlikely to be fishing their own individual stocks and some consolidation regarding conservation measures and management policy is appropriate along a regional scale as determined by the stock structure suggested by the dispersal ability of the larval phase.

It is uncertain as to what the correct scale of the management structure should be. This will depend on the extent to which larvae drift from one area to another. The direction of this exchange also determines who benefits from ‘downstream effects’ of larval dispersal. The implication of this is that individual co-ops who have no stock recovery program could benefit from the stock recovery plans of neighbouring co-operatives. This emphasizes the need for co-ops to consolidate their management policies on a regional rather than a local basis.

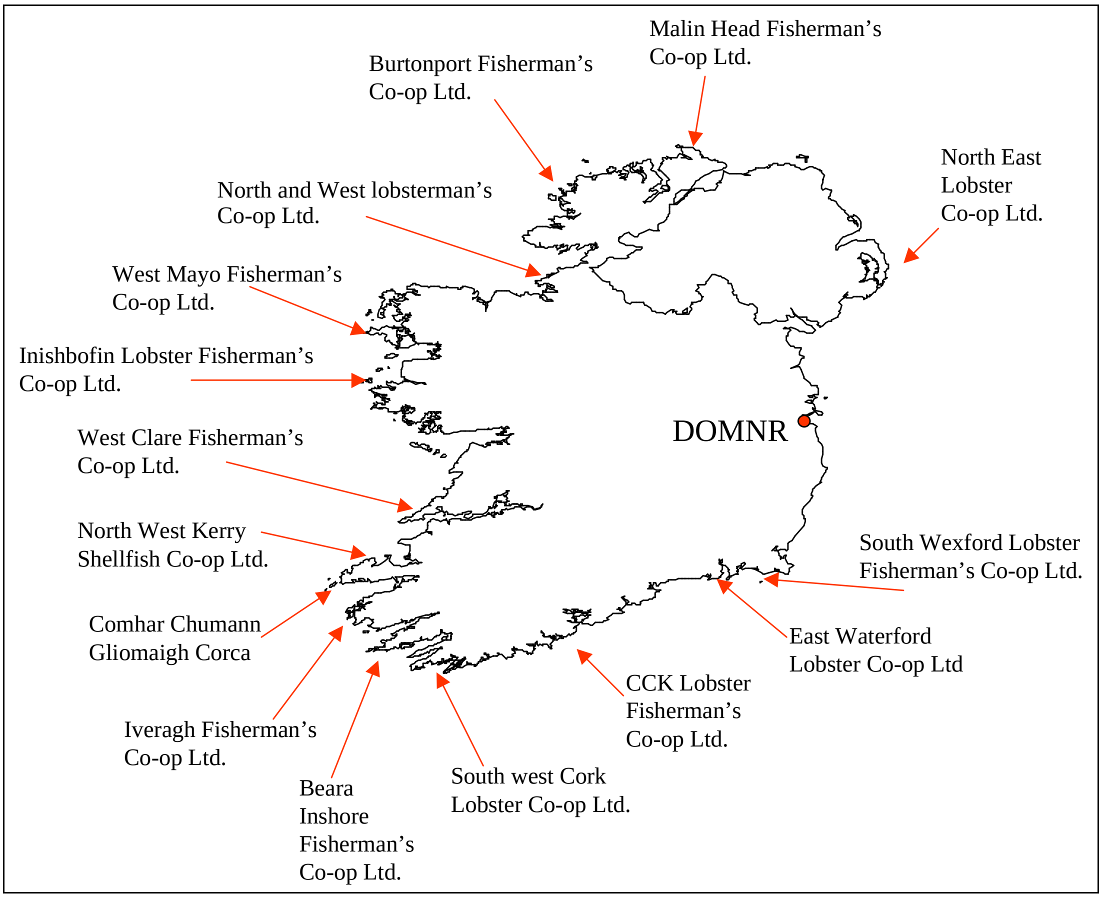

Fig. 1. Lobster co-operatives in Ireland. Other groups may also be active locally and are not included in the map.

Current and evolving management structures in Ireland

Lobster stocks are managed in Ireland by the Department of the Communications Marine and Natural Resources (DoCMNR) who transpose European legislation to Ireland (Figure 2). The direction of communication is in one direction from Brussels to the DoCMNR to individual fishermen. Many elements essential to good management in fisheries are missing from this model :

- There is no consultation between industry and management
- There is very limited capacity to respond to local or regional issues
- There is no regional structure or policy compatible with the regional structure of the stocks
- Although not the fault of the management structure there has been no input of scientific stock assessment into the management process to date in Ireland.
- Historically and today management control is weak : there is no means by which to control fishing and the fishery remains in open access, the conservation measures in place are not ideal for Irish stocks.
- There is no monitoring of the performance of the fishery. Statistics on landings and effort are poor.

Management structures and processes evolving in the Irish lobster fishery as a result of the development of co-operatives in the industry have many potentially useful elements (Fig. 2). The inclusion of the scientific process in management is seen as essential. The scientific effort needs to be focused on the needs of management and to inform it of the merits of different management options.

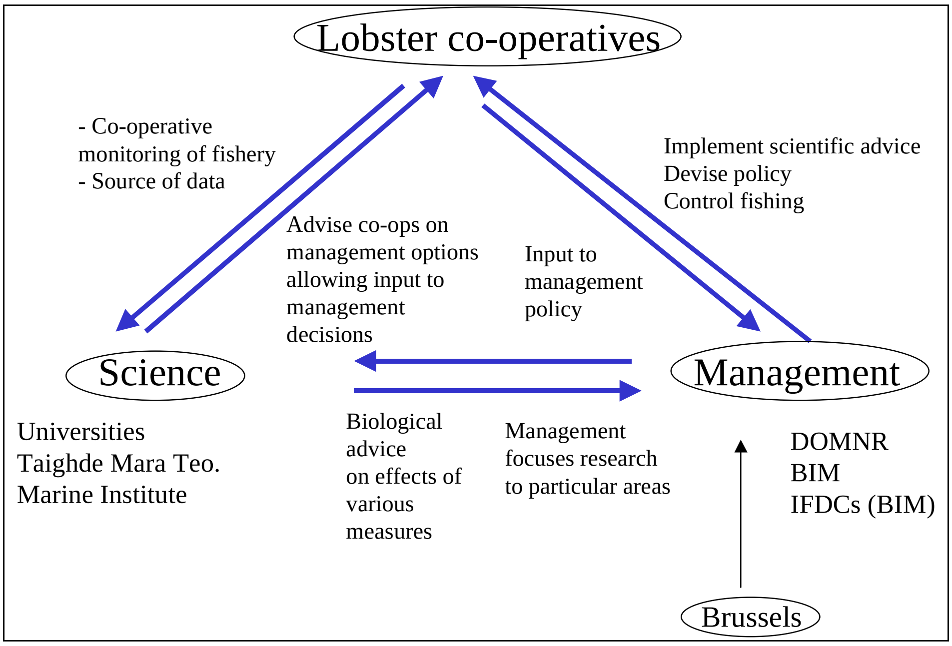

Fig. 2. Evolving management structures in Ireland's lobster fisheries. Interaction between the 3 main players is emphasized

The important elements in the structure shown in Figure 2 are

- Science can advice central management (DoCMNR) on conservation measures. This in itself ensures the use of appropriate measures for the Irish rather than the 'European' fishery
- Because the recent data has been collected at a local and regional scale science can advise local co-ops or regional management structures on policy on appropriate management measures.
- The co-ops and industry in general are seen as the vital source of data on which science depends. Without this interaction the management process breaks down as it will not be sufficiently informed.
- Because the co-ops receive management advice from science on a local and regional scale they can have a stronger interaction and debate with management on management measures and are better equipped to participate in a co-management arrangement.

Adaptive experimental management

Science and management have only an imperfect knowledge of the stocks and the outcome of various management measures are not strictly known in terms of catch rates which are the bottom line for industry. This is likely to remain the case in the medium term.

In this uncertain environment management needs to be sufficiently adaptable so that wrong decisions can be reversed and new policies can be enacted quickly as new information comes to light. Designing management so that it results in an incremental return of information that can be used to inform rather than simply regulate is important. Some examples of such a real world experimental approach might be

- v-notching of widely different numbers of lobsters in each area and monitoring the response in catch rate
- taking on different conservation methods in each region and monitoring benefits to the fishery
- local tagging programs to identify stock movements
- effects of changes in fishing or even closed areas on the size distribution of lobsters

The co-ops are in fact already experimenting in this way. Nobody proved to them that catch rate would improve before they adopted the v-notch measure ! Unfortunately this natural experiment has not been monitored sufficiently to inform management of the real cause effect benefits it may have had. Adaptive experimental management, therefore, requires a very strong interaction between science, management and industry.

Restoring Egg Production in Irish Lobster Fisheries

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Introduction

Recent work on lobster fisheries biology in Ireland has attempted to identify the current level of egg production and to evaluate the effects of different conservation measures on this egg production. The work provides information on the following issues

- It calculates how many eggs the average lobster produces in today's lobster fisheries before it is captured by the fishery
- It calculates how many eggs an average lobster would produce if there were no fishing
- It provided in at least one case study (the Wexford fishery) evidence that catch rates in the fishery are lower than they were in the 1960s for instance and that the stock abundance on the seabed has, therefore, probably also declined. There is little debate about this in the Irish industry.
- It provides a recommendation or an egg production target which managers of Irish lobster fisheries should aim for
- It provides advice on how to get to that target.

The model (the egg per recruit or egg production for every lobster recruiting to the fishery) is the model used to provide management advice in the American lobster fishery.

An explanation of the impact of fishing on spawning stock

In an unfished stock lobsters moult and spawn in alternate years although in some areas and depending on temperature they may spawn and moult in the same year. Natural mortality is low, lobsters live a long time and they produce more eggs in proportion to body size as they get larger. The probability of spawning increases as size increases and the probability of moulting decreases. Such lobsters may on average produce between 90-100000 eggs during their lifetime (Figure 1).

Introduction of a fishery on a previously unfished stock reduces egg production. The effect of this depends on the size of the fishery. Size in this case means how much fishing effort on different size classes of lobster (Figure 2).

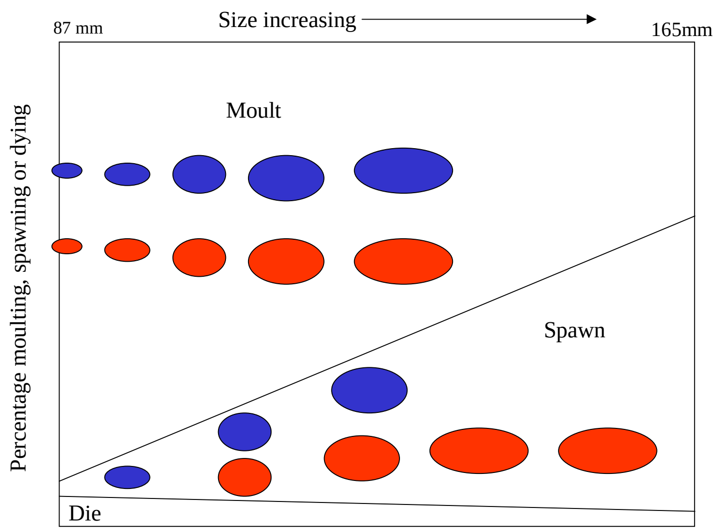

Figure 1. Moulting and spawning schedule in an unfished lobster stock. Moulting decreases and spawning increases as lobsters increase in size

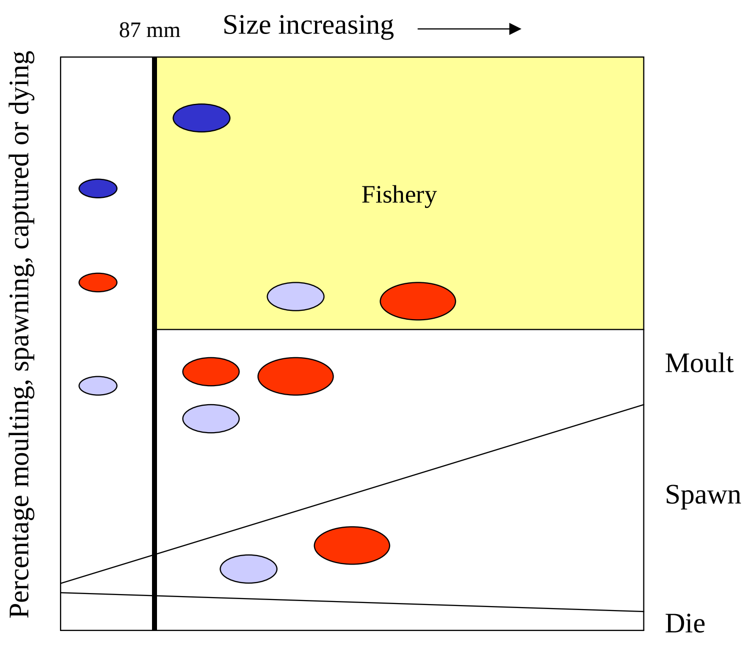

Figure 2. Introduction of a fishery (grey box) reduces the probability that lobsters will moult to a large size or spawn before being captured in the fishery. Spawning output is reduced. The size of the fishing box can be changed by reducing effort (change in height of the box) or changes in size limits (change in width of the box).

Regulation through size limits or effort control ?

An important point to note in Figure 2. is that the size of the fishing box can be changed by two methods

- Changes in effort
- Changes in size limits

and that changes in one can negate the potential beneficial effects of the other eg. if the size limit is increased from 87 mm to 90 mm the width of the fishing box decreases and more spawning will occur but a modest increase in effort would increase the height of the box resulting in zero effect. This begs the question that with no means to control fishing effort in Irish lobster fisheries will size limits or their equivalent be sufficient to restore egg production ? Management needs to be aware of the interaction between fishing effort and technical measures.

A summary of the different methods of controlling the size of the fishing box is given in Figure 3. Technically it is possible to manage spawning stocks with size limits alone. However, some restriction on effort, either directly through limited entry and trap limits (control of inputs) or indirectly through a TAC (control of output or landing), would be necessary if effort continued to increase. Without effort control management would need to put ever increasing restrictions on the size of lobster that could be landed. This would lead to more costly fishing and an inefficient industry i.e more effort going after ever decreasing numbers of legal lobsters.

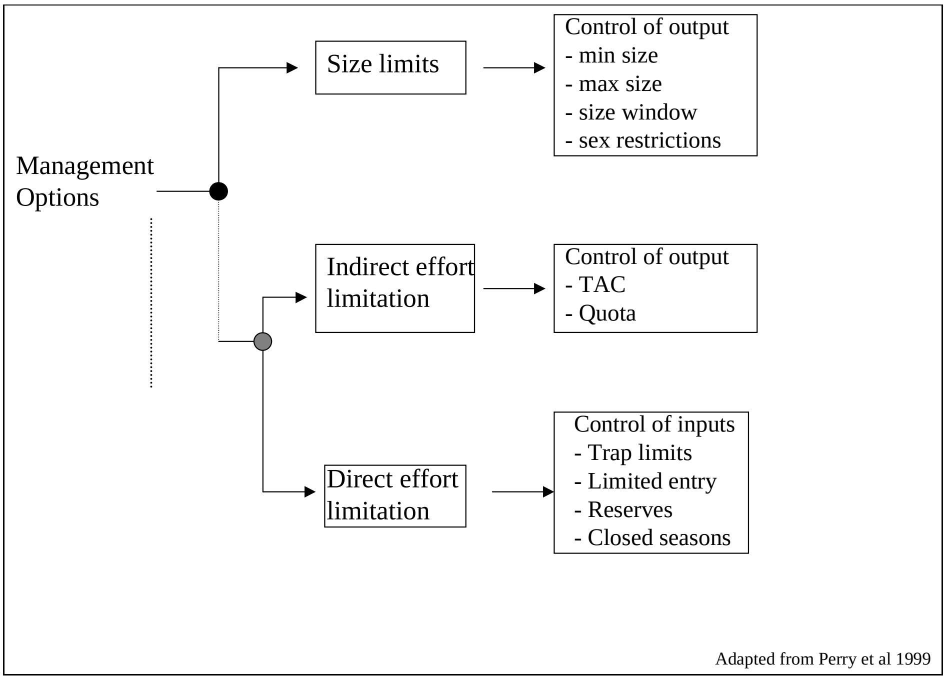

Figure 3. Methods to control fishing and protect spawning stocks.

Size of lobsters landed in Irish lobster fisheries

Figure 4 shows the size distribution of lobsters in the landings by region in Ireland (taken from Tully et al. 2001). Lobsters vary in size from 83 – 165 mm. The upper size is probably due to gear selectivity – larger lobsters may not be able to enter the traps. There are some regional differences :

- Larger lobsters occur in Donegal although these are caught in offshore grounds
- Lobsters in the western region are smaller than in other regions with very few large lobsters being captured.
- The shape of the size distributions suggest a moderate to high level of fishing mortality on the stocks
- A proportion of the landings in all regions are slightly under the minimum size.

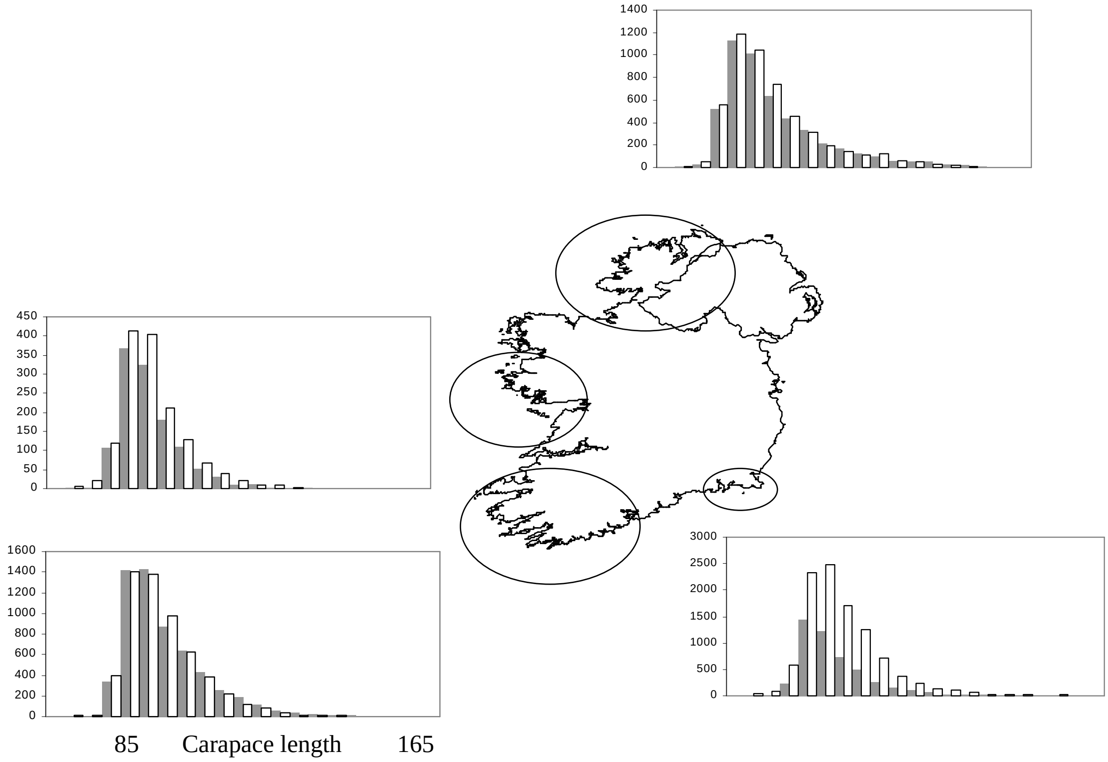

Figure 4. Size distribution of lobsters in the landings in four regions of Ireland. The white columns are females and the grey are males. The majority of samples in the south east were females measured between 1995 – 2000. Samples in other regions were taken during 1998 and 1999 (from Tully et al 2001).

Size at maturity of Irish lobsters

Maturity was estimated by dissection of the ovaries and by making other observations on the cement glands on the pleopods during September 1998 prior to the onset of spawning. The results are shown in Figure 5 and indicate that

- About 15% of the stock are mature below the minimum landing size of 87 mm.
- The size at which 50% of lobsters are mature is on average 95 mm although this varies regionally (Figure 5).
- About 65% of the landings are below the mean size at maturity

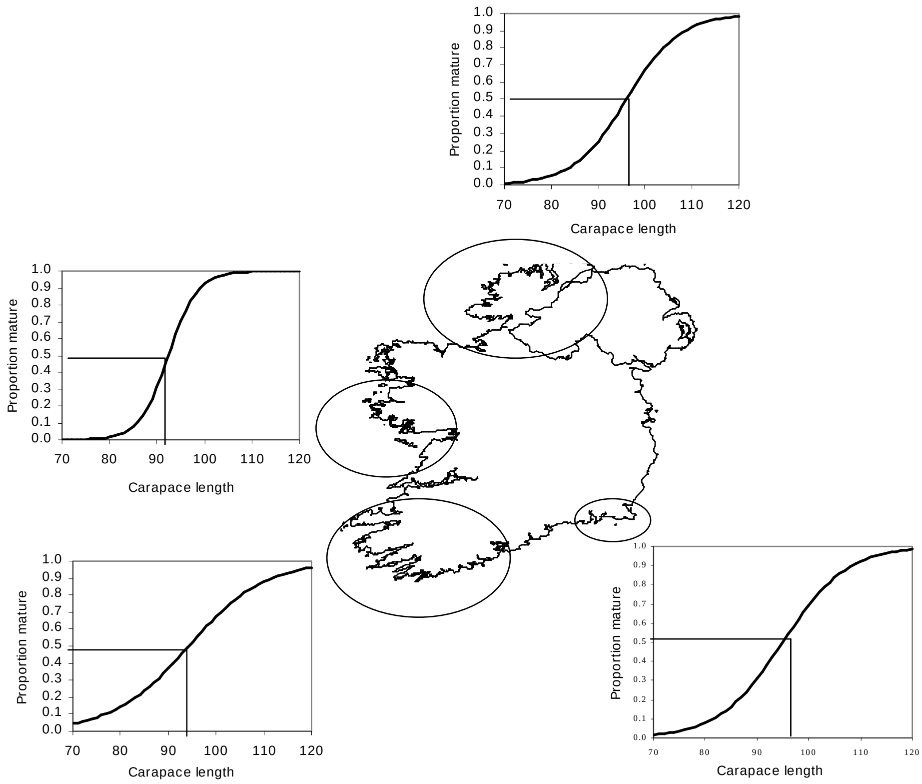

Figure 5. Size at maturity of lobsters in 4 regions of Ireland. The average size varies from 92 – 96 mm (from Tully et al 2001)

The egg per recruit assessment :

The effect of fishing on egg production of each lobster recruiting to the fishery is substantial. The current level of fishing may be reducing egg production per recruit to just 7% of it's potential (Figure 6). This level of egg production is probably limiting recruitment and stocks have almost certainly declined because of this. In the American lobster fishery this same index of egg production is used in management. In that fishery egg per recruit below 10% of that of an unfished stock is regarded as a danger zone to be avoided in order to reduce the risk of stock collapse. A higher figure would boost recruitment and lead to higher catch rates. An egg per recruit of 20% of the unfished stock should be a management objective. This level of egg production is the target used in many other fish stocks.

An egg per recruit of 20% of an unfished stock can be achieved by reduction of fishing effort (Figure 6) or by size limits (Figures 7-9) or a combination of both. This is equivalent to reducing the size of the fishing box in Figure 2 in one or both directions.

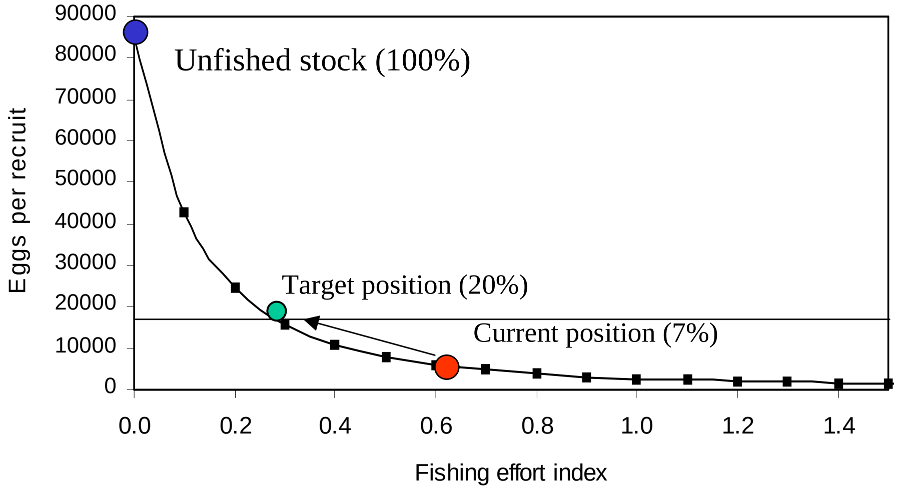

Figure 6. Effects of fishing on egg production in lobsters. The fishing effort index is technically the instantaneous rate of fishing mortality. The current position at 0.6 is determined from an analysis of the size distribution of the landings. A target position of 20% is suggested as a reasonable management target that would protect spawning stock. In this diagram the target is achieved by reduction in fishing effort. This can also be achieved using size limits or other conservation measures.

Effects of changes in minimum size

Large changes in minimum size would result in some benefits to egg per recruit although the target of 20% could not be achieved using this measure alone given the current levels of fishing effort. Increasing minimum landings size to 90 mm would increase egg per recruit from 7% to 8.2%.

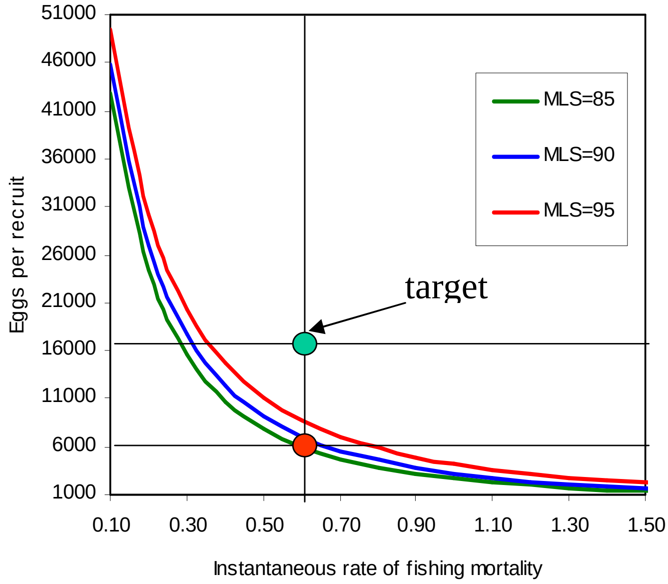

Figure 7. Effect of minimum size on egg per recruit. As seen it is difficult to reach the target only by changing minimum size. This is mainly because mean size at maturity is about 95 mm.

Effects of a maximum size

If the current minimum size of 87 mm was retained and a maximum size of 120 mm was introduced then egg production per recruit would increase from 7% to 11.8%. (Fig. 8). Combined with a modest reduction in fishing effort the target of 20% of virgin stock egg production could be achieved. Maximum sizes greater than 120 mm would result in smaller benefits.

Losses in yield due to a maximum size vary with region. In the north west the losses due to a maximum size of 120 mm would be high at over 20%. In the west the losses would be much lower at 3.5%. In other regions the losses would be about 8%. This represents a permanent loss of yield per recruit although the increased egg production should enhance recruitment and catch rates.

There is a correlation between short term losses and long term gains. In the west therefore the losses are lowest but the gains are also low because few animals reach the maximum size.

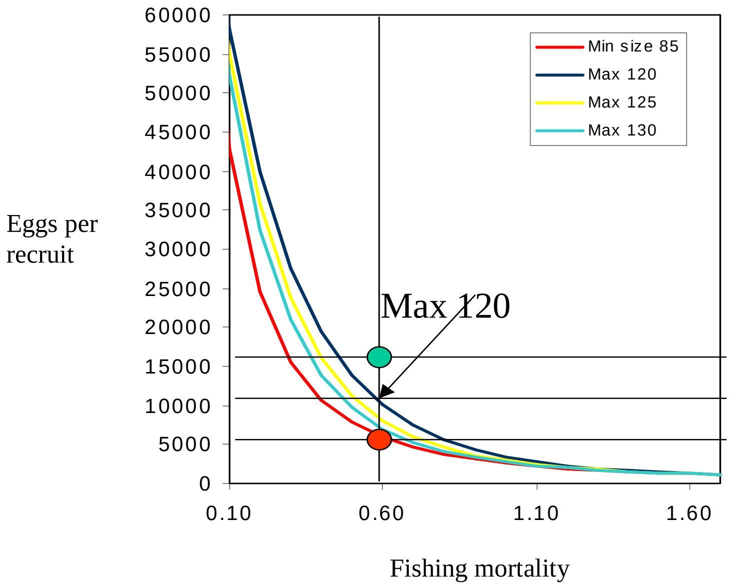

Figure 8. Effect of a maximum size of 120, 125 and 130 on egg production. Current (bottom) and target positions are indicated by the circles

Effects of a size window of 100 – 110 mm

This measure would prevent the landing of lobsters measuring between 100 and 110 mm. The benefits are shown in Fig. 9. Benefits are greater than using a maximum size of 120 mm. The reason being that there are more of these sized animals in the stock. The advantage of using the window as distinct from a maximum size is that there is no long term loss in yield as these animals can be captured when they grow out of the size window.

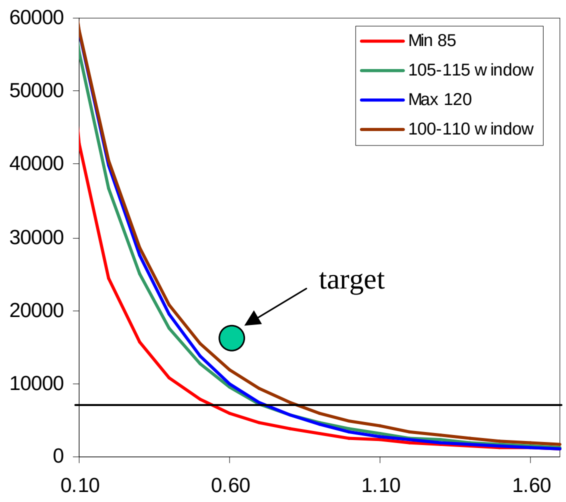

Figure 9. Benefits of a size window of 100-110 mm relative to that of a maximum size of 120 mm and compared to the current minimum size only.

Table 2. Short term losses due to a size window of 100-110 mm in each region

	Male		**Female**		**Average**	
	Number	**Weight**	**Number**	**Weight**	**Number**	**Weight**
Swest	23	29	22	28	23	28.5
Seast	19	25	23	29	21	27
West	16	23	16	23	16	23
Nwest	20	24	19	23	19.5	23.5

Table 3. Percentage benefits of a combination of effort reduction and change in minimum size. The current position is set at zero. Any reduction in effort in particular gives substantial benefits to egg production. The combination of changes in size limits and effort reduction is the best option

Exploitation	Minimum landing size			
rate	**80**	**85**	**90**	**95**
33	51	**80**	108	146
39	**7**	**31**	54	87
45	-21	**0**	**18**	**47**
50	-39	-21	**-6**	19
55	-52	-36	-24	**-2**
59	-61	-47	-37	-17
63	-67	-56	-47	-29
67	-73	-62	-54	-39

A strategy for recovery of spawning stock

Improvements to the existing technical conservation measures could be used to give immediate improvements in egg production. If this was accompanied by at least a stabilization of fishing effort egg production would increase. Technical measures to increase egg production should involve the use of a maximum size or a size window. Maximum size although not very beneficial in areas where fishing mortality is already high could also have the effect of permanently protecting v-notched lobsters from fishing if the size was set correctly. V-notching would then become a mechanism to increase the number of lobsters escaping into the size refuge above the maximum size limit.

References

Tully, O., Roantree, V. and Robinson, M (2001). Size at maturity, fecundity and reproductive potential of the European lobster in Ireland. J.mar.biol. Ass. U.K.

The v-notching program in Ireland: Numbers released by region 1994-2000

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Introduction

V-notching of lobsters began on a formal basis in Ireland in 1994. The schemes were financially supported by the PESCA programme and by industry. Up to 2000 over 70000 lobsters were released in Irish coastal waters (Table 1). The cost of this was probably in the region of €0.6 million taking an average lobster weight of 0.7 kg and an average price per kg of €16. This program is continuing and has been supported by industry and the National Development Plan (NDP) in 2002 and 2003.

Table 1. Number and weight of of v-notched lobsters released by co-operatives in Ireland up to and including the year 2000 releases (data incomplete)

Co-operative	***numbers v-notched***	***weight v-notched***	***Year program started***	***Is program still running***
NE Lobster				
South Cork	514			Yes
Burtonport	8328	6824		Yes
N&W Lobster	18915			Yes
West Mayo				Yes
Inishbofin				Yes
South Connemara	4580			Yes
West Clare				Yes
NW Kerry	4500			Yes
Dingle	9500		1995	Yes
Iveragh	2260			Yes
Beara				
SW Cork	6000			Yes
CCK Cork				
South Wexford	9610		1994	Yes
East Waterford	3918			Yes
Total	**68125**	**6824**		

What are the cost-benefits of v-notching ?

No accurate cost benefit analysis of the v-notching scheme is possible because of the uncertainties about how the increased egg production that has occurred will translate into increased catch rates in the future. However, using even conservative estimates of larval and juvenile survival and assuming that current recruitment is limited by the supply of larvae to the seabed suggests that the costs can easily be recovered. The information to support this claim is, however, not being collected. In particular catch rate data before and after implementation of v-notching in regions other than Wexford and to a lesser extent in the Dingle region are not available so that direct comparison between the level of v-notching and the change in catch rates cannot be undertaken in the future.

Inshore Fisheries Development Committees in Ireland: Facilitating communication between state and industry

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Summary of developments

Inshore Fisheries Development Committee (IFDC) Facilitators were established in 7 areas in Ireland in 2000-2001 (Tully et al. 2003). These facilitators were to establish local Committees (IFDCs) to include representation from all marine stakeholders in the local area. A management plan for local area marine development, which catered specifically for inshore fisheries (vessels < 12 m and fishing inside 12 miles) and which involved broad consultation, was to be established and implemented by the Committee. The local initiatives were to be paralleled by a national umbrella group who would support the IFDCs with appropriate policy development and review the progress of the Committees. The outcome was to result in improved employment opportunities and incomes for small boat fishermen through diversification to other activities and development of fisheries.

The local Committees were established in a number of areas but in most cases foundered for a number of reasons. Firstly the national policy and process that was meant to parallel the establishment of IFDCs and by which local requirements and plans could be given statutory effect did not develop. Secondly the inshore fishing industry itself was fragmented and had weak or few representative structures. Many of it's members were unknown to the regulatory system. This compromised development of realistic management proposals. Thirdly there was a significant information deficit in biological, economic and social data on inshore fisheries on which national and indeed local policies and plans could be based.

The work program of the IFDC facilitators proceeded during 2001 and 2002 to redress the deficiencies in biological, social and economic data and focused on organising local inshore fishermen and identifying issues at local level that were a priority for them. This has led to significant progress in the following areas

1. Availability of biological, social and economic data on the sector and its resources
2. Diversification of fishing activity
3. An increased level of organisation in the industry and awareness of issues
4. Increased interaction between fishermen and the state agencies where IFDC exist and an increased level of service to the industry

The original objective and the main criterion on which performance of IFDC was to be measured i.e. increased income to inshore fishermen has generally not been achieved although some projects co-ordinated by IFDC facilitators did have measurable benefits. A pre-requisite to such an objective is consolidation of current fishing activity and development of sustainable practices in the industry. The centralised, largely non-consultative and open access system of regulation of inshore fisheries is the main issue that needs to be addressed. This system is in fact the main threat to the future socio-economic value of inshore fishing. As previous reports have outlined and which was a stated objective of the IFDC initiative development of a system of co-management of fisheries between the state and the industry is critical to it's future. Analysis shows that the Irish inshore fishing industry including lobster fisheries are good candidates for co-management.

Reference : Tully, O., Breathnach, S., Doyle, O, Hickey, J., Kelly, E., Nee, D., O'Ceinneide, L. and O'Donovan, V. (2003). The Inshore Fisheries Development Committees initiative: status report and recommendations. BIM, Crofton Road, DunLaoghaire, Co. Dublin, Ireland. 50 pp.

Appropriate management structures for inshore fisheries

David Symes, Department of Geography, University of Hull, UK

> *'How does a modern, centralised, economically rational, small government manage a valuable but spatially intricate resource when fiscal reality prevents monitoring, management and enforcement at an appropriately fine scale'?*
>
> *'When the spatial scale of monitoring and management is larger than the scale of the managed populations, the fisheries will remain vulnerable to localised overfishing and on-going population collapses'.*
>
> Prince et al. 1998

Introduction

Although Prince et al. were writing specifically about the abalone fisheries of South Australia, these two statements could apply equally well to European inshore fisheries management in general and to shellfish management in particular. Together the two quotations indicate very clearly that there is much more to the notion of effective fisheries management than simply putting together an appropriate package of regulatory instruments. The scale and structure of the management organizations themselves are also important. Where local management is the result of 'spontaneous combustion' and organic growth, the resulting pattern will tend to be dominated by potentially vulnerable, small-scale structures and the spatial coverage may well be incomplete thus leaving dangerous lacunae where management of the resource is missing. By contrast, where an administrative solution is provided – as with the Sea Fisheries Committees (SFCs) in England and Wales – while the coverage of the coastline may be comprehensive, the geographical boundaries to the management organizations may well be very much larger and defined by reference to regional administrative areas which have little or no relevance to fisheries management nor to common interests in the exploitation of the stocks.

Size is not everything. Equally, if not more, important is the internal architecture of the management organization – the scope of its management responsibility and power, its financial robustness and independence and the composition of its membership. These are the essential parameters of a management organization. They will help to determine its effectiveness and the extent to which local fishermen feel a sense of co-ownership of the management decisions and of co-responsibility for the welfare of the fishery, which should guarantee greater compliance with the management measures.

Local management of inshore fisheries is quite rare in Europe. Here, centralized technocratic systems have largely overwhelmed customary forms of management based on the conservation and allocation of local resources. Where they do exist, as in England and Wales (SFCs) or in France (*comité's de pêche*), they usually reflect the emergence of a bureaucratic culture rather than an expression of local self-management. Moreover, there is an important distinction to be drawn between traditional and modern systems: the latter are principally concerned with resource conservation – maintaining harvestable stocks – and heavily dependent on scientific advice, whereas in traditional systems (*cofradia* in Spain; *prud'homies* in Mediterranean France) the management priority was to secure social equity in terms of access to the resource.

The modern tendency for management has been to dilute the role of central government through decentralization and devolution of management responsibility in the form of co-management, involving a partnership between the state and the principal stakeholders. It is important that co-management embraces both the formulation of policy and its implementation. In fisheries, the trend towards co-management has been rather less pronounced, partly one suspects because of the dominant role of scientific assessment and advice.

Designing appropriate co-management structures

When we pose the question what is the most appropriate management structure for, say, Irish inshore fisheries or for lobster fisheries, we find there are no easy answers. One cannot rely on off-the-peg solutions. Designs which are appropriate for the fisheries of Maine, USA or for England and Wales cannot be simply transplanted into Ireland. Either the body politic will reject the transplanted organ as incompatible with the prevailing political culture or the transplant will fail to knit together with the tissues of the local fishing communities. It is essential that the co-management structure be tailored to the particular conditions: they must harmonize with the national political culture, be sensitive to the complex and often internally diverse conditions of the inshore fisheries, and be able to adapt to local socio-cultural circumstances. In other words, it is not possible to argue that any one management system is intrinsically better than any other, only that it appears to fit a particular set of circumstances.

But equally there may be more than one good fit. Take for example the situation in Britain where there are two very different approaches to inshore fisheries management. In England and Wales, a statutory devolved system of management – the 12 SFCs – has been in place since 1888, funded by the coastal local authorities and with a membership shared between the local authorities (50%) and appointees of central government (MAFF) representing the fishing industry, marine conservation interests and the Environment Agency (50%). The Committees have wide powers, through bylaws and regulating orders, to manage fisheries within the 0-6 nm zone by controlling access to the fisheries, setting minimum landing sizes, designating closed areas and seasons – and regulating fishing gears – all according to the perceived needs of the local fisheries. There are, however, some significant constraints: bylaw making, requiring the final approval of the central government department, is a slow process; regulation is therefore essentially reactive rather than proactive; and there are no emergency powers.

By contrast, Scottish inshore fisheries remain largely subject to centralized management. Since devolution, however, two important initiatives have been taken: first, the introduction of an inshore fisheries advisory committee at national level and the adoption of regulating orders for shellfish management (molluscs and crustacea).

It is impossible to say which of these two contrasting approaches is better – both seem to work equally well. SFCs in England and Wales conform to the principles of co-management – they combine executive decision making and policy implementation, monitoring and enforcement and they strike a balance between democratic accountability and participative government. The Scottish system, on the other hand, dispenses with an overarching statutory framework for inshore management, leaving executive powers in the hands of the Scottish Executive and granting the industry an advisory role. It relies on local expressions of interest for self-management through regulating orders. But herein lies a potential pitfall for, unlike the SFCs, local management committees established to oversee the implementation of regulating orders in Scotland so far lack the means of policing whatever management measures are put in place.

Some key questions for inshore fisheries management in Ireland.

In Ireland the process of filling in the void of local inshore management has only just begun. The Inshore Fisheries Development Committees relies on the voluntary rather than statutory approach with no predetermined template for their organization. As with any management system there are several basic questions which need to be addressed in the early formative stages. Most important are to establish a clear role, define objectives, develop a simple and transparent *modus operandi* (including relationships with other relevant management organizations) and ensure that the structures and resources are fully compatible with the intended functions (see Table 1).

Table 1 Key questions for local inshore management systems

Role	Executive	Advisory
Membership of committee (numbers, interest groups, selection)	V	V
Financial basis (robustness, independence)	V	V
Scientific advice (sources, means of incorporation)	V	V
Audit of managerial capacity	V	V
Range of management instruments available	V	
Facilities for monitoring and surveillance	V	
Powers of sanction and means of enforcement	V	
Flexibility and speed of response to emerging issues	V	
Assurance that advice will be incorporated in management decisions		V

The moral of this short paper is that whereas there is much to be learned from examples of management institutions and practice elsewhere, solutions must be sought locally. They must conform to the norms of national political culture and closely reflect the particular circumstances of the inshore fisheries. Providing they are able to fulfil certain basic conditions, there is no reason to suppose that even within Ireland they must adopt a single structural model.

Reference

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Management of Crustacean Fisheries in France

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Introduction

This presentation deals with management of crab and lobster fisheries because in France. These fisheries are mixed and the same string of traps can be targeted one day at catching lobster and the day after at catching crab. In addition whatever the target, crab **or** lobster, you can expect to catch crab **and** lobster. In such a pluri-specific fishery, management decisions targeted at a single species do not guarantee it's protection.

Currently 1000 boats fish for crabs and lobsters along the Atlantic and the English Channel coasts of France. Some of them are exclusively potters and may, in the case of the offshore vivier boats, fish throughout the year. Most of the others, ranging from 6 to 16 m are pot on a seasonal basis and have one or several complementary activities like dredging, netting, or lining.

The annual landings of this fleet are given in Table 1. The total value is estimated to be 50 million euros.

Table 1. Annual landings of the French potting fleet

Edible crab	>6000 tons
Spider crab	5000 tons
Velvet crab	<300 tons
Lobster	400 tons
Spiny lobster	150 tons

This fishery is managed through a series of technical measures and input controls. Some of these have been enacted recently, some are in place for more than thirty years and have evolved through time, and others, which had been implemented in the past have been abandoned: management is a continuously evolving process.

Technical measures

The technical measures are the easiest to put in place and often are the first step on the road to more complete management control.

Minimum landing size

Among the technical measures, minimum landing size (MLS) are the oldest. The various MLS in use in France are as follows :

- **Edible crab**, 14 cm carapace width (CW) according to EC regulation MLS was 7 cm carapace length (CL) in 1964, 8 cm CL in 1978, 9 cm CL in 1984 and 14 cm CW in 1995.
- **Spider crab**, 12 cm carapace length according to EC regulation and is the same since 1981.
- **Velvet crab**, 5 cm CW according to national regulation

- **Lobster**, 85 mm carapace length according to EC regulation MLS was 20 cm total length (TL) before 1960, 23 cm TL in 1964, 24 cm TL in 1990 and 85 mm CL in 1996 and 87 mm in 2001 according to EC regulation.
- **Spiny lobster** : according to EC regulation MLS is 110 mm carapace length

Output controls
In addition to MLS, some technical measures apply to landings:

- **Soft crabs** : landing of recently molted edible crab and spider crab has been forbidden since 1985. Unfortunately quantifying the soft condition of those species is not easy and it is difficult to enforce these measures (in fact crab condition is more relevant to commercial value and optimisation of yield than it is to legal issues).
- **Claws** : landing of crab claws separated from the body has been forbidden since 1990

Input controls
Four input control measures are used : a closed season, a licensing scheme, pot limits per boat and a prohibition on trawling and restricted use of some types of pots.

- **Gear restrictions** : Pots and nets are the only gear allowed for crab and lobster fishing. Trawling is prohibited but crab by-catches of up to 10% of the total catch are allowed. The parlour pot which was introduced in the 1990's is now banned (except in one fishery, around Jersey. Even there, parlour pots must not exceed 50% of the total number of pots per boat).
- **Closed season :** This measure is aimed at protecting the recently moulted individuals and, currently, only applies to spider crab. It has been in implementation annually since 1985 but the date and duration can vary from one year to another and from region to another. Most generally it takes place in September and October in the western Channel, just after the molting period.
- **Licensing scheme** *:* With a view to protecting the fishery from free access and the series of problems it causes, a licensing scheme was established in 1993 and, it is compulsory to have a license "grands crustacés" in order to fish for crab and lobster, inside or outside of the national waters (12 nm). Only potters and netters may have this license, trawlers may not. For boats larger than 10 m wherever they fish and for those fishing out of the national waters whatever their size, the license is also a "European Special Fishing Permit" (which is compulsory for crab fishing according to EC rule 1627/94).

  The license is administered on a regional basis by industry which, moreover, can limit the number issued. It is issued to the skipper/boat and must be renewed annually. The price of the license, established by industry, is currently between €50-100 (a fixed part of the fee goes to each of the three industry levels : local, regional and national). In the first year of its introduction every applicant got a license but subsequently, decision rules (a priority order) were put in place to deal with new demands. In order to improve the real knowledge of the fishery and subsequently its management logbooks were required from the licence holders.
- **Number of pots** :In addition to the licensing scheme, which aims to control more efficiently the fishing effort, a limit on the pot number was established in 1997. The number of pots allowed per boat was related to the number of crew. In most fisheries it is 200 pots per crew member with a maximum of 1000 pots per boat. Manufactured plastic tags identifying the boat and indicating the pot number must be attached to every pot.

History of Licensing *:*

The license for crab and lobster fishing is not recent in France as the first one was implemented nearly 30 years ago (1971), but the goal it is supposed to achieve has changed over the years. During the decades 60's, 70's and 80's a policy aimed at increasing the spawning biomass was pursued and from 1970 to 1984 the license was mainly a way to collect taxes dedicated to lobster restocking actions :

- landing of berried lobsters was prohibited (but not very well enforced),
- sanctuaries, numerous but small, were created (around twenty of them still remain)
- hatchery produced post-larvae (millions) and juvenile (>100 000) lobsters have been reseeded.

This policy has not prevented a decrease in catch rates of crab and lobster which most probably was the result of an increase in fishing effort. Because of the lack of evident impact of the restocking actions, a growing number of fishermen asked that the fund would be used for more management including a limit on fishing effort and for more control. In 1993 industry made the decision to *«**establish a limitation of the number of licenses to adjust the size and characteristics of the fleet to the resource»,*** which led to the current type of license.

The future

The general feeling is not that "we have an efficient input control system" but that "we have started with an input control system in addition to technical measures. The scheme needs to be improved continuously. Future issues include :

- to listen to ideas from other countries
- to apply and, when necessary, modify and/or strengthen the current regulation composed of both technical measures and input controls. It is very clear that several years are necessary between the time when a decision is made and the time when it is fully applied on a national scale. For instance one Region (accounting for few boats) is still reluctant to use licensing; the rule about the pot number per boat, the link between the pot number and the crew number is questioned : would the use of vessel power be better ? ; is the maximum of 1000 pots per boat a good idea ? Many other questions arise and remain to be resolved.

Changes in Management of Fisheries in Jersey: A 14 year process

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Introduction

The Channel Island of Jersey is located west of the Cherbourg Peninsula, in the Bay of Granville on the South side of the English Channel. The waters around the Island are relatively shallow and generally no more than 40 m datum deep; They are interspersed with many rocky reefs some equal to the area of Jersey itself, and the entire zone is exposed to the west. Because of the shape and orientation of the English Channel, the area around Jersey is subject to a very vigorous tidal regime. The rise and fall of sea water may be as much as 4Oft during equinoctial spring tides. This gives rise to very strong currents around the reefs and the Island itself, current speeds of 3 - 5 knots are common. Thus the area is one that is very difficu1t to work with static gear. Of particular note is the proximity of Jersey to the western coast of the Cherbourg Peninsula. At low water this distance is only some 13 miles and Jersey is essentially within the coastal zone of France. This of course means that there is a lot of joint exploitation of the marine resources by both the Jersey and the French coastal fishing fleets.

The vessels that work from Jersey are between 8 m and 13 m in length and they work strings of 30 - 50 lobster pots. There are some 50 or 60 vessels working out of Jersey and a total of about 17,000 parlour pots and 10,000 traditional inkwell pots are used. This does not include the leisure effort and the French fishing effort in the Jersey zone both of which, at the moment, are unquantified. These pots are set usually day for day within about 12 miles of the Islands coast, the inkwell pots in particular are worked as regularly as possible whereas the parlour pots may be left between 3 and 4 days between lifts. At present the fleet is licensed and a fishing vessel may not go to sea to catch and land fish for profit without a license. There is no limit on the number of pots that are set although this is the subject of some discussion between Jersey and the French Authorities. It is mandatory that all parlour pots set by Jersey vessels, should have an escape gap set in the parlour to allow both the undersized lobsters and crabs to escape. The catch of lobster has remained amazingly constant over the past number of years and at the moment is recorded as being between 150 and 160 tonnes per year. This compares to a more fluctuating catch of spider crab which at the moment is in the order of about 300 tonnes per year and a catch of brown crab in the order of 600 tonnes per year. Thus the lobster, with the high price that it generates, is by far and above the most valuable catch of crustacea landed in Jersey. Wet fish landings are less important and in 1999 Jersey vessels landed a total of 350 tonnes of wet fish species.

Because of the proximity of Jersey to the French Coast and the joint exploitation of the stocks by the Jersey and French fleets, there has been a certain amount of interaction between the two groups of fishermen. This has not been helped by the fact that the only treaty that regulates the fishing between these two countries was agreed in 1839, and was put in place to cover a now extinct oyster fishery . Thus with no proper regulatory mechanisms in place, interaction between the fleets has sometimes boiled over into rather difficult incidents. Newspaper headlines such as, "*Fish Wars - French in* New *Incident*" or "*French Invaders Set San for the Ecrehou*", or "*One Shoots and then One Discusses*" have been seen over the past ten years or so. This whole situation has occurred, because of the lack of clarity on access and management systems for the area, so some 14 years ago the Island decided to push very hard through Her Majesty's Government for proper negotiation to resolve this situation. It was recognized by the Island and the British Government, that certain objectives need to be addressed, these included:-

1. Identification of the management zone
2. Identification of the responsibilities within that zone
3. Creation of a management system that will (a) involve all stake holders (b) manage for the sustainability of the fishery (c) encourage a problem solving dialogue (d) address marine environmental issues.
4. Harmonization of regulations
5. Dealing with control and enforcement issues.

Having identified certain objectives, the Island set about convincing first of all, local political bodies that the system was worth re-negotiating and then, convincing both the Home Office and the Foreign Office to begin opening a negotiating dialogue with France. Thus the chain of negotiation was long and tortuous beginning with the Jersey Fishermen and Department of Agriculture and Fisheries through various local committees, then onto the Home Office and finally the Foreign Office. Even though this long difficult chain of communication was the principle way of negotiating to begin with, it became shortened. The intention was to first extend territorial waters to 12 nautical miles, then negotiate a median one which had not up until this date been done, re-draft the ancient 1839 Granville Bay Agreement and then finally set in place management and feed back systems that would serve to manage the fishery .

The Granville Bay Treaty 2000
A new Granville Bay Treaty was signed on July 4 2000. It has clarified the extent of the Granville Bay zone and the access for the different fishing communities in it. These access arrangements are quite complicated and detailed, nevertheless, the details are necessary to gain agreement by all of the different groups of fisherman from both France and Jersey that were involved. The agreement extends Jersey's 3 mile exclusive zone to 6 miles in certain areas, preserves the ancient A to K between St Malo and north of Carteret and confirms certain access by Jersey boats in the 3 to 6 mile zone north of St Malo and east of the Les Roches Douvres. Access in other areas is only allowed up to 6 miles. More importantly the regime puts in place a management system. There is to be a joint advisory committee composed of 4 Jersey fishermen, 4 Breton fishermen, and 4 Basse-Normandie fishermen together with biologists and administrators. They will advise a senior management committee and the respective governments on management measures they feel need to be implemented. This advice will be vetted to make sure that it does not conflict with EU or other National Legislation, then implemented in the Respective Legislation of Jersey and French Governments. The Granville Bay Treaty also covers control and enforcement and even goes to the detailed level of fines.

Because of the length of time that these negotiations have taken, the management authorities of Jersey and France decided to meet informally before the negotiations culminated in the signing of the treaty . These meetings of the management authorities have already resulted in the agreement of certain conservation issues. A ban of par1our pots in a 70 square mile area of Les Minquiers Reef, a spider crab closed season and a trawler potting zone agreement, to help prevent damage to static gear by trawlers at certain times of the year south west of Jersey, are some issues that have been resolved. The French have already implemented a pot tagging scheme with the idea of ultimately limiting the amount of fishing effort by pots in the area. This is likely to be the next major item to be discussed at the next joint advisory committee meeting. Jersey fishermen are now attuned to the concept of pot limitation, are very open about talks on this subject and are willing to bring in some form of system to address the escalating fishing effort that is occurring on the local crustacean fisheries. Since the Jersey and French fisherman have got together to talk on these joint issues relations between the two authorities has improved and in fact media reports of their work have been very positive. Media have talked of a honeymoon between Jersey and

Granville and of a communal cadre that has sprung up between the fisherman's organizations.

To conclude the fisheries management system around Jersey and the adjacent coast of France up until a few years ago, was totally ineffectual and rested solely on a regime developed in 1839. After a long up hill struggle through complicated bureaucracy a treaty has now been signed whereby participation of local fisherman is encouraged in the management process for a sustainable pot fishery in the waters between Jersey and France. An agreement has already been made on zoning types of gear to be fished and negotiations are beginning on pot limitation for the area. Licenses are already in place for all Jersey and French fisherman and a third communal Granville Bay license will be brought in to cater for the Granville Bay area. Thus the fishermen have recognized that both boat limitation and pot limitation are necessary to maintain both the stocks and the profitability of the industry into the future.

National and Regional Management of Lobster Fisheries in the UK

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Introduction

The fishery for lobster in the UK is primarily a small vessel pot fishery centred around coastal waters within five miles, although the last 25 years has seen an expansion of the fleet to include a significant number of larger or faster vessels which exploit offshore grounds. Officially recorded landings of lobster in the UK has remained relatively stable at around 1000 tonnes for the last 25 years, although there has been an increase in landings in recent years. Currently the UK lobster fishery is worth around £15 million at first sale. Fisheries intelligence, however, suggests that the true level of landings may be very much higher than the recorded level. Whilst catch per unit effort (CPUE), which is a more reliable index of abundance than landings *per se*, has remained stable or even increased in some areas, there are some inshore areas where CPUE has declined in recent years, and there have been calls from the industry for tighter regulations.

Current management of the UK lobster fishery

Lobster fisheries in the UK are currently managed under a hierarchy of management measures. At the highest level they are subject to EU regulations, at the next level down there are a number of national regulations which apply throughout the UK, and finally there are regional management measures enacted and enforced through bylaws of the local Sea Fisheries Committees.

The only current EU-wide legislation is the minimum landing size (MLS) of 85 mm carapace length (CL) which is due to increase to 87 mm CL on 1 January 2002. Under UK national regulations the MLS has already increased to 87 mm CL, and the landing of V-notched lobsters is prohibited. In some districts there are also Regulating Orders which permit the control of fishing effort and other management measures such as providing some degree of ownership for the ongrowing and future re-capture of hatchery-reared lobsters released into the wild. Legislation in the UK previously prohibited the landing of egg-bearing (berried) female lobsters but this legislation was rescinded in 1966, primarily due to problems of enforcement. Currently there is no form of national licensing, restrictive or otherwise, but as will be discussed later, this is likely to be introduced in the very near future. Although present lobster legislation applies nationally, the power exists to adopt regional variations in legislation such as is the case for crab minimum landing sizes.

In addition to these national regulations, a number of regional measures have been introduced by the 12 local Sea Fisheries Committees (SFCs) which cover the coast of England and Wales. No such bodies exist in Scotland where such local or regional management measures have to be enacted under the Regulating Order legislation. Table 1 below describes the range of regional measures currently in operation across the SFCs areas. These measures range from additional technical measures such as a higher MLS than applies nationally or a ban on the landing of berried females, to schemes which may require permit holders to make detailed returns of their landings.

Because of the geographical extent of Sea Fisheries Committees (Figure 1), their bylaws should really be considered as regional rather than local management measures. They can have significant benefits over national legislation. Firstly they can be tailored to meet local biological differences by, for example, adopting regional minimum landing sizes, or specifying the use of only certain types of gear. In contrast national measures must by their very nature usually represent a lower common denominator, that does not fully account for regional differences. A further benefit of SFC bylaws is that they can be locally enforced. SFC bylaws do however have some limitations: they extend only out to 6 miles from the coast and thus enforcement can often be hindered by the requirement to prove that such offences under the bylaw were committed within and not outside the six mile limit. There may also be enforcement difficulties at the boundaries between two areas. SFC bylaws must be approved by the UK Government's Ministry of Agriculture, Fisheries and Food (MAFF). This ensures that the bylaw is based upon sound science, and has conservation merit. It is customary that MAFF ensures that bylaws do not discriminate against particular sectors of the industry. Proposed bylaws may not be ratified until they meet these criteria.

Table 1. Sea Fisheries Committee bylaws

Management measure	**Sea Fisheries Region**
MLS of 90 mm	Cornwall, Devon, Isles of Scilly, South Wales
Maximum size	South Wales (to be confirmed)
Soft lobsters	Eastern, Northumberland
Berried females	Cumbria, Devon, Eastern, Kent and Essex
V-notching	Devon, North Eastern, Northumberland, South Wales, North Western and North Wales
Escape gaps	Cumbria
Permit schemes	Cornwall, Cumbria, Eastern, North Eastern, Sussex, Northumberland, North Western and North Wales, South Wales

Future management of the UK lobster fishery

So far I have outlined the current UK management position. What future management measures could be introduced, what do scientific assessments show about the status of the stocks, and which measures are enforceable and are likely to be acceptable to the industry? Possible measures include a higher MLS than the national measure, maximum landing sizes, prohibitions on landing berried and V-notched females, the release of hatchery-reared juveniles to increase recruitment, and the introduction of restrictive licensing schemes. Many of these have of course already been introduced regionally by SFCs.

Scientific assessment of management measures

Previous scientific assessments of lobster fisheries centred on yield-per-recruit analysis as opposed to egg-per-recruit analysis, i.e. they were concerned more about growth overfishing than recruitment overfishing. These assessments show that:

1. an increase in minimum size or a reduction in fishing effort are generally the only management measures likely to increase yield-per-recruit
2. other measures such as maximum sizes, bans on landing egg-bearing or V-notched lobsters tend not to significantly increase yield-per-recruit

With no current mechanism for limiting fishing effort, fishery managers have concentrated on increasing the minimum landing size as the most effective way of increasing yield-per-recruit whilst simultaneously increasing egg production per recruit. Fishery scientists and managers have recently considered, however, that to ensure sustainability of the fishery through the 21st century, it is essential to safeguard against recruitment overfishing. Egg-per-recruit analysis is therefore now becoming the most appropriate approach. UK scientists recently reviewed a variety of management options and reached the following conclusions on the likely impact of measures on egg production in lobster fisheries:

1. Reducing fishing effort is a very good way to increase egg production
2. Prohibiting the landing of egg-bearing females will substantially increase egg production
3. V-notching female lobsters will only have an impact on egg production if a significant proportion of females are notched regularly
4. Increasing the minimum landing size to 90 mm CL will substantially increase egg production
5. Introducing a maximum size has relatively little effect on egg production at the current levels of fishing effort in most areas
6. All technical conservation measures (2 to 5 above) will only increase egg production if the level of fishing effort is maintained at or near its current level
7. Enhancement of natural stocks through the release of hatchery-reared juveniles could be beneficial in areas where recruitment has failed

UK scientists also looked in detail at the possible impact of V-notching programmes with regard to the scale of the fishery, and reached the following conclusions:

1. V-notching programmes, whether funded by statutory bodies or voluntary, need to V-notch a significant proportion of the population if they are to increase egg production substantially
2. In a relatively small fishery in Ireland, 9,000 V-notched lobsters have been released and have undoubtedly contributed substantially to increased egg production
3. In north east England 7,500 V-notched lobsters have been released but in this area this represents only about 1% of the annual catch of females. Thus many more females will have to be V-notched in this region to make a substantial contribution to increased egg production
4. As funding for V-notching lobsters is unlikely to be maintained indefinitely by statutory bodies, V-notching will probably only be successful if taken up voluntarily by the industry

Industry uptake and enforcement of management measures
From the scientific viewpoint I have summarised the benefits likely to accrue from a range of conservation measures. Success also depends on what can be enforced effectively and has the backing of the industry. Recent dialogue with the industry and enforcement officers suggests the following:

1. Limitation of fishing effort is highly sought after by the industry, but it may be difficult to introduce a fair system of allocation and will be difficult to enforce
2. Proposals to ban the landing of egg-bearing (berried) females receive mixed reaction from the industry, but should be relatively easy to enforce
3. V-notching programmes are popular amongst the industry when statutory bodies pay for the programme, but individual fishermen are generally reluctant to V-notch and release females that could otherwise be landed. The measure should be reasonably easy to enforce, although there are reported problems over V-notches that have partially grown in after a moult.
4. Minimum landing sizes which are appropriate to each region are acceptable, and are very easy to enforce

5. A maximum landing size is simple to enforce and is acceptable in the inshore fisheries, but less so in the offshore fisheries that would bear the brunt of the impact initially

From a scientific viewpoint, limitation of fishing effort is undoubtedly the key management measure required to ensure that yield and egg-per-recruit are sufficient to sustain the fishery. Technical measures can increase egg production per recruit, but analysis shows that this benefit can be negated by an increase in fishing effort. Effort limitation therefore has to occur through a licensing or permit scheme. At present 8 of the twelve SFCs have some form of licensing or permit scheme, but none of these currently restricts the level of effort of individual license holders. Negotiations are currently underway between the UK Government (MAFF) and the fishing industry on the introduction of a national licensing scheme for pot fishing, aimed initially at restricting effort to its current level. Although national in nature, there is likely to be scope to introduce more restrictive measures on a regional basis in the future. A national licensing scheme will require the collection of data from license holders through an obligatory landings return. Such data are already required by 6 of the 8 SFCs who have permit schemes, and these data are essential for a sound scientific base upon which to base future management measures.

Conclusions

A range of management measures is available to ensure continued egg production and future recruitment and thus sustain the lobster fishery throughout the 21st century. Each fishery within Europe will need to introduce those measures that are particularly well suited to the regional and local characteristics of the fishery. Limiting fishing effort is likely to be desirable in all localities and regions, but other measures need to be tailored to meet local requirements. In the UK, varying minimum landing sizes already reflect the nature of local fisheries. In terms of new measures I will illustrate the importance of local variations with respect to two examples. The introduction of a maximum landing size would clearly benefit stocks on the UK offshore grounds where there is currently a low exploitation rate and which might be the source of larvae production for adjacent fisheries. However there is little point in introducing a maximum size in inshore fisheries where the exploitation rate is very high and very few, if any, large lobsters are caught. In this scenario alternative management measures are more appropriate. A second example concerns the release of hatchery-reared juvenile lobsters to enhance natural stocks. Whilst this is likely to benefit fisheries where there has been a recruitment collapse such as in Norway, or where local factors have damaged previously good lobster ground, there is little to be gained from releasing hatchery-reared lobsters on grounds where there is already good recruitment, as on many inshore fishing grounds in the UK. In those circumstances the better aim is to maximise the yield and egg production from the already high level of natural recruits.

Local Industry Lobster Management Plans in Ireland

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Introduction

In this paper the management plans for lobster fisheries devised by local industry in Ireland are described. 'The South Wexford Lobster Fishermen's Co-operative Society Ltd.' developed and implemented a 7 year managed plan for their local fishery in the early 1990s. They successfully implemented 2 main conservation/stock restoration measures; the v-notching of over 9000 female lobsters and the release of over 90,000 hatchery produced juveniles. A stock monitoring and research program was also established. Catch rates in the fishery improved substantially 4 years after initiating the management plan. During the early years of the plan the Co-operative was successful in drawing research and development funds in collaboration with the university and state sector. This assisted the co-op to employ hatchery workers and researchers to provide data on stocks and potential benefits of the plan. The plan represented a unilateral initiative by the Co-operative and was not supported by legislation to limit effort either at national or local level. Without this support the Co-operative had no power to control the fishing activities of fishers in the area. Fishing effort doubled between 1995 and 2003 and catch rates declined to pre-management plan levels by 2003. The initiative foundered due to lack of legislative support. Nevertheless it remains an outstanding example of local industry ability to develop fishery management plans and to effect significant restoration of stocks. The initiative is fully described in this paper where the following issues are examined

- Background to formation of the South Wexford lobster co-operative
- Initial objectives and targets of it's management programme
- What this programme delivered
- Strengths and weaknesses of the programme
- Future Objectives
- Consideration of additional conservation measures

Background to the formation of the Lobster co-op.

106 people were directly employed and a further 35 indirectly employed in lobster fishing in the south Wexford region in 1994. This area of coast is approximately 40 nm in length and lobster fishing extends to approximately 6 miles from the coast. Effort , in terms of number of pots per boat and the number of boats was increasing and the fishing season was being extended. Catch rates were declining and there was, therefore, concern for the future viability of lobster fishing.

In 1992 lobster fishermen from south Wexford approached BIM stating their concerns. In 1993 the conservation meausures in place in the lucrative American lobster fishery were outlined at a seminar at Kilmore Quay. BIM, WORD, & FAS then assisted the co-op to produce a management plan for lobster stocks. In 1994 the co-op was formed and the management plan adopted. The management plan had 2 principal and related objectives:

1. Manage current stocks to prevent further decline
2. Restore stocks in order to improve catch rates

The targets of the plan were

- That the co-op would have a representative structure
- 7000 female lobsters to be v-notched and released
- 70000 stage VI hatchery reared juveniles to be released
- To establish a fisheries monitoring programme
- Funds to be raised through a 2% levy on landings and matching funds to be obtained from grant aid
- Obtain legislation in order to protect investment

In addition the objectives of the local non-statutory management co-operative were to

- Maintain the number of participants in the fishery
- Achieve sustainable CPUE/income levels
- Optimise market returns

7 year Management plan achievements

- V-notching : 9,600 lobsters were released up to the end of 2000 producing an estimated 45 million eggs per annum. These contributed possibly 60% of total population egg production
- Juvenile releases : A facility was adapted as a lobster nursery and later upgraded to a lobster hatchery and nursery facility. 90000 stage VI lobsters were released into the fishery
- Representative structure : Co-op with 127 members established and the area was selected as a BIM pilot area for an Inshore Fisheries Development Committee (IFDC)
- Legislation to protect v-notched lobsters was introduced in 1994
- Monitoring : Log books were distributed to all boats and a database of catch rates established in 1995. This is updated on an annual basis. Surveys, including onboard boat surveys and acoustic seabed classification surveys were undertaken with a view to identifying critical habitats for juveniles.
- Funding: The co-op was very successful at attracting grant aid either independently or in collaboration with researchers. Sources of funding include
    - Once off membership fee payment: Total fishermen's membership to date £16,000
    - Levy system 2%, increased to 4% in 1999: Total fishermen's levy contribution to date £125,000
    - Matching grants from the following sources : BIM, PESCA, DG Fisheries, Local LEADER, WORD, Direct LEADER, FAS, FORBAIRT, TCD , MARINE INSTITUTE

Impacts on the fishery ?

Landing per 100 traps increased from 7.6 in 1995 to 9.4 in 1999. Catch rates of undersized lobster increased from 4.9 in 1995 to 11.2 in 1999 indicating that recruitment had increased

Table 1. Changes in catch rates since the start of the programme

Year	**Undersized/ 100 pots**	**V notched/ 100 pots**	**Landings/ 100 pots**	**Total No. Of pots**
1960's			33	5,000
1995	4.96	0.18	7.57	
1996	5.70	0.58	7.23	

1997	4.79	0.75	7.06	11,000
1998	8.38	0.98	7.72	
1999	11.20	0.78	9.40	
2000	-	0.56 (provisional)	-	14,500

Some concerns :

- Catch rates of v-notched lobsters declined in 1999 and 2000 suggesting that the v-notch was being lost due to moulting and that the egg production from v-notched lobsters may be significantly lower than estimated. The egg per recruit without v-notching is thought to be 7% of that of an unfished stock and 11% if all the v-notched lobsters are still in the fishery.
- Uncontrolled expansion in effort : The number of pots increased dramatically during the late 1990s (Table 1). This meant that there was a lack of protection for stakeholders originally involved in the management plan.
- Enforcement of regulations : There were difficulties in enforcing the legislation locally reflecting the lack of authority of the local management structure.

Critical to the achievement of the management objectives of the co-operative were

- Control fishing effort
- Continue and develop current programme
- Set target goals over a time scale
- Strengthen the monitoring programme
- Establish a structure that can easily modify the programme
- Have a strong local structure
- A commitment by stakeholders is critical to the success of the management objectives.

Control of fishing effort was central to the conservation objectives of the co-operative. They and a number of other co-operatives had a common view on how this should be implemented. The South Wexford, Dingle, West Galway (Clifden area) and East Waterford lobster Co-ops agreed the following objectives.

1. To prevent over expansion of fishing effort, by way of input controls
2. A licensed limited entry system should be established for all crustaceans, excluding shrimp
3. License to be issued by DoCMNR with local industry consultation
4. Track record of fishing for lobster to be used as a criterion for obtaining a licence
5. License to be issued annually
6. License to be non transferable privately
7. That a logbook be completed as a condition of licence renewal
8. That national legislation to limit the number of pots per boat be introduced
9. Ability to set limits on a regional basis to cater for regional differences (set by local management structure)
10. All pots to have approved identification on both pots and on water surface

In 2003 the south Wexford and Waterford co-ops agreed jointly to introduce a pot limit of 400 per boat by majority (90%) vote. Legislation to support this initiative is planned for 2004.

Conditions necessary for Additional Legislation Under Current Management Structures in Ireland

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Legal basis for regulation of fishing
Two sources of legislation govern regulation of lobster fishing in Ireland– EU (European Commission) and National. EU legislation is transposed into national legislation. National legislation cannot dilute EU legislation but can make it more stringent. EU legislation is a regulation a directive or a decision. It is automatically valid in Irish law. Two aspects of Irish legislation are very relevant to the current discussion on regulations relating to lobster fishing. Both are based on the fisheries act 1959

1. Section 222b – licensing of sea fishing vessels. The Minister may insert conditions on these licensing arrangements.
2. Section 223a. The Minister may adopt measures of conservation to ensure rational exploitation of fisheries eg. MLS and v-notch.

The Minister may introduce legislation only for the purposes stated in the relevant sections of the fisheries act. This legislation must be fair and non-discriminatory and individual rights must not be infringed. There is a constitutional right to earn a living. Any proposed legislation should be supported by scientific evidence that the stocks are under pressure and cannot sustain additional fishing.

Existing legislation :
1. A requirement for a sea fishing boat license. No fishing is allowed without such a license.
2. Prohibition of the landing of lobsters less than 87 mm carapace length
3. SI 304 1994 to protect v-notched lobsters. This is national legislation. The wording in the legislation in fact prevents the landing of lobsters with any mutilation in the tail fan.
4. There has been a ban on taking lobsters by skin diving since 1966.

A lobster license
There have been consultations between The Department of the Marine and Natural Resources (DoMNR) and the Attorney General's office. Some constitutional issues have been raised. However, the minister has the power to bring forward legislation if scientific support is available that would justify introduction of such legislation and if that information shows that existing legislation is not sufficient to achieve rational exploitation of the resource. Rational exploitation in this sense means maximization of the value of the resource. Policy should be scientifically based to withstand any legal challenge. Measures must be fair and non-discriminatory.

In conclusion there does seem to be a way forward in the fisheries legislation for the introduction of additional measures. Such measures will not dilute EU legislation. In fact the Minister is also publicly committed to protecting the livelihoods of fishermen. In this regard the vouched support from the majority of fishermen in the industry would be a significant help in developing new legislation.

Lobster Management in Maine, USA

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The early fishery

The commercial lobster fishery in the state of Maine, USA began nearly one hundred years prior to Maine's statehood in 1820. Lobsters were so plentiful that they could be harvested by hand or with nets in the intertidal zone during periods of low tide or in the sublittoral fringe. In time, however, both the abundance of lobsters and average size began to decrease forcing fishermen to use other means of capture. Around the middle of the 19th century, fishermen began using baited traps or pots to harvest lobsters. Shortly after the pot fishery began, in 1872, Maine enacted one of the first protective measures to ensure a healthy fishery that prohibited the catching, buying, or selling of berried females (Nicosia and Lavalli 1999). This law was repealed two years later and a closed season from 1 August to 15 October adopted to protect ovigerous females (Dow 1949). Beginning in 1917, berried lobsters could only be sold to the state of Maine's commercial fisheries bureau, later named the Department of Sea & Shore Fisheries, which, today, is named the Maine Department of Marine Resources (DMR). Marine wardens would punch a hole in the uropod of these ovigerous lobsters and release them back in the general vicinity where they were caught. These lobsters were considered the property of the state and possessing them for sale or other commercial endeavor was illegal. In 1948, the uropod punch was replaced by the V-notch (Miller 1995).

Since 1874, the Maine fishery has also been regulated by a minimum size law. The minimum size is a straight line measure from the eye socket to the distal end of the carapace, referred to as the carapace length (CL). The earliest measure of 92.1 mm CL (3 5/8-inches) was the highest minimum size (1874 – 1919). Since that time, the minimum size has fluctuated between a low of 77.8 mm CL (3 1/16-inches; 1933 – 1942) and a high of 82.6 mm CL (3 ¼-inches; 1989 – present). Since 1933, Maine has supported regulations governing the maximum size harvested. Initially, this measure was 101.6 mm CL (4-inches), which was increased to 127 mm CL (5-inches) from 1935 to 1958. For three years beginning in 1958, the maximum size was 131.8 mm CL (5 3/16-inches), but, since 1960, the maximum size has been 127 mm CL (Nicosia and Lavalli 1999). Both minimum and maximum size laws are intended to increase the production of eggs per individual recruited to the fishery.

Commercial landings and current management schemes

Historically, the Maine lobster fishery has been a roller coaster of boom-and-bust periods. The lowest landings occurred during the 1920's and 1930's when an average of 2,000 – 3,000 metric tons (mt) were caught. A dramatic increase in the catch occurred during the second World War as landings doubled from a pre-war figure of 4,000 mt in 1940 to a post-war level of 9,000 mt in 1949. From 1949 to 1980, landings fluctuated marginally from a high of 11,000 mt in 1957 to a low of 7,500 mt in 1974. Beginning in 1988 and continuing throughout the decade of the 1990's, the boom period of lobster fishing in Maine occurred. In 1997 and 1998, nearly 22,000 mt were landed with a dockside value of approximately $140 million (£IR 131 million). Fishermen and scientists have different explanations for the boom-and-bust cycles; however, both believe that a combination of fishing practices and environmental variables have resulted in the recent surge in landings (Acheson and Steneck 1997). Biologists point to the importance of fishing effort and increases in seawater temperatures that have resulted in nearly a 1°C increase in mean annual seawater temperatures since the mid-1950's. Fishers believe that lobster populations have been strongly affected by environmental factors (what they term "natural cycles"), the way people fish and the regulations imposed on the fishery (i.e., by a reduction in the amount of illegal activity, by restrictions on size and taking of breeding females, etc.). In addition, fishers generally believe that biotic factors, such as the recent decreases in predation on lobsters by groundfish, have also played a major role in recent landings increases. These central divisions between fishermen and scientists are the foundations of a co-managed fishery in Maine. As a result, biologists are committed to controlling effort while fishers believe that management should be based on rules to conserve the breeding stocks directly (Acheson and Steneck 1997).

One of the biggest worries managers of the Maine fishery face today revolves around recruitment overfishing, a term used to describe the relatively large proportion (> 90%) of lobsters that enter the fishery prior to maturity. Scientists argue that the current minimum size of 82.6 mm CL is not large enough to produce a supply of eggs that will be self-sustaining. That is, fisheries managers believe there is not enough of a margin of error in the minimum size law to compensate for the rate that immature animals are being taken. They would like to increase the minimum size and allow more lobsters to mature first before entering (recruiting to) the fishery. In addition, they would like to reduce pressure on the fishery through limited entry and lower trap limits. Fishermen argue that catch and effort have been positively related during the past decade. That is, the more traps fished, the better the catch and that mathematical models scientists use to estimate maximize yields by decreasing fishing effort are unrealistic, or, at least, do not adequately model what is presently occurring in the fishery. In addition, fishermen are convinced that the management tools currently in place (trap limits, biodegradable escape vents, minimum and maximum size, V-notching, and making possession of ovigerous females illegal) provide significant compensation for a fishery in which > 90% of the individuals are immature. Maine fishermen are prepared, however, to increase the minimum CL size to 84.1 mm over a two-year period when other New England states adopt the same minimum size.

Specific rules and regulations

Maine's lobster fishery management plan has been used as a model for other New England states and the federal government that has jurisdiction from twelve miles offshore to the 200-mile limit. Several of the laws (such as minimum and maximum size on carapace length, V-notching, and license fees) have been in effect for more than a half a century. Others regulations such as escape vents, trap limits, licensing classes, and trap tags have been in effect for two decades or less. Today, seven regional management committees decide the way in which local waters will be fished and regulated and these rules are superimposed upon statewide regulations. The management committees may not override a statewide rule or regulation, only make it more stringent.

The following section contains excerpts from Chapter 619 (LOBSTER AND CRAB FISHING) of State of Maine regulations and statutes (12 M.R.S.A. Subchapters I (§6421) – V (§6477) [2000])

a) Minimum and Maximum Carapace Length

- Minimum carapace length = 82.6 mm, or 3 ¼ inches
- Maximum carapace length = 127 mm, or 5 inches

b) Licensing

All fishers who wish to harvest lobsters in Maine must be licensed. The license enables the licensee to "fish for, take, possess, ship or transport within the State (of Maine) lobsters (*Homarus americanus*) or crabs (*Cancer irroratus* and/or *Cancer borealis*) and sell lobsters or crabs the license holder has taken (caught)." The license *does not* authorize the license holder to remove lobster meat from the shell or to take, possess, transport or ship lobster parts or meat.

There are seven discrete classes of licenses and an annual license fee:

a) Class I -- $46 for applicants under 18 years of age; $93 for applicants 18 years of age and older. A Class I license authorizes the holder to fish for lobsters and crabs by the individual who is named in the license. Any individual assisting or helping a Class I license holder in these activities must also be licensed.
b) Class II -- $186 for all applicants. A Class II license authorizes the license holder to fish for lobsters and crabs by the individual and the license holder may engage one unlicensed crew member to assist in the licensed activities under the direct supervision of the Class II license holder.
c) Class III -- $279 for all applicants. A Class III license authorizes the license holder to fish for lobsters and crabs by the individual and the license holder may engage two unlicensed crew member to assist in the licensed activities under the direct supervision of the Class III license holder.
d) Apprentice -- $46 for applicants under 18 years of age; $93 for applicants 18 years of age and older. An apprentice lobster and crab fishing license authorizes the apprentice so licensed to fish for lobsters and crabs by the individual on that apprentice's sponsor's vessel when the apprentice's sponsor is on board the vessel. A person who holds an apprentice lobster and crab fishing license may not tend any traps unless the traps are fished by the sponsor of the apprentice so licensed. An applicant for an apprentice lobster and crab fishing license may designate up to 3 sponsors. An "apprentice's sponsor" means a person who holds a Class I, Class II or Class III lobster and crab fishing license.
e) Student -- $46 for all applicants. A student license authorizes the license holder to fish for lobsters and crabs by the student, but the licensee may not submerge at any one time more than 150 lobster traps in the coastal waters of the State (of Maine). An applicant for a student license shall designate a sponsor. A person issued a student license is enrolled in the apprentice program. A "student's sponsor" means a person who holds a Class I, Class II or Class III lobster and crab fishing license.
f) Commercial (over 70 years of age) -- $46 for all applicants.
g) Noncommercial -- $46 for all applicants. A noncommercial lobster and crab fishing license authorizes the license holder to fish for lobsters and crabs by the licensee; however, he/she may not submerge at any one time more than 5 lobster traps in the coastal waters of the State (of Maine).

In 2000, the following number of licenses were sold in each class: Class I – 2,008; Class II – 2,799; Class III – 459; Apprentice – 563; Student – 927; Commercial (over 70 years of age) – 351; Noncommercial – 1,406. There was a total of 7,107 licenses sold, 75% of which were either Classes I, II, or III. Of the total number of commercial licenses sold in 2,000, 92% went to license holders in Classes I, II, or III.

The state of Maine has imposed a limit on the number of fishermen because a Class I, Class II, Class III, apprentice, noncommercial or student lobster and crab fishing license may only be issued to an individual and is a resident license. Further, a Class I, Class II or Class III license may be issued to a person only if the person possessed a Class I, Class II or Class III lobster and crab fishing license in the previous calendar year. Individuals who retire from the fishery may not "pass along" their license to anyone.

c) V-notching and Egg-bearing female protection
The state of Maine and fishermen have been v-notching lobsters since the 1940's. It is unlawful to take, transport, sell or possess any lobster which is bearing eggs or any *female* lobster marked

with a v-notch in the right flipper next to the middle flipper or any female lobster which is mutilated in a manner which could hide or obliterate that mark. The right flipper is determined when the underside of the lobster is down and its tail is toward the person making the determination. If a fisherman hauls a trap that contains an egg-bearing or v-notched female, no violation of the law will occur if the lobster is immediately liberated alive into the coastal waters or when taken or discovered in a lobster pound. If an egg-bearing female is discovered in a lobster impoundment, the pound owner will notify the DMR who will take the lobster, v-notch her if not already notched, and liberate the lobster into the immediate vicinity outside the impoundment area. The pound owner will be reimbursed the price of the lobster at a rate that is agreed before the season begins by the DMR and the Maine Lobsterpound Owner's Association.

If anyone is caught possessing an egg-bearing female illegally or any lobster whose right flipper is v-notched or mutilated in a manner which could hide or obliterate such a mark shall be *prima facie* evidence that the lobster is a v-notched female lobster. The penalty for possession of lobsters is a fine of $50 for each violation and, in addition, a fine of $100 for each lobster involved that is bearing eggs and a fine of $50 for each female lobster involved that is marked with a v-notch.

It is also illegal to artificially remove the extruded eggs from a female lobster or to take, buy, sell, possess, transport or ship any female lobster from which extruded eggs have been removed by any means other than natural hatching. The penalty for this is a fine of $500 for each violation and, in addition, a fine of $150 for each lobster.

d) Traps, Tags, and Escape Vents

A maximum size for traps in Maine is a volume no larger than 22,950 cubic inches. Beginning in 1996, lobster and crab fishing license holders had to purchase tags (one per trap) for the purpose of identifying and tracking traps. Tags must be purchased through the DMR and cost $0.50 each. Trap tag fees must be deposited in the Lobster Management Fund.

An escape panel or "vent" is required in every lobster trap in the State of Maine. Therefore, it is unlawful to fish for or to take lobsters unless the lobster trap is equipped with unobstructed vents or gaps in the parlor section as follows: a rectangular or oblong escape vent not less than 1 3/4 inches (44.5 mm) by 5.75 inches (146 mm) located next to the bottom edge or on the top if the escape vent is placed over the head of an end parlor section. Circular escape vents can also be used, but there must be two of them and they must be not less than 2 1/4 inches (57.2 mm) in diameter located next to the bottom edge or on the top if the escape vents are placed over the head of an end parlor section. An escape vent may also be created in a wooden trap by creating a gap caused by raising, modifying or separating horizontal laths to so as to create a space that is at least 44.5 mm x 146 mm. In a wire or plastic trap, an escape vent may be a gap created by cutting vents (at least 44.5 mm x 146 mm) in the side or end. Whenever the minimum legal carapace size is adjusted, the commissioner of the DMR shall specify by rule the dimensions of vents in lobster traps which shall be appropriate for the minimum legal lobster size in effect.

Beginning 1 January 1990, all lobster traps were required to be equipped with a biodegradable ghost panel. A "ghost panel" is an escape panel that is designed to release lobsters from traps that are lost while fishing. The majority of escape panels double as ghost panels which means they must be replaced every 1-2 years.

e) Closed Periods

Maine law establishes two closed periods during the fishing season during which times it is unlawful to raise, haul or transfer any lobster trap from the coastal waters. These are:

Summer. During the period 1/2 hour after sunset until 1/2 hour before sunrise from June 1st to October 31st, both days inclusive; and
Weekends. During the period from 4 p.m., Eastern Daylight Savings Time, Saturday, to 1/2 hour before sunrise the following Monday morning from June 1st to August 31st, both days inclusive, except that it is lawful to raise, haul or transfer traps during this period if a hurricane warning issued by the National Weather Service is in effect.

These closed periods were created to reduce the chances of illegal hauling by unlicensed fishers during the summer and on weekends.

f) Trap Limits and Management Zones

Beginning in 1996, Maine adopted a statewide limit on the number of lobster traps that could be fished by a licensee. The limit began at 1,200 per license. From 1 January 1998 to 29 February 2000, the limit was reduced to 1,000 per license. After 1 March 2000, the statewide trap limit per license has become 800.

In 1996, the Maine Department of Marine Resources and Maine lobster fishermen agreed on a new policy to effect local control over managing lobster stocks. Legislation created seven distinct, non-overlapping management zones. A person must declare on an application for a Class I, Class II or Class III lobster and crab fishing license the lobster management zone in which that person proposes to fish a majority of that person’s lobster traps. A license must identify the zone in which the person is authorized to fish a majority of that person’s lobster traps.

Management zones are intended to produce local rules for fishing effort or other schemes that are stricter than current statewide law. For example, zones may extend limits on the number of traps fished by an individual lobster license holder or two or more lobster license holders who fish from the same boat fishing in a particular lobster management zone and the time periods allowed for complying with that number. Zones may impose a limit on the number of lobster traps allowed on a trawl fished or place limits on the time of day when lobster fishing may occur. Each zone is governed by a policy council that abides by a local set of bylaws. Councils may conduct their business and decide all issues by consensus except the decision to hold a referendum on lobster fishing effort limitations. This decision must be approved by a majority of the council members present and voting. Each voting council member has one vote. No vote is binding unless a quorum of two thirds of the council members are present and voting. After a council votes to hold a referendum, the referendum question must be mailed to all eligible license holders who have designated that zone as their declared zone. The referendum ballots will include a postage-paid return address at the Department of Marine Resources. The council may submit a proposed effort limitation rule to the Commissioner if it is approved by two-thirds of those voting in the referendum. If a lobster management policy council recommends a rule to limit lobster fishing effort in its zone after approval in a referendum, the Commissioner of the DMR may adopt and publish the rules verbatim or may adopt and publish rules that accurately reflect the intent of the council's recommendation. The Commissioner also may reject the proposed rule if he/she finds it to be unreasonable.

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Effects of Fishing Strategies on Yield and Egg Production of American Lobsters in Nearshore Gulf of Maine

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Introduction

Different fishing strategies for American lobster, *Homarus americanus*, have evolved in part due to variations in resources, markets and the types of management measures supported by fishers. In the United States, with a few minor exceptions, there are no regulated seasons, and limits on traps have only recently been adopted. The evolved patterns of fishing show a temporal concentration of effort, and subsequent high proportion of landings over a very short portion of the year. This is, in part, a response to competition amongst fishers. A simulation model, using population dynamics parameters for lobsters, was developed to examine yield and egg production of lobsters under different life history patterns and/or management and harvesting regimes. The model allows multiple time steps during a year to incorporate these differences in life history and fishing tactics on a fine temporal scale. By using this model we have examined the differences in yield and egg production and evaluated relative effects of different fishing strategies

Egg and Yield per recruit model overview

Conventional egg production and yield per recruit models are not useful for lobster because age determination is difficult, growth in length is not continuous and the relationship between size and annual egg production is complicated. The model used in this study incorporates size-specific annual molt probabilities, assumptions about intermolt duration, molt increments, maturity schedules, fecundities and length-weight relationships. Calculations incorporate interactions between reproduction and growth (e.g. female lobsters suspend molting and growth when they are carrying eggs) and size specific management measures for female lobster (e.g. maximum and minimum size regulations).

In these models for lobsters, it is important to distinguish among “nominal” encounter, capture, retention and fishing mortality rates. The *nominal encounter rate* is a measure of the rate at which individual lobsters encounter and enter traps. In baseline runs, nominal encounter rates were assumed equal for lobsters of all sizes. *Capture rates* measure the rate at which individual lobsters enter traps without leaving. Capture rates are less than encounter rates because escape vents allow small lobster to leave traps. Capture rates depend, in part, on size because large lobsters are unable to leave traps through escape vents. *Retention rates* are based on management regulations and fishery behavior. Legal requirements (minimum and maximum size, prohibition of landing berried lobsters, and v-notch protections) as well as size specific and/or other quality considerations affect release of captured lobsters. Only those lobsters retained are removed from the model population. Encounter and retention parameters in the model can be changed to simulate management measures. In contrast to nominal encounter and capture rates, *fishing mortality rates* measure the rate at which lobsters are landed and killed. Fishing mortality rates are usually less (and never greater) than capture rates because management measures (e.g. maximum and minimum size limits, restrictions on landing berried or v-notched females) require that some lobsters caught in traps be released.

Each model run was based on a cohort of male and female lobsters. Growth is modelled using 1 mm size groups. Growth is determined by the interaction of size specific molt interval (the time between molts) and a range of molt increments. The model simulates growth and mortality and keeps track of the number of survivors, number of natural deaths, numbers landed, number mature, number v-notched, number molting and egg production by size group in each time step over the lifetime of the cohort. A monthly time step allows investigation of temporal differences in growth and implementation of management measures.

Simulations

The model was run using combinations of different management measures, minimum size (MIN) of 83mm CL; maximum size (MAX) of 127 mm CL; protection of berried females (EP) and v-notching (VN) and subsequent protection, for two molts, of notched females. The combinations of measures examined were

1. minimum size protection only
2. minimum size and berried females protection
3. minimum size, berried females and maximum size protection
4. minimum size, berried females and v-notching
5. minimum size, berried females, v-notching and maximum size protection.

In all cases, all protections apply to females. However only the minimum and maximum gauge sizes offer protection to males, so combinations 1,2 and 4 are equivalent (minimum size protection only) and combinations 3 and 5 both offer the same minimum and maximum protection. Model runs were made over a range of encounter rates from 0 to 2.0, and yield and egg per recruit estimates were compared for the five sets of management measures.

Results

The results, in terms of egg production and yield per recruit for the five combinations of management measures are shown in Table 1, for two values of F(capture) or effective effort; the low F = 0.3, the high F = 1.0. The yield per recruit (YPR) values are for both sexes combined (values for males, females follow in parentheses). Egg production per recruit (EPR) are also shown. An additional metric is presented. This is listed as a relative catch per unit effort (RCPUE) ratio. This is simply the YPR under low F divided by the YPR at high F times the inverse ratio of F capture rates (effective effort). In this case, the effort ratio is 1.0/0.3 = 3.333. This is an indication of the additional effort (at high F) required to produce the YPR difference.

Discussion and Conclusions

YPR an EPR differences, among scenarios, are functions of the type and timing of protective measures implemented . In the majority of the US Gulf of Maine (GOM) (in terms of lobster abundance), large animals (> 127 mm CL) of both sexes, and v-notched females are non-harvestable.

Table 1: Effects of different management controls in terms of yield and egg production per recruit.

Run	Management Controls	Low F YPR	High F YPR	RCPUE RATIO	Low F EPR	High F EPR
R1	1) MIN only	325 (340, 310)	316 (329, 304)	3.4	4198	296
R2	2) MIN + EP	324 (340, 308)	318 (329, 306)	3.4	7682	834
R3	3) MIN + EP + MAX	312 (340, 285)	313 (329, 296)	3.3	11487	2306
R4	4) MIN + EP + VN	279 (307, 250)	312 (329, 296)	3.0	18616	2484

R5	5) MIN+ EP + VN + MAX	284 (307, 260)	317 (329, 305)	3.0	15100	1032

MIN *= Minimum landing size (83 mm CL),* ***EP*** *= Egger Protection*
MAX *= Maximum landing Size (127 mm CL),* ***VN*** *= v-notching and v-notch protection*
RCPUE Ratio = (Low F YPR/High F YPR)(High F/Low F)*

The “bottom line” of these differences in management measures is that, for a given capture rate, there is a gain of some egg production per recruit while giving up some in terms of total yield per recruit, and the increase in effort necessary to acquire that yield. The yield curves demonstrate this well (Figures 1 and 2). Under current US management in nearshore GOM, the female yield per recruit is asymptotic. Since females are protected *via* v-notching and a maximum size, the usual peak at low exploitation is dampened by the unavailability of those animals. The males in most of the GOM are also protected by a maximum size, and show a similar damping of maximum yield, but not to the same degree. Total yield though dampened by the female contribution, still shows a peak at low exploitation.

What is very clear from this exercise, is that the benefits of these management regimes are higher at low exploitation or low fishing effort (Figures 1, 2 and 3). This is simply the manifestation of allowing the lobsters to express those traits that give them protection from harvesting. In the US, this means that at low harvest rates, both male and females are allowed to reach the maximum size (127 mm CL) that ensures their return to the water. In regard to v-notching, a female must become mature to become egg-bearing and thereby have a potential to be v-notched and then protected. With the minimum size of 83 mm CL, only about 2-5% of the females are mature, and are about 1 molt away from 50% maturity (around 95 mm CL). Additionally, with a year-round fishery, the mature females may be harvested before they extrude eggs, and thus the potential protection (both from being berried and also possibly notched) is not realized. When the harvesting rate is low, more animals will mature and then be potentially notched (Figure 4) and survive to the maximum size.

It appears that the most effective way to provide sustainable lobster resources is to attempt to reduce the harvesting rates. The gains in yield, and potential decrease in costs associated with harvesting, should make this an attractive avenue to pursue. Additionally, the current restrictions introduce inefficiencies into the harvesting of lobsters. While some minimum size is practical, in terms of markets as well as some protection of spawning stock, the other measures all require greater discarding of animals that are not legally harvested. It is this process that flattens out the YPR curves, and creates the likely increased effort to get what is available (legally) from the resource. As effort increases, and the size composition of landings is more compressed, the only thing that maintains harvest levels is constant or increased recruitment. Additionally, the size composition of the resource itself will become compressed if the minimum size is insufficient to protect mature females. As noted above, at present in the Gulf of Maine, the minimum legal size of 83 mm CL is essentially the onset of maturity for female lobsters. With nearly 90% or more of the landings coming from sizes within one molt above this minimum size (i.e., 94 mm CL or less), this means most lobsters do not have the opportunity to spawn once. At the current level of removals, the incorporation of a maximum size, v-notching and berried female protection cannot compensate for the reduction in spawning potential. Currently, in the GOM, there is essentially open access to the fishery. If all legal permits were to fish the current trap “limits”, there could be a 2 to 3 fold increase in the amount of gear, assuming there is sufficient room to fish that much gear. As it is, reports of areal expansion, into regions formerly lightly (if at all) exploited are more frequent. The current management tools that incorporate inefficiencies, without addressing control of effort, cannot be expected to protect the resource at present levels of recruitment, much less in the event that recruitment should drop off.

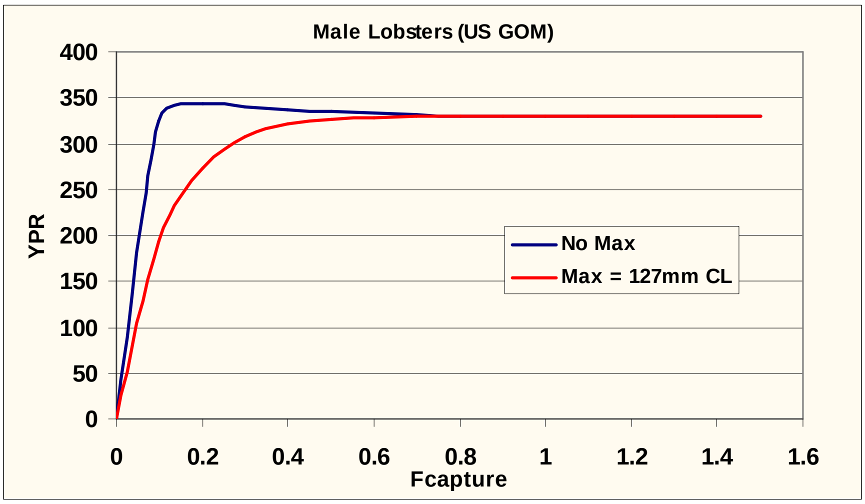

Figure 1 Yield per recruit for male lobsters in the Gulf of Maine.

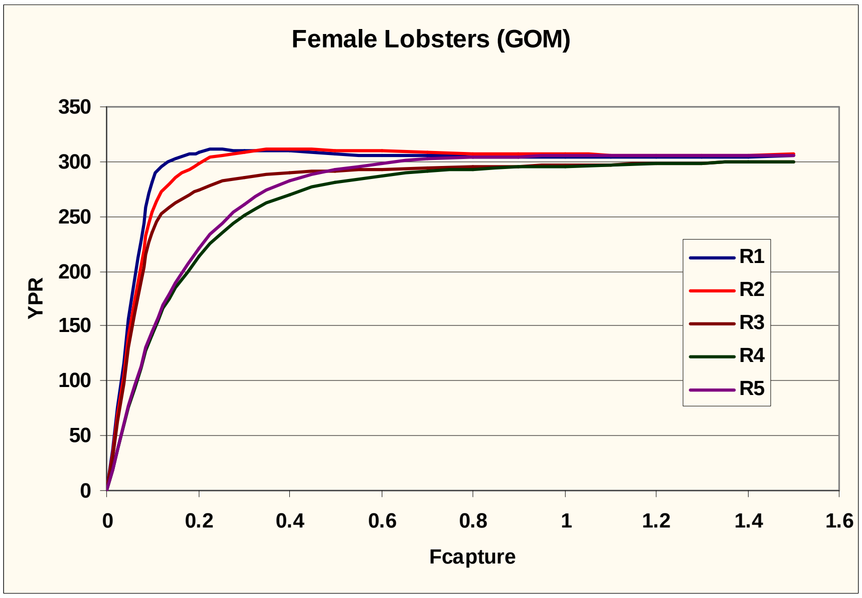

Figure 2 Yield per recruit for female lobsters in the Gulf of Maine

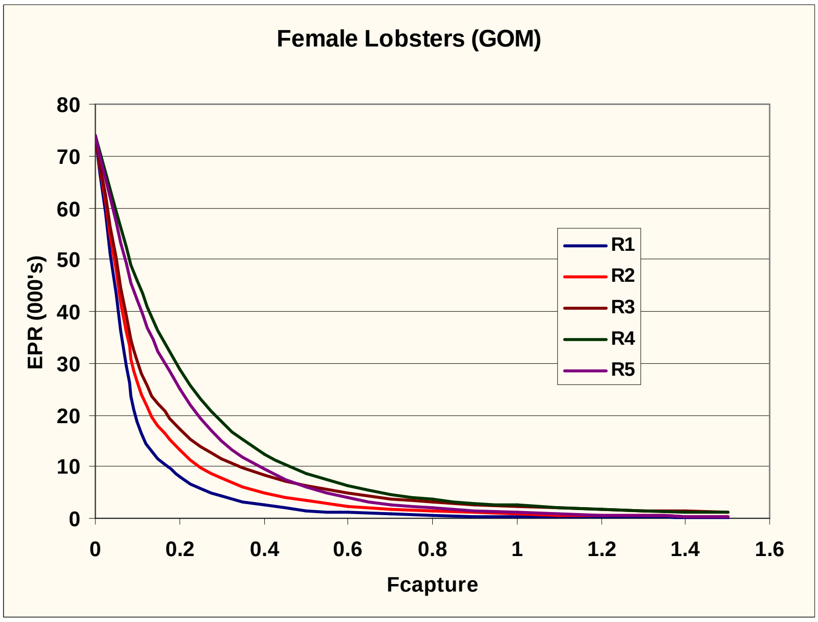

Figure 3 Egg per recruit for female lobsters in the Gulf of Maine

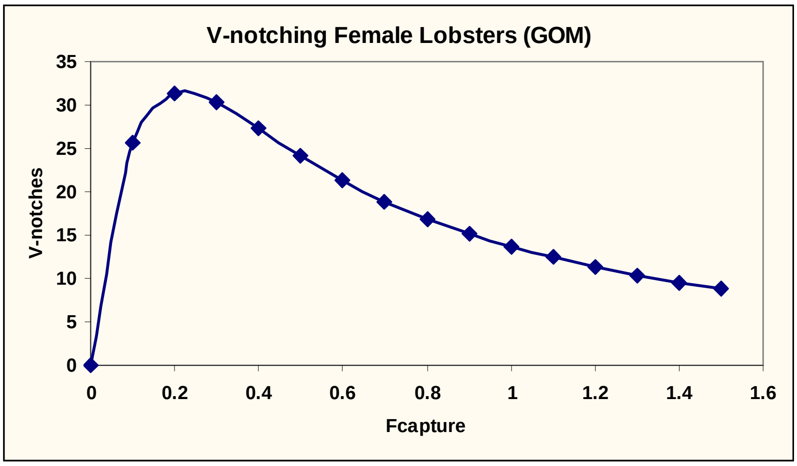

Figure 4 V-notching as a function of fishing effort in the Gulf of Maine. At low effort more females mature, spawn and are available for v-notching.

Lobster Management In Ireland Europe And USA : A Summary

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Development of management structures and measures in Ireland (1992 – 2000)
Concern from lobster fishing groups about stock levels has led to the establishment of a range of management strategies and attempts at restocking or enhancing exploited fisheries in Europe and North America. In Ireland it is generally perceived, both by fishers and state bodies (see Appendix 1 for a list of relevant bodies involved in management and research in Ireland) that the pressure on lobster stocks is increasing with possible depletion of stocks. In the past eight years, a number of innovations have occurred in the Irish lobster fishery . Many of these initiatives were pursued by local and voluntary groups, which in turn generated considerable enthusiasm for conservation measures and their legislative development.

This section describes some of the events and work that occurred over the last decade in Ireland. Many of the activities described are interrelated and were undertaken over a period of several years with multiple participants and organisations involved. A summary of the major events and programmes are listed in Table 1 in chronological order.

Table 1. Chronology of recent events in Irish lobster fisheries management

1992	Lobster stock enhancement programme commenced SRL/TMT .
	Ir-Am-Aqua conference with emphasis on lobsters (Galway).
1993	Beal undertook lecture circuit of Ireland (Galway, Donegal, Wexford and Kerry) funded by UnG and SRL.
	Voluntary conservation of "V -notched" lobsters commences.
	Wexford lobster Co-op initiated (BIM, WORD, FAS).
1994	Wexford lobster nursery began.
	International lobster Conference in Galway (organised by Mercer (SRL).
	Irish Lobster Association (ILA) established
	Irish fishermen visit and work in USA (Maine) at invitation of Maine Lobster Fishermen's Association (MLFA).
	Legislation introduced to protect "V" notched lobsters.
1995	Lecture circuit of Ireland by Dow (MLA) on lobster conservation.
	Lobster conservation posters campaign (ILA).
	A review of potting and creeling by BIM.
	A study of the impact of v-notching in Wexford began (Tully, TCD)
1996	Lobster ecology and recruitment study (LEAR) commenced.
1997	ILA became a registered Co-operative Society .
1998	Study on the genetics of European lobsters (GEL) commenced.
	A study on egg per recruit production in Irish stocks began (TCD and TMT)

1999	BIM review and recommendations on inshore fishery sector .
2000	Establishment of Local Inshore Fisheries Development Committees (Wexford, Dingle, Galway).
2001	Expansion of the IFDCs to 7 areas
2002	V-notching supported by NDP program, voluntary logbook program, lobster tagging, BIM
2003	V-notching supported by NDP program, voluntary logbook program, lobster tagging, BIM

Summary or lobster management in Europe and USA:
At the workshop there were many interesting issues presented relating to the management policies and structures in Europe and USA (Table 2). From these presentations it appears that fisheries regulations should support predefined objectives and in many instances a combination of regulation are required to produce the desired results.

Table 2. Lobster fishery regulations in north America and Europe

Regulation	USA	Maine	Norway	UK	France	Jersey	Ireland
Berried female	Yes	Yes					
Minimum size	Yes	Yes	Yes	87 mm	85 mm	85 mm	85 mm
Maximum size	Yes	Yes		Proposed			
v-notching	Yes	Yes		6 areas			Yes
Licensing	Yes	Yes		8 areas	Yes		
Trap limits		Yes			Yes		
Gear regulation	Yes	Yes			Yes		
Season		Yes	Yes				
Reserves					20 locations		
Other	*	*					

* *escape vents, lobster fund from license fee*

Although the European lobster fishery has existed for as long as the American fishery, the present day European regulations are few in number and simple. In general the sole and common regulation in Europe until relatively recently has been a minimum size limit with some notable exceptions as detailed in Table 1. In contrast the Maine (USA) management strategy includes protection of egg bearing females, licensing, limited entry of commercial fishers, minimum & maximum lobster size, "V -notching", closed periods, trap limits and requirements that traps have escape vents and biodegradable elements to prevent ghost fishing. In addition to these regulations there are three organizations that benefit financially from lobster license fees, these are the Lobster Fund, Lobster Management Fund and the Main Lobster Promotion Council. The overall format of Maine regulations is such that a portion of the broodstock is protected and the competitive nature of the fishery is constrained by the current limits imposed. However, even in Maine there is a debate on the issue of recruitment overfishing (see papers by Beal and Idoine this report)

From the presentations at the workshop it appears that some of the management objectives of Irelands Lobster fishery are:

(a) Enhance landings.
(b) Protect a significant proportion of the breeding stock.
(c) Control the cost of fishing.

Licencing policy needs to preserve the social and economic profile of lobster fishing. This is a traditional activity and mainstay fishery of the small boat sector in Ireland. Control of individual effort in order to distribute economic benefits throughout the sector is required.

Appendix
Irish Agencies involved in lobster management and research :

1. The Department of the Marine and Natural Resources (DoM&NR) (Roinn na Mara) is responsible for policy issues in relation to fishing and marine industries, shipping, marine research and technology , aquaculture, marine safety and general marine conservation policy.
2. Board Iascaigh Mhara (BIM), (Sea Fisheries Board) is the state body with primary responsibility for the developments of the sea fishing and aquaculture industries. It provides financial, technical, educational, resource development and marketing services to the catching and aquaculture sectors through to the processing and marketing sectors of the overall fishing industry .
3. The Marine Institute {MI) is responsible for undertaking, co-ordinating and promoting marine research and development in Ireland.
4. Udaras na Gaeltachta (UnG) is part of the "Department of Arts, Culture, the Gaeltacht and Islands" and it has responsibility to promote the cultural, social and economic welfare of the Gaeltacht (Irish speaking areas). It brief includes inshore fisheries, aquaculture, and fish processing development. It is also involved in research into new species, technologies and cultivation methods, and in providing grant aid and training to operators.
5. Taighde Mara Teo. (TMT) is a private marine resource research and development company funded by Udaras na Gaeltachta. 5 field researchers and a manager staff it, these employees are strategically located in the Donegal, Mayo, Galway and Kerry Gaeltachts.
6. The Shellfish Research laboratory (SRL) in Carna, Co. Galway is part of the Zoology Department and affiliated to the Martin Ryan Marine Science Institute of the National University of Ireland Galway {NUIG). The activities of the laboratory are research, technological development and demonstration up to pilot commercial scale.
7. Trinity College Dublin (TCD). Within the Zoology Department research on crustacean stock assessment is carried out both within Ireland and as part of European scale projects.

Open Discussion

Panel : M O Driscoll, D Healy, J Hickey, J Addison, O. Tully, D. Latrouite

After the formal presentations at the conference an open discussion was held during which various opinions on lobster management were raised by fishermen and other industry participants. The following are the main points discussed during the open session. The points are presented in chronological order in which they were raised.

ILA Donal Healy : Thanked the speakers for sharing the information with Irish industry and on behalf of the ILA thanked everybody for coming. Indicated that the ILA are looking for the licensing of the inshore fisheries or for lobster specifically or to include other species. The ILA had received criticism from some sources on the lack of progress on the license issues. The ILA had met with the Minister. The Minister promised at the recent ILA AGM that a license would be put in place.

The NW Kerry Co-op commented that the co-ops have demonstrated a track record in conservation, stock management and fishing that should be sufficient to demonstrate to the DoMNR that they are a responsible body and could be issued with a license.

Suzanne Henderson from Shetland described the process of issuing licenses in the Shetland Islands which is now managed by a regulatory order covering Shetland waters. These licenses were limited to 160-170 and issued on a track record of fishing in Shetland waters.

An Inishbofin representative questioned the number of convictions that were successfully brought by the DoMNR annually and whether hotels were targeted by the fisheries officers.

Michael O Driscoll answered that this data could be sourced if needed. He stressed that the number of enforcement officers around the coast did not allow for adequate inspection at all ports for all species. The number of officers is set to increase from 20 to 38.

Trevor Simpson of the Waterford co-op indicated that he was dissatisfied with the lack of action and progress on the license issues.

The issue of unlicensed or unregistered boats was raised and a question asked as to the possible impact on the egg per recruit of removing those boats from the fishery. O. Tully responded that reduction in effort, of any type, would have the effect of increasing egg production. However, removal of unregistered boats from the fishery although they are strictly operating illegally would probably not be the correct approach to take when considering the issuing of licensing. Above all the license system must be seen as being non-discriminatory and fair in the long term.

Michael O Driscoll added that yes these boats need a license to fish and that there could be no possibility of issuing a specific lobster license to a boat that did not already hold a valid sea fishing license.

The issue of unregistered boats was raised by a number of speakers and it seems to be a major issue in drafting decision rules on the issuing of lobster license. It is clear that the status of these boats has to be regularised before the lobster license can be implemented nationally.

Lorcan O'Ceinneide pointed to some precepts about future legislation. Would the DoMNR welcome a submission that would contain a clear statement of the conditions associated with issuing of licenses and that would include the scientific evidence for the need for additional legislation.

Michael O'Driscoll indicated that it would be useful to give a 'shopping list' to the DoMNR which was supported by the science. Information required by the DoMNR might include : what is the opinion within the majority of the industry. ? What is required by the majority ? Many pressure stocks have a specific license such as herring. There is a precedence therefore in the Irish inshore sector.

Mark Norman asked for clearer definition of what a license is in relation to lobster fishing eg. what does it allow fishermen to do and what conditions might be attached to it.

Oliver Gallagher indicated that with the investment that fishermen have made something must be put in place to protect that investment. Otherwise outsiders will come in and reap the rewards. He saw no reason why a fishery license could not be brought in on the lines of the herring fishing or the salmon fishing license. Peoples livelihoods were at stake and fishermen had made a large contribution to the development of the fishery over the past number of years. This has to be protected. For new entrants there should be some track record as an apprentice or some other conditional entrance. Otherwise no progress will be made.

Oliver Tully asked if the industry saw the issuing of a license as a necessary pre-requisite before additional conservation measures would be acceptable. This is important given that the time lag between introduction of real conservation measures and beneficial effects on catches is at least 5 years. The issuing of a license nationally could also take some time.

A comment from the floor was that some areas may be different to others in what they see as important. In the north east increases in the minimum size would have a large effect in the shallow water fishery. In the UK there are regional measures to accommodate these biological differences.

Julian Addison responded that yes there are different minimum sizes in the UK. On the south coast it is currently 90 mm. There are no restrictions on any fleets. Most have a requirement to return catch and effort information. Some have no such requirement. There are no pot limits. A national licensing scheme will probably come in the future but it may be operated locally with regional specific restrictions.

On request from Julian Addison Daniel Latrouite clarified the French regulations. The same limits for all regions apply. It is still evolving and it may be feasible to divide the coast into specific management areas. The pot limits could depend on the abundance of the resource in each area. But what is a regional level ? What is the best level at which to make the decisions? It is clear that the more fishing effort is increased then the more fish and fishermen are in danger. It is necessary to cut fishing effort and therefore to cap the number of boats and the number of pots in the fishery. This is not an easy task. Who will be the owner of the license? Probably the skipper with his boat. This means that if the skipper wants to sell his boat he loses his license and a license is free. A set of decision rules have to be put in place. This is also not an easy task. It has taken several years in France to put this in place. Fishermen are the resource that is in danger really.

John Mercer indicated that a lot of progress had been made since 1994 with the formation of the ILA and allied developments and research support. Fisheries management was being developed, however, without full biological knowledge which can be dangerous. Full life cycle knowledge of the species is required. He asked how the panel thought the interaction of management and biological knowledge of the species should develop in the future

Oliver Tully responded by saying the egg per recruit model could be a valuable management tool in the absence of complete knowledge. It is in no way dangerous to the fishery to manage like this and is compliant with the precautionary principle. It is appropriate using the current biological knowledge to advise both industry and the legislators to move on controlling effort and adopting additional control.

Brian Beale stated that we know very little about the ecology of lobster and that ecological studies are fundamental to the successful management of the stocks. He made the point that it seemed logical to protect berried females if egg production was too low.

Julian Addison responded indicating that the ban on berried females is difficult to enforce and at any rate it is the number and size of mature females that it is critical to protect rather than berried females *per se*. There is no added advantage in protecting berried females only. The egg per recruit model demonstrates this.

Oliver Tully added on the issue of ecological knowledge and management that management through ecology is an ambitious worthwhile target but the industry cannot wait for perfect knowledge of the species to be acquired before it recommends new management approaches.

John Fouere added some comments on marketing of lobsters. His experience of selling lobsters to the European market spans over 50 years. Large lobsters (>1.5 kg) are difficult to sell. A maximum size would not negatively affect markets, therefore, and may be supported by the buyers. With regard to enforcement he indicated that there was a complete lack of consultation between EU countries that made enforcement much more difficult. John also made comment about the disgraceful history of the crayfish fishery in Ireland which was wiped out in 30 years by tangle nets. There was a complete lack of conservation measures and these came too late and from the EU. He asked Daniel Latrouite why France did not support the recently imposed MLS of 110 mm on crayfish. An additional question was put to Michael O'Driscoll on the reasons why a new gauge had not been issued for crayfish that would enable the legislation to be enforced. The following comments were made on those issues.

Daniel Latrouite : New measures need to be justified and be tailor made for each region. A minimum size of 110 mm was unjustified for France as the size at maturity was small

John Mercer : The EU regulation came from a thesis lodged at the EU and was based on populations on the south coast of the UK where size and size at maturity have been shown to be quite large. The measure in fact was a biological impossibility as the posterior edge of the eye socket was not definable in crayfish.

Michael O'Driscoll : Not as simple to get new gauges as it seems but this is in progress. Calibrations etc have to be carried out.

A representative of the NW Kerry co-op suggested that 1 mm increments in minimum size for lobster would reduce or at least spread out the short term losses and asked Michael O'Driscoll if this was possible.

Michael indicated that yes it was if it was supported by industry.

Donal Healy suggested that the DoMNR, BIM, ILA and Scientists would put a body of people together to get consensus on license and how it might work.

A representative from the NW Kerry co-op asked what is the ILA agenda after the regional workshops that took place last year. Is the Beara Co-op (to which the ILA chairman is affiliated) agenda recently published in the press the same as that of the ILA?

Donal replied that the ILA agenda is different to that of the Beara Co-op and will be clarified at a later date.

The representative from NW Kerry asked that the ILA clarify it's position and policy and distribute that to the co-op's

Ian Lawler recollected that from the regional workshops there was no regional consensus on what measures were wanted. Given the regional differences in the biological characteristics of the stocks it would be useful to have a regional policy probably to account for both differences in opinion and needs of the industry and the regional differences in stock so that measures can be tailored to the regions, otherwise there is going to be dissatisfaction. Ian also made a comment on the egg per recruit data that if shown to be below a given threshold level that it could be used as a benchmark to demonstrate over-fishing to the DoMNR.

Oliver Tully closed the meeting by stating what the future actions would now be :

1. That a report would be issued from the meeting by end of November
2. That the co-ops would discuss with their members the various points raised at the meeting regarding licenses and other controls on fishing.
3. That a future meeting might be held to discuss those findings
4. A meeting between TCD, Taighde and representatives from the co-ops would take place immediately after the close of the meeting (see next section of this report for a short report on that meeting).

Future Actions : A Post-Conference Meeting Of 15 Co-Ops /Groups Representatives Present At The Conference

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Introduction

Given the emphasis during the open discussion on the issue of a lobster license a short meeting was held after the conference to discuss on how best to get some momentum going on the licensing of the fishery. 15 co-ops or groups were represented at the meeting chaired by TCD and Taighde Mara.

The following actions were agreed at the meeting :

1. That the co-ops would call an extraordinary meeting of their members to vote on the acceptability of licensing the fishery. Signatures of the members attending the meeting were to be retained along with the result of the vote.
2. That representatives from each co-op would attend a meeting hosted by TCD and Taighde Mara early in 2001 and that at that meeting each co-op would report on the result of the vote on licensing. Those co-ops receiving a mandate from their members would then discuss the conditions under which they wanted the licenses to be issued and that a set of decision rules be drawn up and agreed.
3. That with each co-op having proven mandate from it's members and with all co-ops having agreed on conditions and decision rules for the issue of licenses that an approach to the DoMNR would then give the best chance of success. This complies with the major requirement specified by Michael O'Driscoll of the DoMNR at the conference that a majority mandate from the industry is required in order to implement new legislation. The second requirement is to demonstrate that the stock is under pressure and that livelihoods are at stake. This can be demonstrated from the scientific data collected to date and which was presented at the meeting.