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MAREA PROJECT
MEDISEH (Mediterranean Sensitive Habitats)
Specific Contract No 2 (SI2.600741)

MediSeH
Mediterranean Sensitive Habitats

FINAL REPORT

Heraklion April 2013

This report was prepared by:

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General Objectives and Background

Based on the following Terms of Reference (TOR) of the content of the European Commission DG MARE request Ares (2011)665688:

"Compile information supporting the identification and location of nursery areas (juveniles in their first and, if appropriate, second year of life) and spawning aggregations. This information, which is to be collated and archived in formats adequate for GIS rendering, shall refer to all the demersal and small pelagic species in the Mediterranean included in Appendix VII of Council Regulation (EC) No 199/2008 as well as for the species subject to minimum size (Council Regulation (EC) No 1967/2006-Annex III). In addition, ecological characterisation of these areas, both in terms of biological community (assemblage) and habitats therein, must be provided."

the technical tender form of the Specific Contract 2 (MEDISEH) defined the following objectives

- Review of historical and current data on the locations and the status of seagrass beds, coralligenous and mäerl beds in different GSAs (Geographical Sub-Areas amending amending the Resolution GFCM/31/2007/2) all over the Mediterranean basin.
- Transform the information into a digitilized format within the framework of a geodatabase
- Review and map of all existing specific Marine Protected Areas (MPAs) in the Mediterranean area as well as areas that are under any form of national or international regulation.
- Identify and map suitable areas for *Posidonia*, coralligenous and mäerl communities by developing habitat distribution models at different spatial scales
- Review and map all existing information on historical and current data of nurseries and spawning grounds of certain small pelagic **(**i.e., ***Engraulis encrasicolus, Sardina pilchardus*, *Scomber spp., Trachurus spp.)*** and demersal species (i.e., ***Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris*, *Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa)*** that are included in the Data Collection Framework for the Mediterranean and subjected to minimum landing size based on Council Regulation No 1967/2006-Annex II
- Analyze existing survey data and apply spatial analysis techniques in order to identify locations that are more likely to be density hot spot areas or are being more suitable for fish nurseries and spawning grounds for ***Engraulis encrasicolus, Sardina pilchardus*, *Scomber spp., Trachurus trachurus, Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris*, *Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa*** These areas will also be characterized from an environmental and ecological perspective upon data availability.
- Integrate and present the aforementioned information through a Web-based GIS viewerwith an associated geo-referenced database that will operate as a consulting tool for spatial management and conservation planning.
- Following the revision of the knowledge base, to identify gaps and suggest future research priorities.

In order to meet these objectives, an expert team was composed within the MAREA Consortium from scientists with established expertise in the different topics required, and working in different areas of the Mediterranean basin. The team formed to execute the project includes the main Institutes of EU countries in the Mediterranean, all having solid reputations in the fields covered. The participating Institutes/Entities operate in the Western, Central and Eastern parts of the Mediterranean basin, and this ensures familiarity with the geographical areas that are related to the specific tendering. Moreover, a large number of scientists outside of the MAREA Consortium collaborated on a volunteer basis with data and other input. Details on the list of experts and external collaborators can be found in each Work Package in the present report. For CV details, check the MAREA expert web-site *http://www.mareaproject.net/*.

Executive summary on the Work Achieved

Within the framework of the project and in accordance with the MEDISEH proposal, four meetings were held during the course of the 18 month project.

A kick-off meeting was held in Heraklion (Crete) on 10-13 October 2011, in order to standardise the work among the partners involved: timeframe for work and deliverables, the input data format as well as the GIS (Geographic Information Systems) requirements. In addition an introduction on the modeling techniques that could be applied was made. The work was held in parallel concerning the three work packages in order to save time and travelling cost.

A second meeting was held by month 6 according to the proposal, in Palermo (Italy) on 6-8 February 2012. Brief presentations on the progress of work were made, emphasis was given on the difficulties and the problems encountered and extended presentations were made on the modeling techniques that could be applied depending on data nature and data availability. Concerning especially WP1 a special session was devoted to define environmental and/or anthropogenic variables to be tested for habitat modeling depending on data availability.

A third meeting was held by month 12 according to the proposal, in Rome (Italy) on 26-28 September 2012. During this third meeting the revision of existing information per work package and Task was presented, the timeframe to follow in order to meet the project objectives and deliverables along was discussed and agreed. The meeting focused on the evaluation of the modeling techniques applied and the initial modeling results obtained in the framework of both WP1 and WP2. Special attention was given to Task 1.3 and the initial results of habitat distribution models of *Posidonia*, coralligenous and mäerl communities. Different approaches on spatial modeling techniques depending on data availability were presented by Prof. Michele Scardi and Dr. Corinne Martin and discussed. Problems encountered due to misallocated records and the spatial resolution of the examined environmental variables, were exhaustively discussed. Furthermore an updated version of GIS viewer (WP3) by Vasilis Valavanis (HCMR) was presented and a long discussion was also devoted to the improvement of the GIS viewer and the presentation of revised data and model output.

A fourth meeting was held by month 17 and took place in Heraklion (Greece) 8-10 January 2013. During this fourth meeting the progress of the work and the deliverables per work package and Task were presented, the timeframe and the scheme to follow for the final report was discussed and agreed. The meeting focused on the presentation of the final modeling results obtained within the framework of both WP1 and WP2. Special attention was given to the updates of Task 1.2 due to recent data input from non Consortium colleagues for the Western Mediterranean Sea, Croatian and Tunisian waters and subsequently to the evaluation of Task 1.3 results from the applied habitat distribution models for *Posidonia*, coralligenous and mäerl communities. Furthermore the updated version of GIS viewer (WP3) was presented by Vasilis Valavanis (HCMR) that included deliverables already finalized by the time of the meeting. A long discussion followed concerning the improvement of the presentation of project results, what to include in the associated information to the ".shp" files and potential queries to include in the viewer.

By the end of the fourth meeting it was also apparent that an extension of the project was a prerequisite, without which the quality of the project output and deliverables could have been largely undermined. The following problems that evoked resulted into the need for one month and a half extension in order to fulfill the project deliverables and reporting in the best possible way to meet the Commission requirements. Specifically:

- Updated data concerning coralligenous information from the western part of the Mediterranean was received by the Task coordinator of the respective Task at the beginning of Month 17, largely due to lack of willingness from non Consortium partners to collaborate before this time.

- The above mentioned data required additional time and effort to be incorporated in the updated dataset as well as to re-run and re-evaluate the respective habitat model (Deliverable for Task 1.3).
- The evaluation of the nursery and spawning grounds model output for the demersal fish revealed some problems that required the re-application of modeling for certain species in certain areas. This results in a subsequent delay in the construction of the respective GIS shapefiles and reporting.
- The recent update of shapefiles for Fishing Restricted Areas and Marine Protected Areas in the respective database at http://www.protectedplanet.net/ and http://www.medpan.org/mapamed imposed the need to compare and re-evaluate existing information collected within the framework of the project in order to deliver the best and most updated information to the Commission.

Thus an extension of one and a half month was requested and approved by the Commission in order to complete project deliverables and report in the best way possible.

Within the framework of the project all (100%) of the deliverables foreseen have been produced. Extensive efforts were made especially concerning the revision of existing information on phanerogams (i.e. *Posidonia oceanica, Cymodocea nodosa, Zostera noltii, Zostera marina, Rupia maritima, Halophila stipulacea*), coralligenous and mäerl formations and Marine Protected Areas all across the Mediterranean basin, searching through reports, grey literature and maps with or without geo-referenced information. The availability of this information in GIS compatible format and/or good resolution shapefiles (.shp) was not always an easy task and proved to be more time consuming than initially foreseen. A large part of the available information was not digitilized, there was high heterogeneity in the restitution scale of maps (from 1:4.000 to 1:250.000) and the legends, and in addition different geographical projection were used depending on the country and region. Concerning the revision of information in areas where partners were not directly active, considerable input was provided by non partners in terms of good collaboration and scientific ethics that promoted greatly the objectives of MEDISEH. As a result we obtained a largely improved picture of the distribution of phanerogams throughout the Mediterranean compared to the previously available one, a sharp increase in our knowledge concerning the distribution of coralligenous and mäerl formations with pronounced improvement of the available knowledge in the Eastern Mediterranean Sea. Details are given in each respective section of the report and the respective maps can be visualized in the online GIS viewer.

Considerable work was done underTask 1.3 for the habitat modeling of *Posidonia*, coralligenous and mäerl beds, based on environmental variables. The implementation of this Task was largely based on an exchange of expertise between participants involved in modelling and participants with expertise in the biology of the species modelled. Methods potentially suitable for habitat modelling were presented and discussed during the second project meeting and modelling outputs were continuously evaluated from then on by the respective experts. In the end, the Random Forest Modelling Approach was followed for Posidonia (as presence and absence data were available) whilst Maximum Entropy was applied to coralligenous and mäerl (as only presence data were available). Details are presented in the corresponding section of this report, and model output is available in the GIS online toolbox. Difficulties encountered concerned mainly the fact that the Posidonia datasets in most of the eastern Mediterranean was based on experts' personal knowledge, not on published information or scientific surveys. Moreover, the fact that coralligenous and mäerl referred to communities instead of single species, along with the lack of true absence information for this group created additional difficulties in the construction of habitat models.

An extensive work was done concerning any form of protection/management across the Mediterranean i.e. the Marine Protected Areas, the Fishing Restricted Areas (FRAs: Fishery Closure Area or Fisheries Restricted Area defined as a fishery closed or restricted by a government entity or a regional authority. A Fisheries Restricted Area is an area closed to fishing permanently, temporary or seasonally and this closure may apply to one or more gears. (http://www.protectplanetocean.org/introduction/introbox/glossary/glossary/introduction-item.html#mpa), the SPAMIs and the Proposed Marine Protected Areas in order to cover the entire Mediterranean basin with up to date information and provide this information into a GIS compatible format. Specifically, Information on existing MPAs (part of the NATURA 2000 Network, parks, reserves, other designated types etc.) was identified at GSA level. Information on proposed MPAs and SPAMIs (Specially Protected Areas of Mediterranean Importance under the SPA/BD Protocol of Barcelona Convention) was collated along with their current status and potential implementation. Most important, information on habitat areas subjected to particular protective fishing measures in the Mediterranean (FRAs). Information on the FRAs and the fishing restrictions applied, was not was not easy to organize mainly due to the large number of gears applicable in many cases. In the end we have retrieved over 400 FRAs (+ GIS shapefiles) across the Mediterranean where some sort of spatial (12 months per year) or temporal (>2 months per year) prohibition is applied for 4 major gears categories: all gears, bottom trawls, purse seines and small scale fishery. Information collected was revised in comparison with the recent update of shapefiles for MPAs, SPAMIs, Marine Parks and Marine and Nature Reserves and any other MPA type in the respective databases at http://www.protectedplanet.net/ , http://www.medpan.org/ and www.mapamed.org in order to deliver the best and most updated information to the Commission. Moreover, collected information on proposed MPAs & FRAs from various organizations was revised and updated in terms of newly available shapefiles.

Concerning WP2 and the revision of the information on the spawning and nursery grounds of demersal and small pelagic fish, this work was completed according to the proposed schedule for the entire Mediterranean Sea. Existing gaps in knowledge mainly concern information from North African areas. Moreover, available past and recent survey data suitable for modeling and the identification of nursery and spawning areas have been retrieved and used in the report. In addition, considerable effort was put to standardise the analysis of available data and the modeling approach. Scripts in R statistical interface were specifically developed for this purpose. One issue raised in particular was the identification of suitable density thresholds to identify the high concentrations of juveniles and spawners.

In the case of small pelagic fish (i.e. *Engraulis encrasicolus, Sardina pilchardus*, *Scomber colias, Scomber scombrus, Trachurus trachurus, Trachurus mediterraneus)* where suitable surveys were available only in certain areas thus in order to get information for the whole Mediterranean we applied habitat suitability modeling based on environmental information using pooled data from different areas and years and three different type of surveys depending on the species (i.e., acoustics, pelagic hauls, demersal trawls). A workshop was devoted during the second project meeting to present the different modeling approaches and discuss them in terms of data availability and data characteristics. Moreover, initial modeling results were presented and evaluated during the 3rd meeting of MEDISEH and subsequent changes were applied in the framework of data analysis. Depending on data availability two different modeling approaches were followed: Generalized

Additive Models and Maximum Entropy Models. All models were evaluated with areas not included in model construction. Based on the selected models annual probability maps were constructed along with mean probability and standard deviation maps for the whole Mediterranean basin. In a subsequent step, habitat allocation maps (i.e. persistent, occasional and rare habitat) were made for the whole Mediterranean basin. For certain species like *Trachurus spp., Scomber ssp*. where revised information showed almost complete lack of knowledge for both nurseries and spawning grounds we used available MEDITS information and acoustic surveys and we largely improved our knowledge. For *Scomber colias*, *Scomber scombrus*, available information covered limited areas and thus models constructed were evaluated as a very good source of initial information for these species but of course data from more areas are needed to make more robust estimations. Since the catchability of each survey type largely differentiates when it comes to small pelagics, cautious was given in data analysis (e.g. density thresholds, estimation of length at first maturity) and the modeling approach followed in order to obtain biologically meaningful results.

For the demersal target species (i.e. ***Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris, Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa)*** MEDITS bottom trawl survey data /species/ life stage were used to identify length at first maturity (depending on the species spawning period) and obtain No/km^2 per recruits/spawners. Spatial analysis techniques were applied per species/GSA/life stage and different modeling approaches were applied per GSA depending on data peculiarities e.g. GAMs, GAMMs, CoziGams, ZiGams, geostastics in order to obtain annual density/ probability maps. Density hot spot areas were identified per GSA and subsequently persistent maps based on the probability of each point being a hot spot. Difficulties encountered involved mainly the problem that MEDITS bottom trawl survey is not designed to cover the distribution of all target species: especially the nurseries can be very coastal and thus not well covered by the survey; MEDITS take place during the summer period only, thus there is an issue matching between spawning season and survey period; often available data were not adequate or consistent within the sampling period to apply models and bottom type, a variable that is very well associated to demersal species, is available at a very coarse spatial resolution for the Mediterranean.

Final results were presented in the project's final meeting. Details on the progress achieved and the deliverables obtained according to the project objectives are given in the respective section of this report. Maps are presented in the online GIS viewer.

Finally, a key part of the project's objectives concerns data availability in GIS compatible format, and their presentation in a web-based GIS viewer that aims to facilitate the provision of information to the Commission and the visualization of areas that are important sensitive habitats and might require protection measures. A workshop on GIS requirements was held during the kick-off meeting of the project in order to standardise the revised data input and agree on a common protocol. Moreover, available GIS databases were presented concerning environmental satellite data, bathymetry data, distance from large cities, rivers etc. Details are given in the respective session of the report.

Thus a web-based GIS viewer was developed (available online at http://mareaproject.net/mediseh/viewer/med.html), including maps and metadata of the revised information collected by the different tasks. All GIS files are also available in the respective folder of MEDISEH in the MAREA web server. The viewer has been developed and highly customized to the requirements of the project in a 'standalone' approach, where no dedicated server side is required to view shapefiles and geo-referenced images of raster datasets. Details are given in the respective section of this report.

Moreover, we considered that the MEDISEH project provided an unprecedented opportunity for filling an important gap of knowledge: providing a quantitative assessment of the distribution of vulnerable habitats such as *Posidonia* meadows, coralligenous and mäerl across the

Mediterranean Sea. An important outcome would be to identify priority sites for conservation/management in the Mediterranean Sea through a systematic conservation planning approach that takes into account and analyses quantitative data on the distribution of priority habitats, existing threats and existing conservation initiatives. For this purpose we applied MARXAN which is a software for spatial optimization with an algorithm that relies on the static distributions of biodiversity features, like species distribution, habitats and landscape types to identify, prioritize and select candidate sites for conservation/management. This was done in addition to project agreed deliverables. We decided on the conservation targets in accordance to the EU Habitats Directive (92/43/EEC), the Marine Strategy Framework Directive (2008/56/EC), the Convention on Biological Diversity (http://www.cbd.int/convention/) and the commitments undertaken at the World Summit on Sustainable Development in the Convention on Biological Diversity, approved by Council Decision 93/626/EEC. Following this legislation and taking into consideration the ecological value of each habitat type, we decided to apply the target of 60% conservation of coralligenous and Posidonia formations across the basin. Results show that, at present, only the 4% of *Posidonia* and the 8% of coralligenous are presently protected within the already established MPA's. The best solution suggested considering the current MPAs and meets the predefined conservation targets, shows a scenario that protects the 6,3% of the basin. Results from Marxan show that areas such as Tuscany, Apulia, portions of Tunisia and Greece are most frequently selected to reach conservation targets.

In order to facilitate the reader and reduce the size of the report two kinds of Annexes were included in the final reporting. A series of general Annexes that refer to a short description of the scripts for spatial analysis produced within MEDISEH along with meetings agendas and an Annex including explanations on the abbreviations used within this report. In addition Annexes related to specific Tasks milestones and deliverables that could not be incorporated in the report but were submitted as separate files in the MAREA ftp server (http://mareaproject.net/mediseh/viewer/med.html).

Acknowledgements

The Consortium involved in MEDISEH and scientists working in the different Work Packages would like to thank:

The Commission and the Joint Research Centre for the provision of the MEDITS database in order to use it to fulfil the deliverables of MEDISEH.

For data input concerning phanerogam distribution we would like to thank:

- Dr Tatjana Bakran-Petricioli from the University of Zagreb (Croatia)
- Dr Sami Ben Haj from Thethis Bizerte (*Tunisia)*
- Dr Enrico Cecchi from ARPAT (Tuscany, Italy)
- Dr. Fabrizio Serena from ARPAT (Tuscany, Italy)
- Dr Stefano Coppo from Regione Liguria (Italy)
- Dr Gianni Diviacco from Regione Liguria (Italy)
- Dr Annalisa Falace from the University of Trieste (Italy)
- Dr Gérard Pergent and Dr Christina Pergent-Martini from the University of Corsica (Corte), Faculty of Sciences , Equipe Ecosystèmes Littoraux- EQUEL (France)
- The Institute for the Nature Conservation –INCA (Albania)
- Dr Francesco Bitetto from the Centre d'Estudis Avançats de Blanes (CEAB – CSIC, Spain)

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- C. Venier (Italy)
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- S. Rizzardi (Italy)
- L. Faresi (Italy)
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- B. Ozturk (Turkey)
- J. Ben Souissi (Tunis)
- I. Benamr (Libya)
- M. Aplikioti (Cyprus).

For their input concerning the information of Marine Protected Areas we would like to thank:

- Dr Bruno Meola from the Network of Managers of Marine Protected Areas in the Mediterranean (MedPAN.org)
- Dr Marie Romani from the Network of Managers of Marine Protected Areas in the Mediterranean (MedPAN.org)
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- Dr Charis Charilaou from DFMR MOA GOV (Cyprus)
- Prof. Menachem Goren from University of Tel Aviv, Dept Zoology

WP1. Protected habitats

Task 1.1 Seagrass beds distribution along the Mediterranean coasts

(Scientific Responsible: A. Belluscio (CIBM), Partners involved: HCMR, CNR-IAMC, CNR-ISMAR, CIBM , COISPA, CoNISMa, FCD - MSDEC)

Cited as: Belluscio A, Panayiotidis P, Gristina M., Knittweis L., Pace M.L.,Telesca L, Criscoli A, Apostolaki ET, Gerakaris V., S. Fraschetti, M. T. Spedicato, G. Lembo, M. Salomidi,R. Mifsud, G. Fabi, F. Badalamenti, G. Garofalo A. Alagna, Ardizzone G.D., Martin C., V. Valavanis 2013. Seagrass beds distribution along the Mediterranean coasts. Mediterranean Sensitive Habitats **(***MEDISEH) Final Report, DG MARE Specific Contract SI2.600741.*

Background

In the Mediterranean, “seagrass” is a collective terms for the species *Posidonia oceanica*, *Cymodocea nodosa*, *Zostera marina* and *Zostera noltii.* Other seagrasses species in the Mediterranean are *Ruppia cirrhosa* and *Ruppia maritima,* and *Halophila stipulacea.*

Main characteristics of these species are listed below:

Species	Distribution on European coasts	Description of the meadow	Approximate maximum depth
Zostera noltii	Atlantic, Mediterranean and Black Sea	Loose meadows, 20-25 cm high, thin leaves, 1-2 mm wide	Up to 10 m
Zostera marina	Atlantic (except Canary Islands) and Mediterranean	Meadows are 30-60 cm in height, reaching up to 1 m or over, with ribbon-like leaves, 10-12 mm wide	Up to 10 m
Cymodocea nodosa	Atlantic and Mediterranean	Loose meadows, 30-40 cm high, thin leaves, 2-4 mm wide	Up to 30 m
Posidonia oceanica	Mediterranean	Meadows are 40-60 cm in height, reaching up to 1 m over, with thick, ribbon-like leaves, 5-12 mm wide	Up to 30-40 m or over if there is enough sunlight

Posidonia oceanica is the only species that makes meadows, similar to the forest habitat for the terrestrial environment. *Posidonia oceanica* meadows are the most diverse, complex and productive *stratocenosis* existing along the coastline of the Mediterranean Sea (Buia et al., 2003). The phenomena of regression and fragmentation of habitat to which they are subjected, affects the composition of benthic (Turner et al., 1999), epiphytic (Hovel et al., 2004) and fish (Vega Fernandez et al., 2005) communities who live there. Other seagrasses species also occur along the Mediterranean coasts and present seasonal variability, associated to environmental variables and other local factors. The cartography of these species (*Cymodocea nodosa* in particular) often is a “secondary task”, following the cartography of *Posidonia* beds. Nevertheless, these other seagrasses often comprise an important step in the ecological succession prior or following *Posidonia* beds. Other seagrasses in the Mediterranean Sea (i.e. *Zostera noltii, Z. marina*) present a very coastal distribution, often dominating coastal lagoons. Recently the distribution of *Halophila stipulacea*, a warm waters seagrass is expanding in the eastern Mediterranean coasts since its introduction from the Red Sea (Short et al., 2001).

Regulation EC 1967/2006 defines that all destructive fishing practices should be banned upon this vulnerable habitat, named as "seagrass beds i.e. areas where the seabed is characterized by the dominant presence of phanerogams, or where such vegetation has existed and is in need of restoration action".

Objectives

The main objectives of this Task are:

- The revision of historical and current data on the locations and the status of seagrasses beds in different GSAs all over the Mediterranean basin.
- The transformation of available information into a digitilized format within a geodatabase.
- Integration of the aforementioned information within a web-based GIS vieweralong with an associated geo-referenced database. This aims to operate as a consulting tool for spatial management and conservation planning.
- Following the revision of the knowledge base identify gaps and suggest future research priorities.

In order to meet these objectives within the framework of MEDISEH an expert team was composed within the MAREA Consortium from scientists with long term expertise on seagrass beds, habitat modeling, spatial statistics, GIS expertise, working in different areas in the Mediterranean basin. Moreover, a large number of scientists outside the MAREA Consortium collaborated on a volunteer basis with data and input. Details on the list of experts and external collaborators one can see below in Tables 1.1.1 and 1.1.2. For CV details check the MAREA expert web site *http://www.mareaproject.net/*.

Table 1.1.1. List of experts involved in WP1, Task 1.1

Participant	Participant affiliation
A. Belluscio	CIBM
P. Panayotidis	HCMR
E. Apostolaki	HCMR
M. Gristina	CNR-IAMC
L. Telesca	CIBM
L. Criscoli	CIBM
M. T. Spedicato	COISPA
G. Lembo	COISPA
V. Gerakaris	HCMR
M. Salomidi	HCMR

Participant	Participant affiliation
L. Knittweis	FCD - MSDEC, Malta
G. Fabi	CNR ISMAR
G. Garofalo	CNR-IAMC
A. Alagna	CNR-IAMC
F. Badalamenti	CNR-IAMC
S. Fraschetti	CoNISMa
G.D. Ardizzone	CIBM
C. Martin	HCMR/ Current affiliation: UNEP-WCMC (Cambridge, UK)
M. L. Pace	FCD - MSDEC, Malta
R. Mifsud	FCD - MSDEC, Malta
V. Valavanis	HCMR, Input from WP3

Table 1.1.2. List of external collaborators involved in WP1, Task 1.1

Collaborator	Collaborator affiliation
Tatjana Bakran-Petricioli	University of Zagreb: *Croatia*
Marie Louise Pace	Ministry for Resources and Rural Affairs (FCD (MSDEC)): *Malta*
Sami Ben Haj	Thethis Bizerte: *Tunisia*
Enrico Cecchi	ARPAT: *Tuscany (Italy)*
Stefano Coppo	Regione Liguria: *Liguria (Italy)*
Gianni Diviacco	Regione Liguria: *Liguria (Italy)*
Annalisa Falace	University of Trieste: *north Adriatic Sea (Italy)*
Gérard Pergent, Christine Pergent-Martini	University of Corsica (Corte), Faculty of Sciences, Equipe Ecosystèmes Littoraux- EQUEL *(France)*
INCA	Institute for the Nature Conservation in Albania: *(Albania)*
Francesco Bitetto	Centre d'Estudis Avançats de Blanes (CEAB - CSIC) (*Spain)*

Moreover, for organisation purposes, responsibilities for seagrasses data collection were allocated per partner and area, based on the scheme below (Fig. 1.1.1):

Greece, S. Turkey, Egypt: HMCR (E. Apostolaki) for GSAs: 20, 22, 23 24, 26.

Libya (GSA: 21), **Syria, Lebanon, Israel** (GSA 27), **Cyprus** (GSA 25) + **Greek Natura sites**: HMCR (P. Panayotidis).

Middle/South Western Mediterranean: CNR-IAMC (M. Gristina) for GSAs: 15 (**Malta**), 16 (**Sicily**), 12, 13, 14 (**Tunisia/Algeria**), 2, 3, 4, (**Algeria, Morocco**), 21 (**Lybia**).

Western Mediterranean: CNR-IAMC (M. Gristina) for GSAs: 1, 5, 6 (**Spain**).

North Western Mediterranean: CIBM (A. Belluscio) for GSAs: 7, 8, 9 (**France, NW Italy**).

Adriatic Sea: CNR-ISMAR (G. Fabi) for GSA: 17 (north **Adriatic**).

Ionian Sea: CONISMA (S. Fraschetti) for GSAs: 18, 19 (**Ionian**).

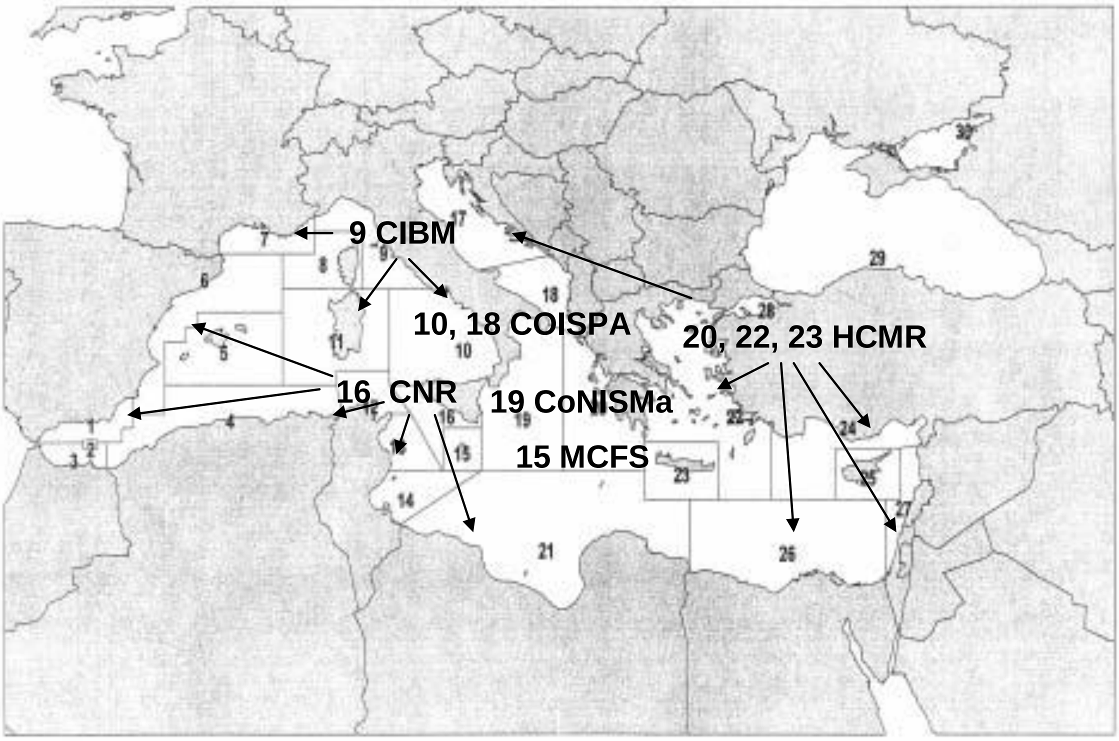


Fig. 1.1.1. Responsibilities for data collection per partner and GSA. Following the kick-off meeting of the project the responsibility for GSA 15 was moved from FCD - MSDEC (MCFS on the map)) to CNR-IAMC.

Deliverables and Milestones foreseen by the Project

The following table describes the task deliverables and milestones as foreseen by the proposal: the state of the art of each deliverable is reported.

Table 1.1.3. The state of art for the milestones and deliverables foreseen by the proposal

Deliverable	Description	% of foreseen results
M1.1.1	Revision of existing information of past seagrass beds along the Mediterranean coast	100%
M1.1.2	Revision of existing information of current seagrass beds along the Mediterranean coast	100%
M1.1.3	Production of GIS files indicating the position of past and current seagrass beds along the Mediterranean coast	100%
D1.1.1	Geo-referenced database covering all revised information on seagrass beds spatial distribution	100%
D.1.1.2	Integrated maps presenting the known spatial distribution of *Posidonia* and other seagrass species across the Mediterranean	100%
D.1.1.3	GIS compatible file for input to WP3	100%

Progress achieved

Within the framework of Task 1.1 and according to MEDISEH proposal four meetings were held within the framework of the project. Specifically:

A one day workshop took place following the kick-off meeting of the project that was held in Heraklion **(Crete) in October 2011**, in order to homogenize the work among the partners involved and standardise the input data format in order to be suitable for modeling. In addition an introduction on the modeling techniques that could be applied was made. Participants were: Eugenia Apostolaki, Vasilis Gerakaris, Vessa Markantonatou, Maria Salomidi, Nadia Papadopoulou, Chris Smith and Vasilis Valavanis (Greece), Leyla Knittweis (Malta), Gianna Fabi, Fabio Grati, Michele Gristina, Simonetta Fraschetti (Italy) and the task coordinator Andrea Belluscio (Italy).

Two days workshop was held within the second meeting of the MEDISEH in **Palermo (Italy) in February 2012**. The aim of this workshop was to define environmental and/or anthropogenic variables to be tested for habitat modeling, depending on data availability. The first session on Monday 6th February involved presentations by A. Belluscio (General introduction plus data on the W Mediterranean) (GSA 7, 8, 9, 10, 11, 17, 18), M. Gristina on the southern part of Mediterranean (GSA 1, 2, 3, 4, 5, 6, 12, 13, 14, 15, 21) and P. Panayotidis for Greece and eastern Mediterranean Sea (GSA 20,21,22,23,24,25,26,27,28). The general discussion for Task1.1 and Task1.2 mainly addressed the difficulties encountered. On Tuesday 7th and

Wednesday 8th February (Workshop) the discussion focused on problems related to habitat modeling.

Three days workshop was held within the third meeting of the MEDISEH **in Rome (Italy) in September 2012**. The aim of the workshop was to have an overview of the updates from the second meeting. The first session on Wednesday 26th September involved presentation by Andrea Belluscio, which showed the additional data collected and the main problems encountered, and Michele Scardi (overview of the work done concerning *Posidonia* using the Random Forest approach and difficulties encountered). On Thursday 27th and Friday 28 th (Workshop) the discussion focused on a review and updating of the data collected and the model.

A final three days workshop was held in Heraklion **(Greece) in January 2013**. The aim of the workshop was to have an overview of the deliverables and to evaluate the data collected and the maps created. On Tuesday 8th Luca Telesca showed a presentation with the last updates and the final maps regarding seagrasses distribution, whereas Corin Martin presented the final outcome of the model on behalf of Michele Scardi. On Wednesday 9th and Thursday 10th January has been performed a revision of the overall data. Participants were: Luca Telesca, Alessandro Criscoli, Eugenia Apostolaki, Panayotis Panayotidis.

The interim reports and meetings agendas are reported in the MAREA FTP Site.

Moreover, details on the progress achieved towards the Task deliverables and milestones within the framework of the project are cited in the report.

Sources of data

The dataset of seagrasses distribution across the Mediterranean produced in the framework of MEDISEH derived from the compilation of published and unpublished information (Table 1.1.4). For example literature search was made using mainly the ISI Web of Knowledge engine, selecting the keywords: seagrass (*Posidonia oceanica, Cymodocea nodosa, Zostera marina, Z. noltii, Halophila stipulacea, Rupia maritima, R. cirrhosa)* AND (regression OR decline OR progression OR recovery OR status OR cartography OR limits OR cover OR density). At the same time a new search started from the “Bibliographic References” at the end of each paper. We amended the data set with our own unpublished data (grey literature). Moreover, we included data from reports of national and EU research projects and data networks. A major contribution to the improvement of our knowledge on seagrasses in the Mediterranean and especially Posidonia derived from the establishment of Natura 2000 network.

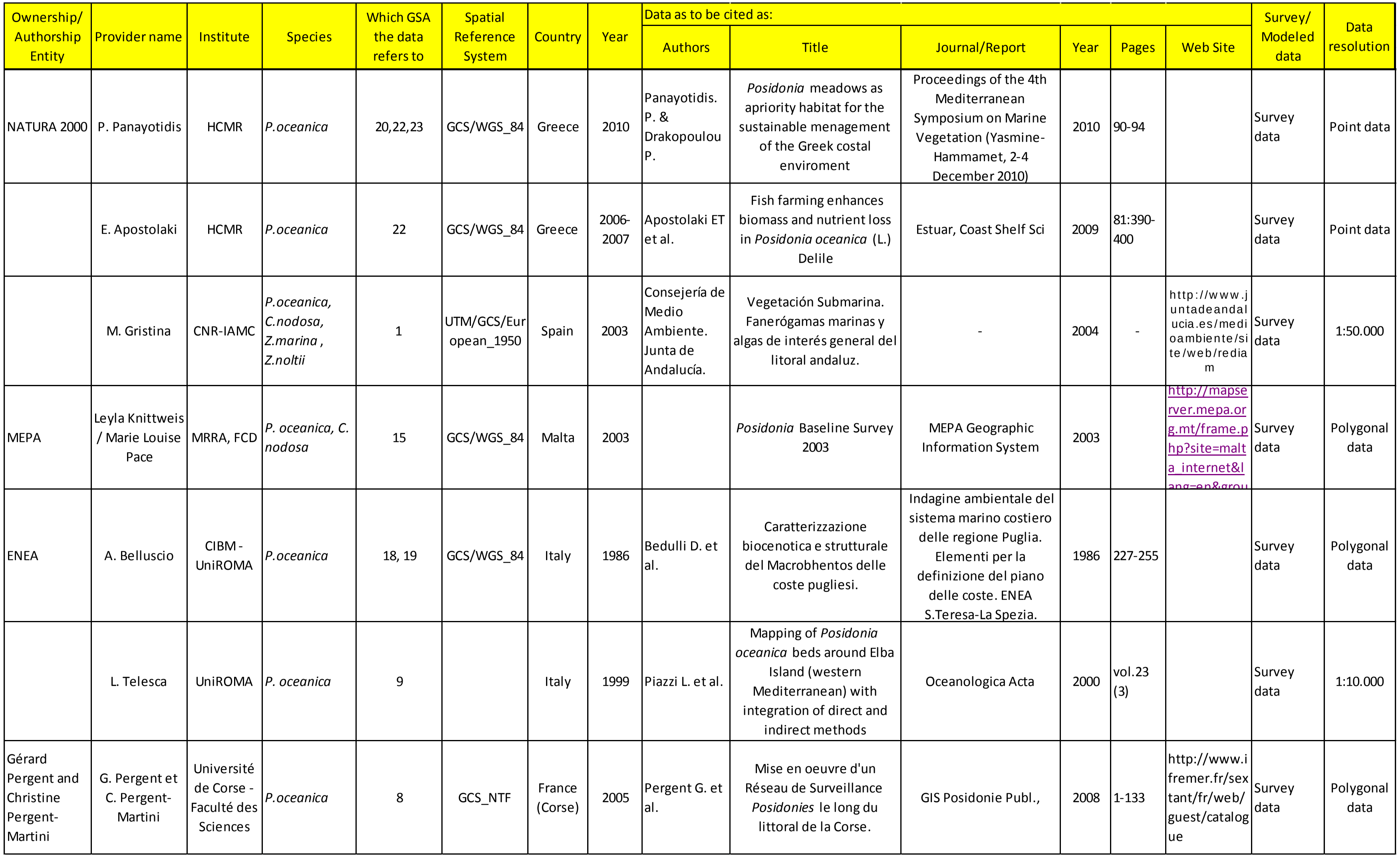
To date several habitat mapping efforts have been carried out by different research institutes and countries at different spatial and temporal resolutions. A census of the available maps of distribution of *Posidonia oceanica* beds has been carried out, and data are reported in a standard form (Excel file) (see the respective folder in Annex 1.1.1).

Table 1.1.4. Sources of data used for the dataset of seagrass distribution (data include only information on presence/distribution, status and regression but not general information on seagrass (chemical, physiology, etc.).

Type of data	Number
Published articles	142
Unpublished Datasets	10
Reports of EU projects	36
Reports of national projects	59
Data Networks	12

All the information on seagrasses at different localities are reported in the respective database for species, with geographical coordinates (when available), spatial reference system, year of publication, bibliographic references, scale of detail, methods of survey.

All data collected has been listed in bibliographic tables reported in Annex 1.1.1 In Fig.1.1.2 is shown an example of these bibliographic tables. Data collected from each country, were available in different format (Table 1.1.5). Most of collected data were only available on hard copy. This means that a lot of Posidonia (and other seagrasses) data distribution were in jpeg or .pdf format, or only, as description in a text. So, this kind of information had to be digitilized in order to associate it with a map and incorporate it in the GIS viewer. The final result was a shapefile with the exact position of seagrass, limits, extent, etc (Fig.1.1.3).



Ownership/ Authorship Entity	Provider name	Institute	Species	Which GSA the data refers to	Spatial Reference System	Country	Year	Data as to be cited as:						Survey/ Modeled data	Data resolution
								Authors	Title	Journal/Report	Year	Pages	Web Site		
NATURA 2000	P. Panayotidis	HCMR	*P.oceanica*	20,22,23	GCS/WGS_84	Greece	2010	Panayotidis. P. & Drakopoulou P.	*Posidonia* meadows as apriority habitat for the sustainable menagement of the Greek costal enviroment	Proceedings of the 4th Mediterranean Symposium on Marine Vegetation (Yasmine-Hammamet, 2-4 December 2010)	2010	90-94		Survey data	Point data
	E. Apostolaki	HCMR	*P.oceanica*	22	GCS/WGS_84	Greece	2006-2007	Apostolaki ET et al.	Fish farming enhances biomass and nutrient loss in *Posidonia oceanica* (L.) Delile	Estuar, Coast Shelf Sci	2009	81:390-400		Survey data	Point data
	M. Gristina	CNR-IAMC	*P.oceanica, C.nodosa, Z.marina , Z.noltii*	1	UTM/GCS/European_1950	Spain	2003	Consejería de Medio Ambiente. Junta de Andalucía.	Vegetación Submarina. Fanerógamas marinas y algas de interés general del litoral andaluz.	-	2004	-	http://www.juntadeandalucia.es/medioambiente/site/web/rediam	Survey data	1:50.000
MEPA	Leyla Knittweis / Marie Louise Pace	MRRA, FCD	*P. oceanica, C. nodosa*	15	GCS/WGS_84	Malta	2003		*Posidonia* Baseline Survey 2003	MEPA Geographic Information System	2003		http://mapserver.mepa.org.mt/frame.php?site=malta_internet&lang=en&grou	Survey data	Polygonal data
ENEA	A. Belluscio	CIBM - UniROMA	*P.oceanica*	18, 19	GCS/WGS_84	Italy	1986	Bedulli D. et al.	Caratterizzazione biocenotica e strutturale del Macrobhentos delle coste pugliesi.	Indagine ambientale del sistema marino costiero delle regione Puglia. Elementi per la definizione del piano delle coste. ENEA S.Teresa-La Spezia.	1986	227-255		Survey data	Polygonal data
	L. Telesca	UniROMA	*P. oceanica*	9		Italy	1999	Piazzi L. et al.	Mapping of *Posidonia oceanica* beds around Elba Island (western Mediterranean) with integration of direct and indirect methods	Oceanologica Acta	2000	vol.23 (3)		Survey data	1:10.000
Gérard Pergent and Christine Pergent-Martini	G. Pergent et C. Pergent-Martini	Université de Corse - Faculté des Sciences	*P.oceanica*	8	GCS_NTF	France (Corse)	2005	Pergent G. et al.	Mise en oeuvre d'un Réseau de Surveillance *Posidonies* le long du littoral de la Corse.	GIS Posidonie Publ.,	2008	1-133	http://www.ifremer.fr/sextant/fr/web/guest/catalogue	Survey data	Polygonal data

Fig. 1.1.2. Example of bibliographic table from Annex 1.1.1

Table 1.1.5. Type of data collected related to spatial distribution of *Posidonia oceanica* along the Mediterranean basin (Y: yes; N: no).

Country	**Type of data collected:**		
	Shapefile	**Point data**	**.pdf/.tiff**
Spain	Y	N	Y
France	Y	N	Y
Italy	Y	Y	Y
Slovenia	N	N	Y
Croatia	N	Y	Y
Montenegro	N	Y	Y
Albania	Y	N	Y
Malta	Y	N	N
Greece	Y	Y	N
Turkey	N	Y	Y
Cyprus	Y	Y	Y
Syria, Lebanon, Israel	Y	Y	N
Egypt	N	Y	N
Libya	N	Y	Y
Tunisia	Y	Y	Y
Algeria	N	Y	Y
Morocco	N	N	N

A list of the available shapefiles has been uploaded to the FTP server of MAREA (http://www.mareaproject.net/FTPMareaProject/) and accompanied by metadata excel files (http://mareaproject.net/FTPMareaProject/#16/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission /wp1/task 1.1/Annex 1.1.2/).

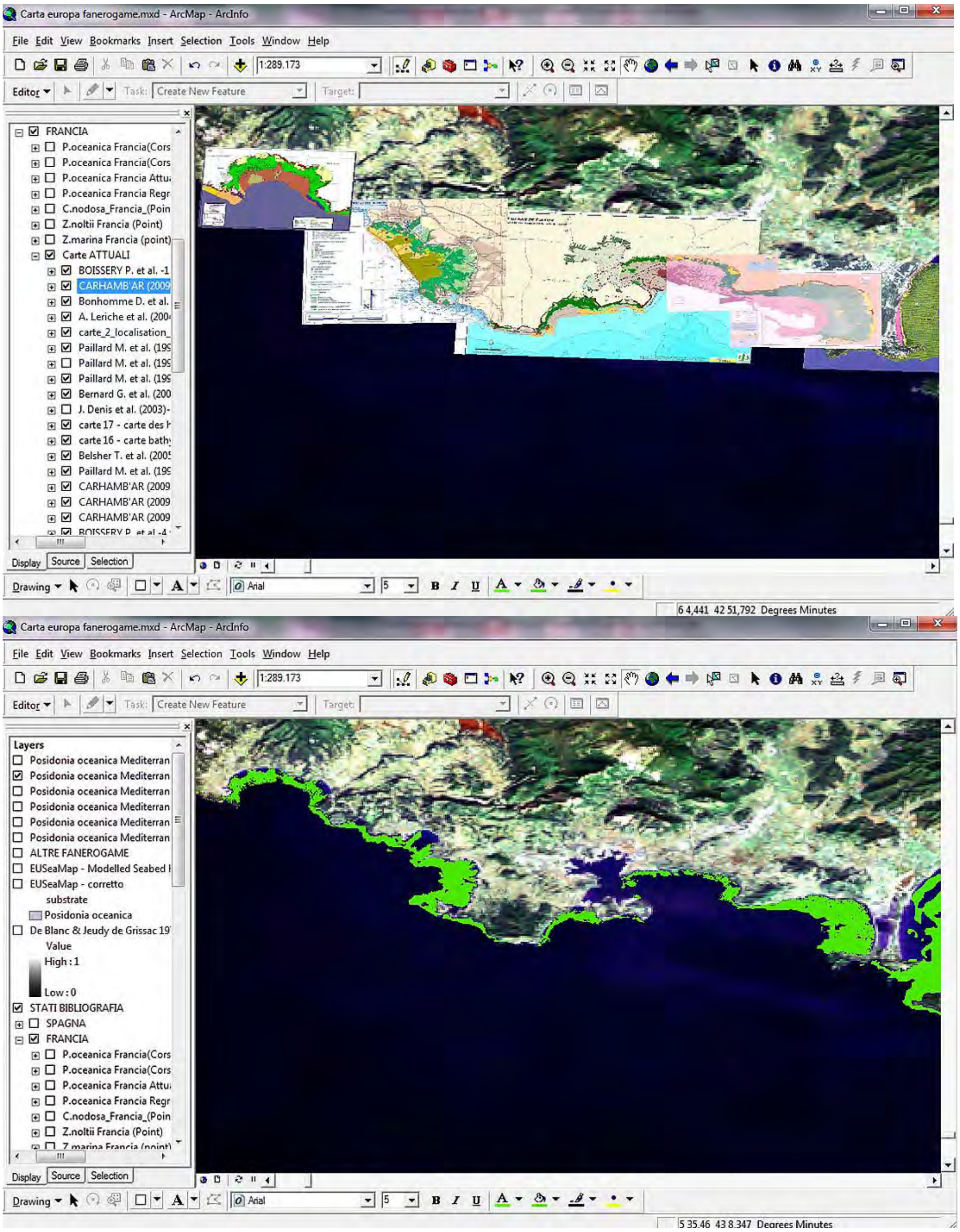


Fig. 1.1.3. An example of the work done: from different format of maps to a unique, georeferenced shapefile.

Revised information on current seagrass beds (M 1.1.1, D1.1.1)

The current distribution of *Posidonia oceanica* meadows in the Mediterranean Sea based on Task results is presented in this session. The information included in the interim report was updated with additional presence data with special focus in areas with known absence records of seagrass. Seagrass distribution maps have been completed and transformed into shapefiles for the whole Mediterranean. It should be noted that data are not equally represented across the Mediterranean, as research effort (published or not) differs between countries being less intense in the east and south part of the Mediterranean. Effort was made to cover gaps in knowledge requesting the contribution of experts from countries outside the consortium (e.g. France).

A synthesis on the data availability of seagrass spatial distribution is reported in Tables 1.1.6-1.1.7. All the available data have been added in the database and included in the MEDISEH web-based GIS viewer.

Table 1.1.6. Shapefile information types and data availability related to the spatial distribution of *Posidonia oceanica* along the Mediterranean basin (Y: yes; N: no).

Country	**Shapefile:**		**Known current distribution**	**Known historical distribution**
	Polygons	**Points**		
Spain	Y	N	100%	90%
France	Y	N	100%	80%
Italy	Y	Y	100%	27%
Slovenia	Y	N	100%	_
Croatia	Y	Y	14%	_
Montenegro	N	Y	100%	_
Albania	Y	N	100%	_
Malta	Y	N	100%	_
Greece	Y	Y	8%	_
Turkey	Y	Y	29%	6%
Cyprus	Y	Y	30%	_
Syria, Lebanon, Israel	N	Y	100%	_
Egypt	N	Y	63%	3%
Libya	Y	Y	11%	_
Tunisia	Y	Y	81%	13%
Algeria	Y	Y	16%	_
Morocco	N	N	100%	_

Table 1.1.7. Data availability related to the current spatial distribution of other seagrass species along the Mediterranean basin.

Country	***C. nodosa***	***Z. noltii***	***Z. marina***	***H. stipulacea***	***R. cirrhosa***	***R. maritima***
Italy	100%	20%	10%	100%	10%	10%
France	60%	100%	10%	0%	5%	5%
Spain	90%	30%	25%	0%	25%	20%
Greece	90%	5%	0%	100%	5%	5%
Turkey	5%	5%	0%	100%	0%	0%
Slovenia	100%	100%	100%	0%	0%	0%
Croatia	10%	5%	5%	0%	0%	0%
Montenegro	100%	100%	0%	0%	0%	0%
Albania	10%	0%	0%	100%	0%	0%
Morocco	0%	0%	0%	0%	0%	0%
Malta	100%	0%	0%	100%	0%	0%
Cyprus	50%	0%	0%	100%	0%	0%
Algeria	0%	0%	0%	0%	0%	0%
Tunisia	40%	10%	5%	100%	5%	5%
Libya	5%	5%	5%	100%	5%	0%
Egypt	30%	5%	5%	100%	10%	0%
Syria, Israel, Lebanon	30%	40%	0%	100%	0%	0%

During the last six months the upgrade of current information included also certain corrections to the data points from Greece as well as the addition of personal observations from the same area where limited cartographic data exist. This was considered necessary in order to improve and strength model output. Towards the same approach, we have added cartographic data from Tuscany (Italy) and historical data point along the Turkey and Tunisia coastline.

The overall dataset has been separated into historical and current data. The current data are further divided into presence, absence and no data. Details for each dataset are cited below.

Posidonia oceanica **meadows**

The current distribution of *P. oceanica* is shown in Fig. 1.1.4. This map represents "the state of art" of the actual knowledge and it is a significant improvement compared to the existing knowledge prior to the MEDISEH project. Figures 1.1.5a and 1.1.5b show the current distribution of *P. oceanica* separately for the Western and Eastern Mediterranean.

Posidonia is present along the most part of the Western Mediterranean coasts (Spain, France and Italy, Sardinia, Sicily and Corsica included), and in the Eastern basin (Tunisia, Croatia, Greece and Cyprus). Current knowledge shows that meadows are absent along the Morocco coastline and in certain areas of the eastern part of the Mediterranean basin (Syria, Lebanon, Israel, part of the Turkish and Egyptian coasts). Along the northern African coasts (i.e. Algeria, Libya, Egypt) and along the Turkish and Greek coastline in the Aegean Sea information on *Posidonia* is relatively scarce.

In the Central – Western Mediterranean Posidonia is present along most of the coasts, excluding the area closed to the main river mouths (i.e. Ebro, Guadalquivir, Rodano, Tevere, Arno, Po) and the western Adriatic Sea.

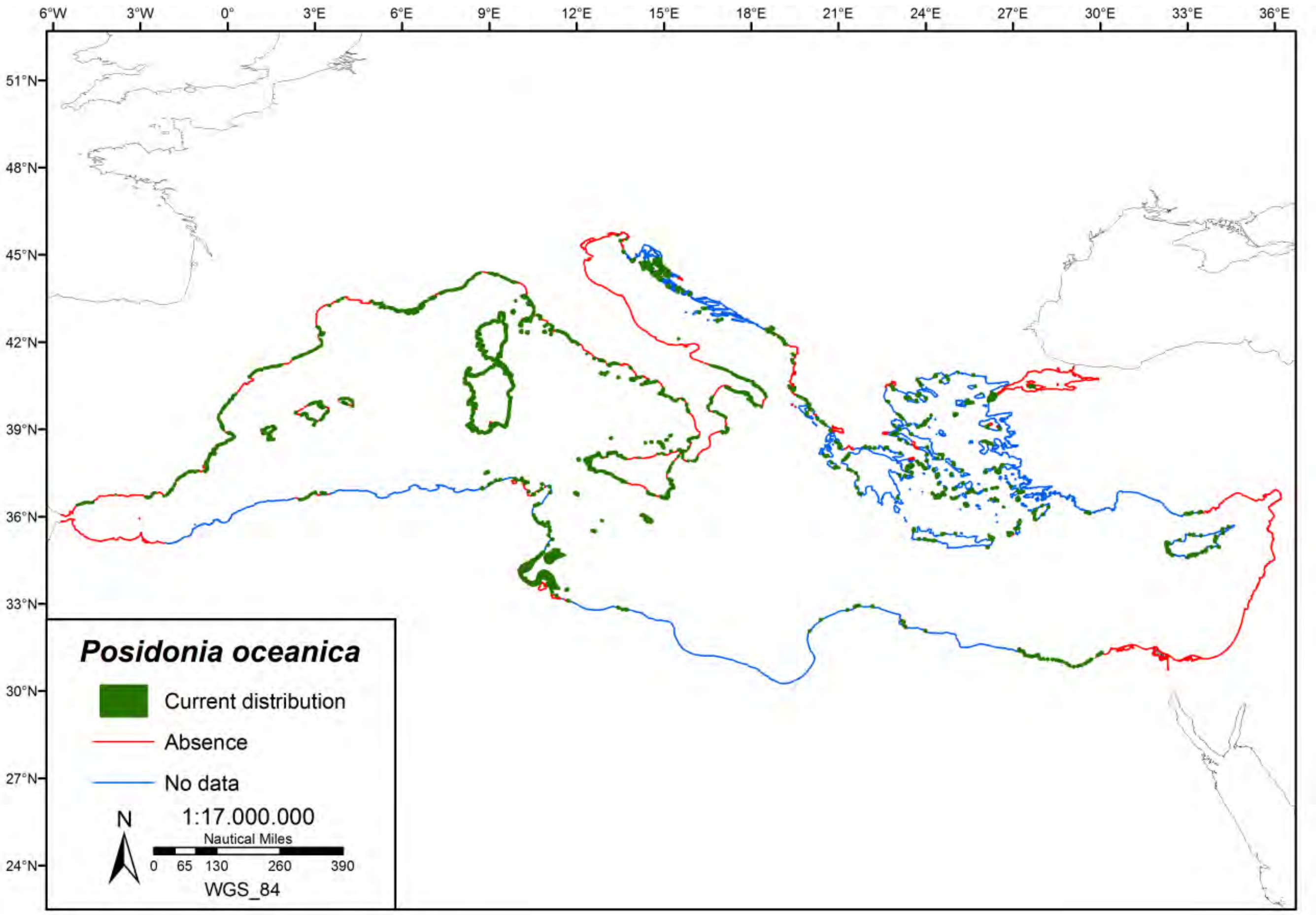


Fig. 1.1.4. Current distribution of *P. oceanica* across the Mediterranean Sea.

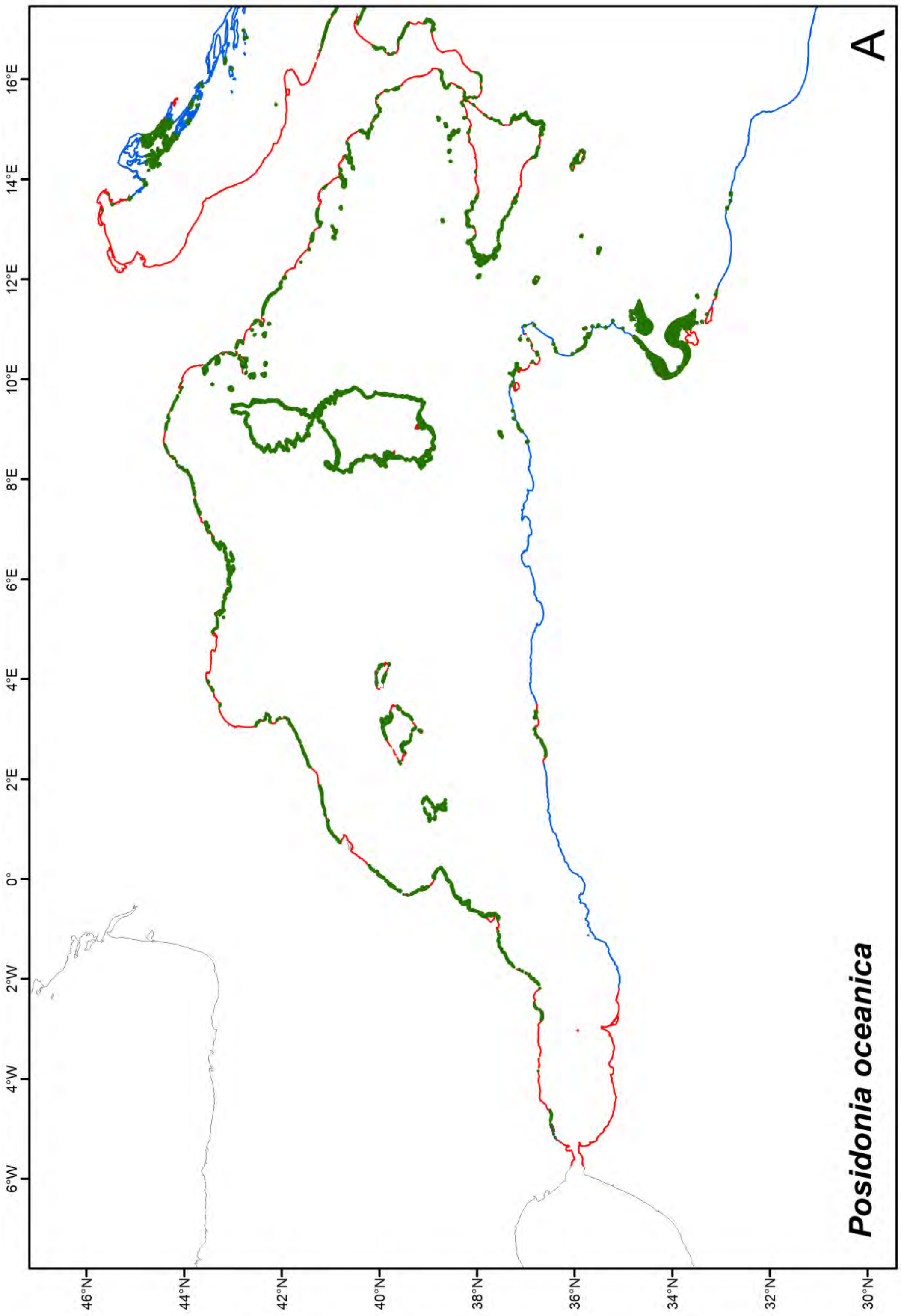


Fig. 1.1.5a. Current distribution of *P. oceanica* in the Western Mediterranean Sea (green: presence; red: absence; blue: no data).

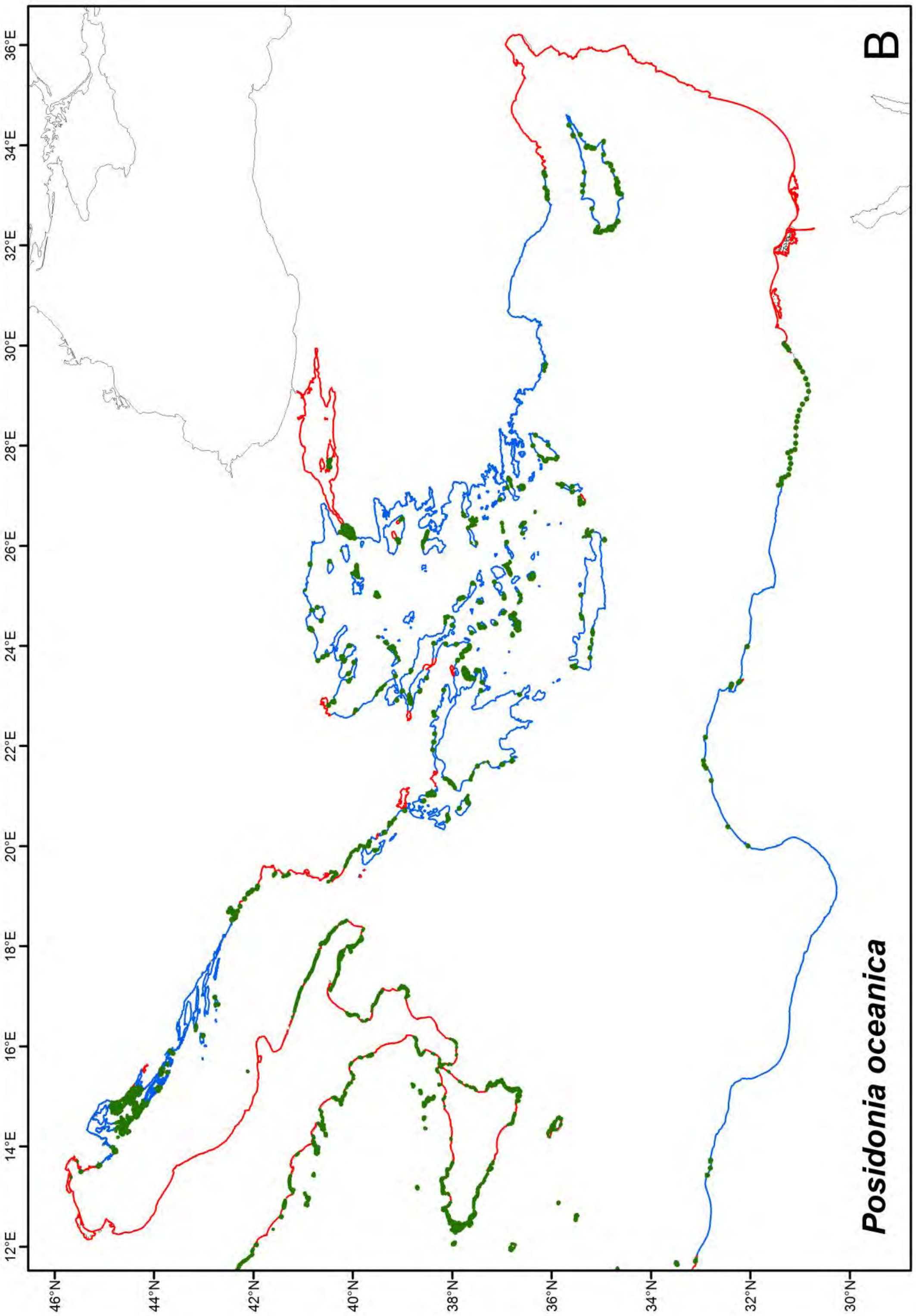


Fig. 1.1.5b. Current distribution of *P. oceanica* in the Eastern Mediterranean Sea (green: presence; red: absence; blue: no data).

In the Western Mediterranean there is a sharp difference between the European and African coasts. Along the southern part of the Spanish coasts *P. oceanica* is present although it exhibits a fragmented distribution, opposed to the Moroccan coastline where meadows are completely absent (Fig.1.1.6).

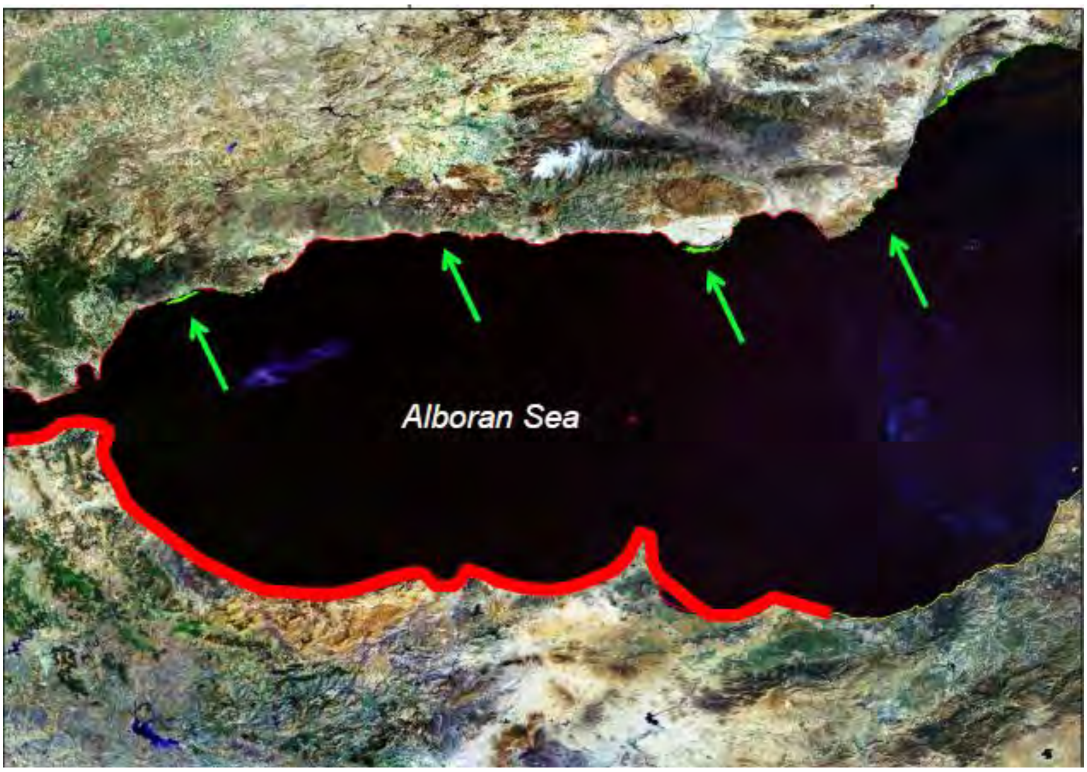


Fig.1.1.6. *P.oceanica* boundaries in the Western part of Mediterranean basin (*Alboran Sea*) (green arrow: *Posidonia* meadows presence).

In the Eastern Mediterranean *P. oceanica* spatial distribution is characterized by a gap in the distribution in the middle of the southern Turkish coastline and it is completely lacking (based on the current knowledge) from the coast of the Levantine countries (Fig.1.1.7).

Fig.1.1.7. *P. oceanica* boundaries in the Eastern part of Mediterranean basin.

More specifically at the eastern boundaries of Posidonia in the Mediterranean the following situation occurs:

- Meadows Northern limit is a sharp cut off limit along the Turkish coastline at 36°09'N, 33°26'E (Gucu and Gucu, 2002).
- Posidonia is completely absent along the Eastern part of Mediterranean Sea (i.e. Syria, Lebanon and Israel).
- The southern limit of Posidonia along the eastern part is associated to the Nile's delta influence at the Egyptian coastline.
- Exception stands for the Cyprus coasts where *Posidonia oceanica* is present.
- In Marmara Sea only few records of *Posidonia* presence are available. The meadows are known to occur along the coasts of Dardanelles Strait and central Marmara Sea's islands (Fig.1.1.8).

Fig. 1.1.8. *P.oceanica* distribution along the Marmara Sea coastline.

On total, known *P. oceanica* meadows cover 11.687 Km² (1.168.725 hectares) in the Mediterranean basin. Reliability for this estimate is subjected to experts' knowledge and judgment. "No data area" accounts for 18.682 Km of coasts whereas "No Posidonia area" accounts for 10.974 Km of coasts. The following pictures (Figs. 1.1.9 to 1.1.13) include high resolution maps showing details in *Posidonia oceanica* meadows for selected areas (e.g. for Spain, France, Italy, Greece and Malta) as exported from our database. More detailed maps or for additional areas can be seen in the online GIS viewer (http://mareaproject.net/mediseh/viewer/med.html).

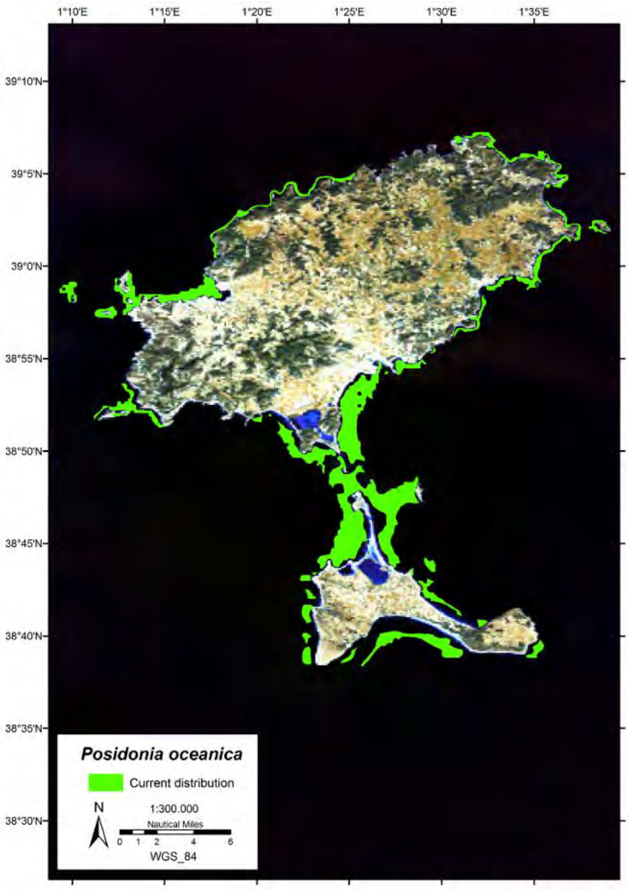


Fig.1.1.9. *Posidonia oceanica* current distribution at Ibiza and Formentera (*Spain*).

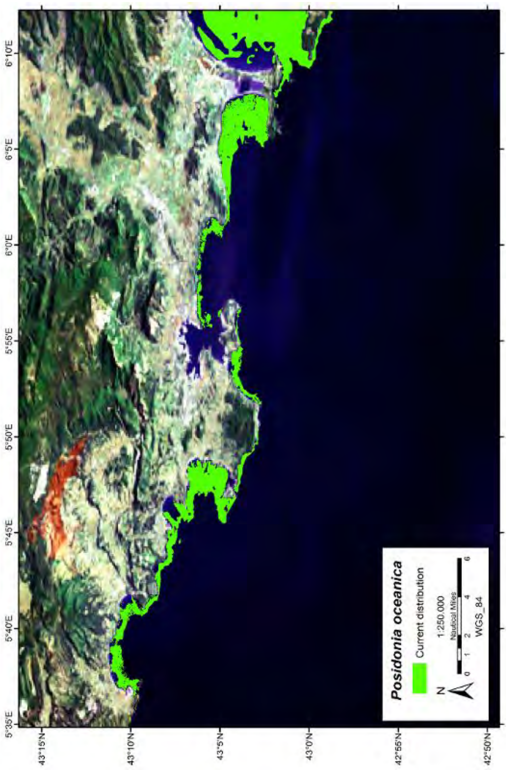


Fig.1.1.10. *Posidonia oceanica* current distribution between La Ciotat Bay and Gulf of Giens (*France*).

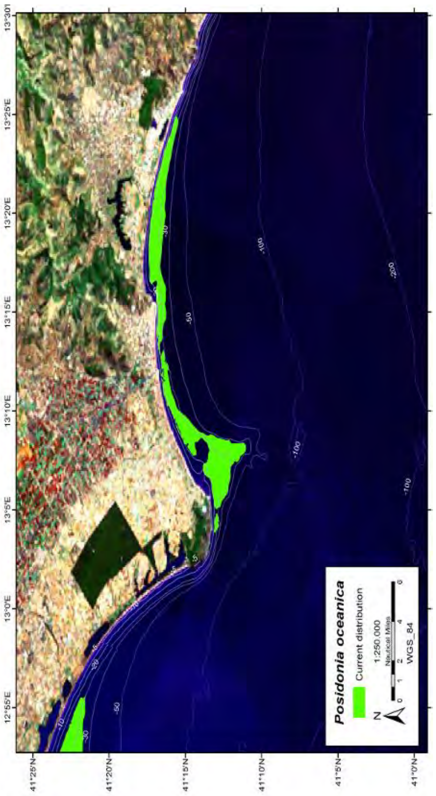


Fig.1.1.11. *Posidonia oceanica* current distribution between Circeo and Terracina (*Lazio region, Italy*).

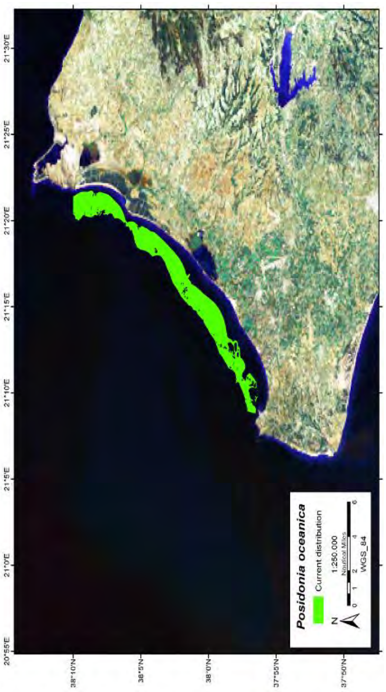


Fig. 1.1.12. *Posidonia oceanica* current distribution along the coast of the marine protected area of Killini (*Greece*).

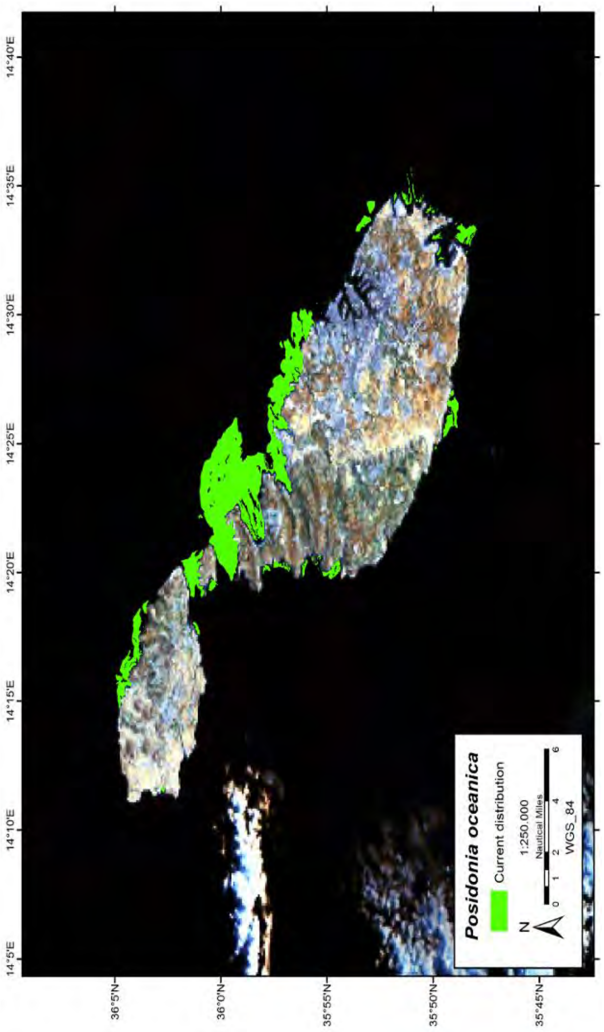


Fig.1.1.13. *Posidonia oceanica* current distribution from the coastline of Malta.

Other phanerogams

Mediterranean Sea, in addition to *P. oceanica,* hosts 6 more seagrasses species: *Cymodocea nodosa, Zostera marina, Z. noltii, Halophila stipulacea, Ruppia maritima* and *R. cirrhosa*. Although *P. oceanica* meadows represent the most significant and abundant ones, the other species are also important in terms of goods and services they provide. However, scientific research effort is not equally distributed between seagrasses species in the Mediterranean, where 72% of the published papers reported in Web of Science^{TM} (in December 2009) refers to *P. oceanica*. As a result, there is limited cartographic information regarding the other mediteranean seagrass species. Furthermore, most of these species do not form permanent meadows or beds like *P. oceanica*, so cartographic representation can easily end up with inaccurate or invalid information.

C. nodosa is a warm water species and is widely distributed throughout the Mediterranean, around the Canary Islands and down the North African coast in the Atlantic. The species does not extend further north than the southern coasts of Portugal. *C. nodosa* can be found from shallow subtidal areas to very deep waters (50-60 m).

The current distribution of *C. nodosa* is shown in Fig. 1.1.14. This map represents “the state of art” of the actual knowledge and it is a significant improvement compared to the existing knowledge prior to this project. Figures 1.1.15a and 1.1.15b show the data for Western and Eastern Mediterranean.

C. nodosa distribution covers most part of the Mediterranean basin, distributing along the coasts of Spain, France, Italy, Tunisia, Greece and Cyprus. Current knowledge on the spatial distribution of *C. nodosa* is very good concerning the Western European coasts. Along the Eastern Mediterranean and African coastline information about *Cymodocea is* relatively scarce (Figs. 1.1.14, 1.1.15a, 1.1.15b)

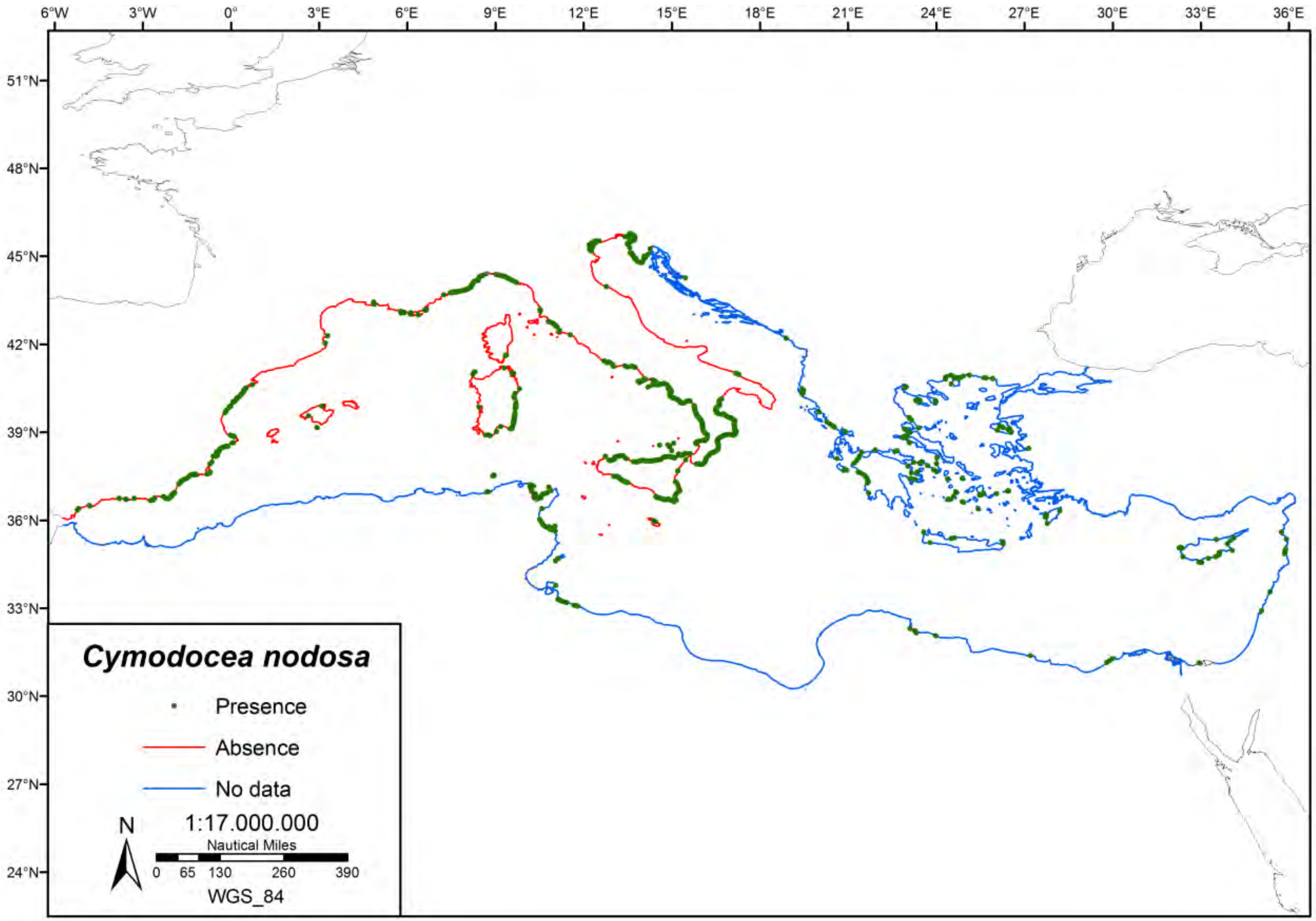


Fig. 1.1.14. Current distribution of *C. nodosa* across the Mediterranean Sea.

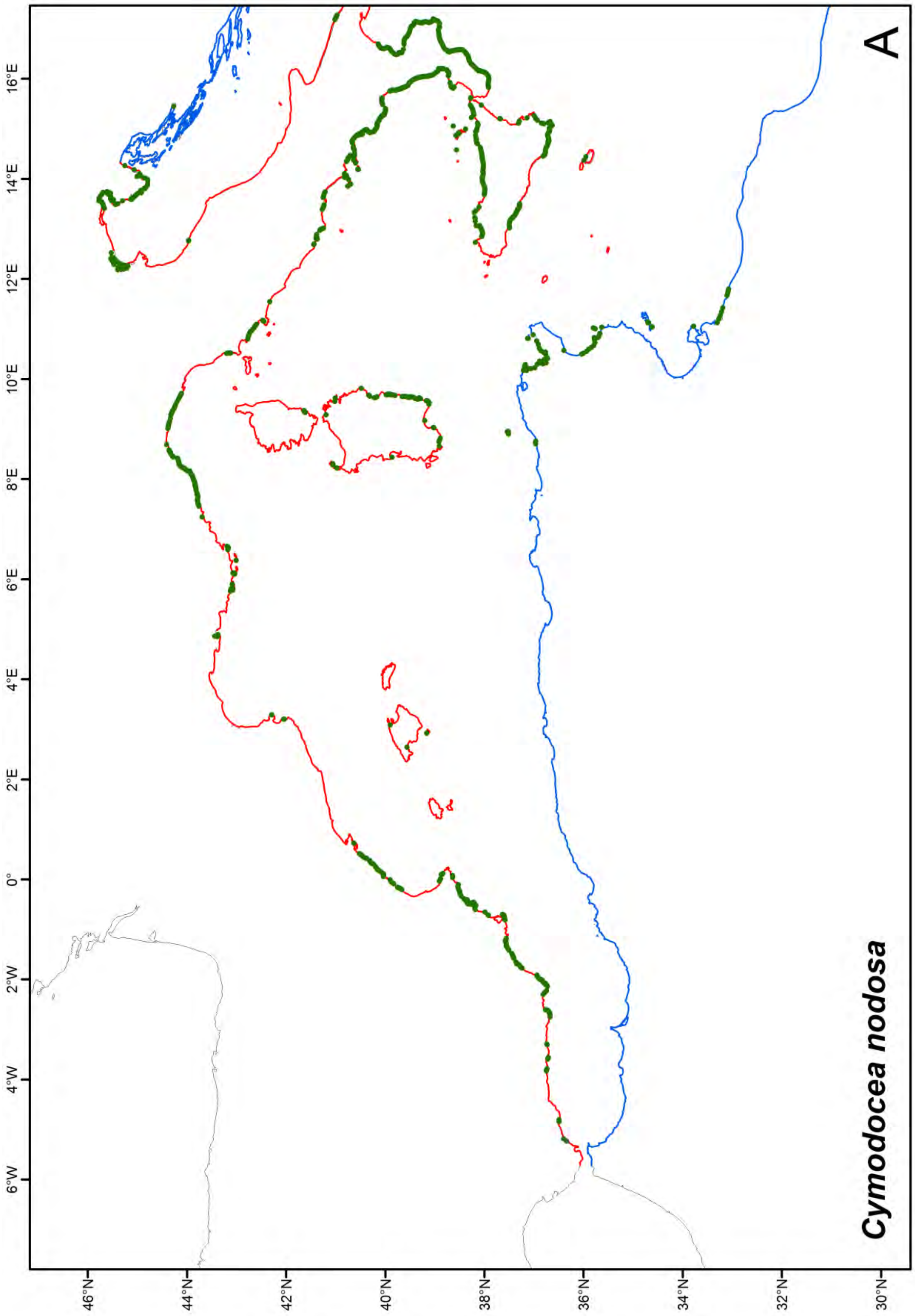


Fig. 1.1.15a. Current distribution of *C. nodosa* in the Western part of Mediterranean Sea (green: presence; red: absence; blue: no data).

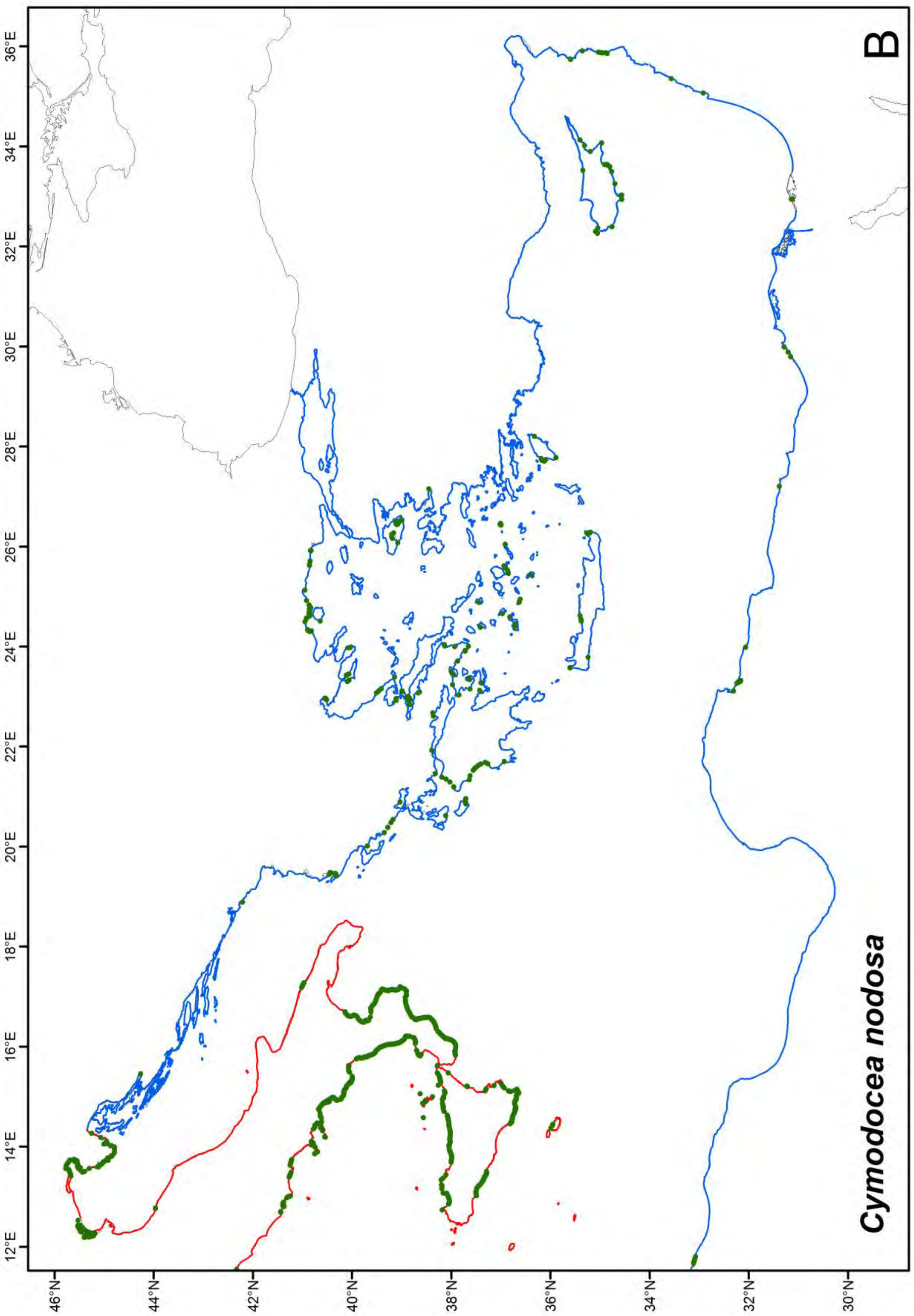


Fig. 1.1.15b. Current distribution of *C. nodosa* a) in the Eastern part of Mediterranean Sea (green: presence; red: absence; blue: no data).

Zostera spp. refers to two species: *Zostera marina* (eelgrass) and *Zostera noltii* (dwarf eelgrass). *Z. marina* in the Mediterranean is mostly found as small isolated stands, especially, in lagoons. They are predominantly subtidal species and may grow down to 10-15 meters depth depending on water clarity. *Z. noltii* forms dense beds in the muddy sand of intertidal areas, where *Z. marina* is sparse due to its lower tolerance to desiccation. *Z. noltii* also occurs subtidal but often seems to be outcompeted by other seagrasses where the water cover is permanent. Some authors separate *Z. marina* in two species, *Z. marina* and *Z. angustifolia*, but the distinction based on species characteristics is not clear.

Existing information on *Zostera* spp*.* seems to be limited to scattered records in Aegean Sea, the lagoon systems of the east part of Ionian Sea, the north and the south part of the Adriatic Sea, limited areas in the western part of Sicily, the Tyrrhenian Sea. Records have been identified along the Lebanese coast in the Levantine (Fig. 1.1.16). The current distribution of *Z. marina* is shown in Fig. 1.1.16., the map represents "the state of art" of the actual knowledge being a significant improvement compared to the existing knowledge prior to this project. Figures 1.1.17a and 1.1.17b show *Z. marina* distribution for the Western and Eastern Mediterranean.

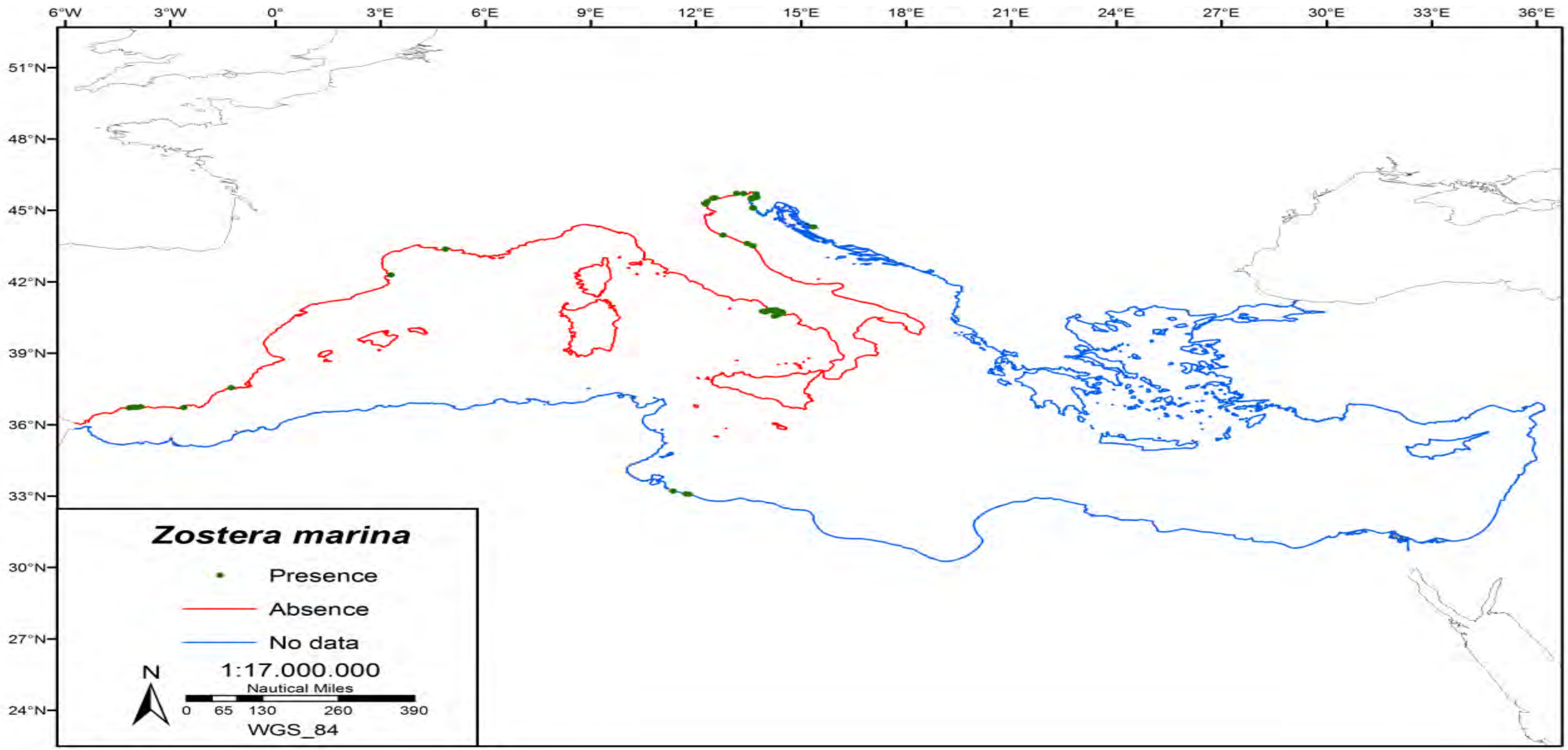


Fig. 1.1.16. Current distribution of *Z. marina* across the Mediterranean Sea.

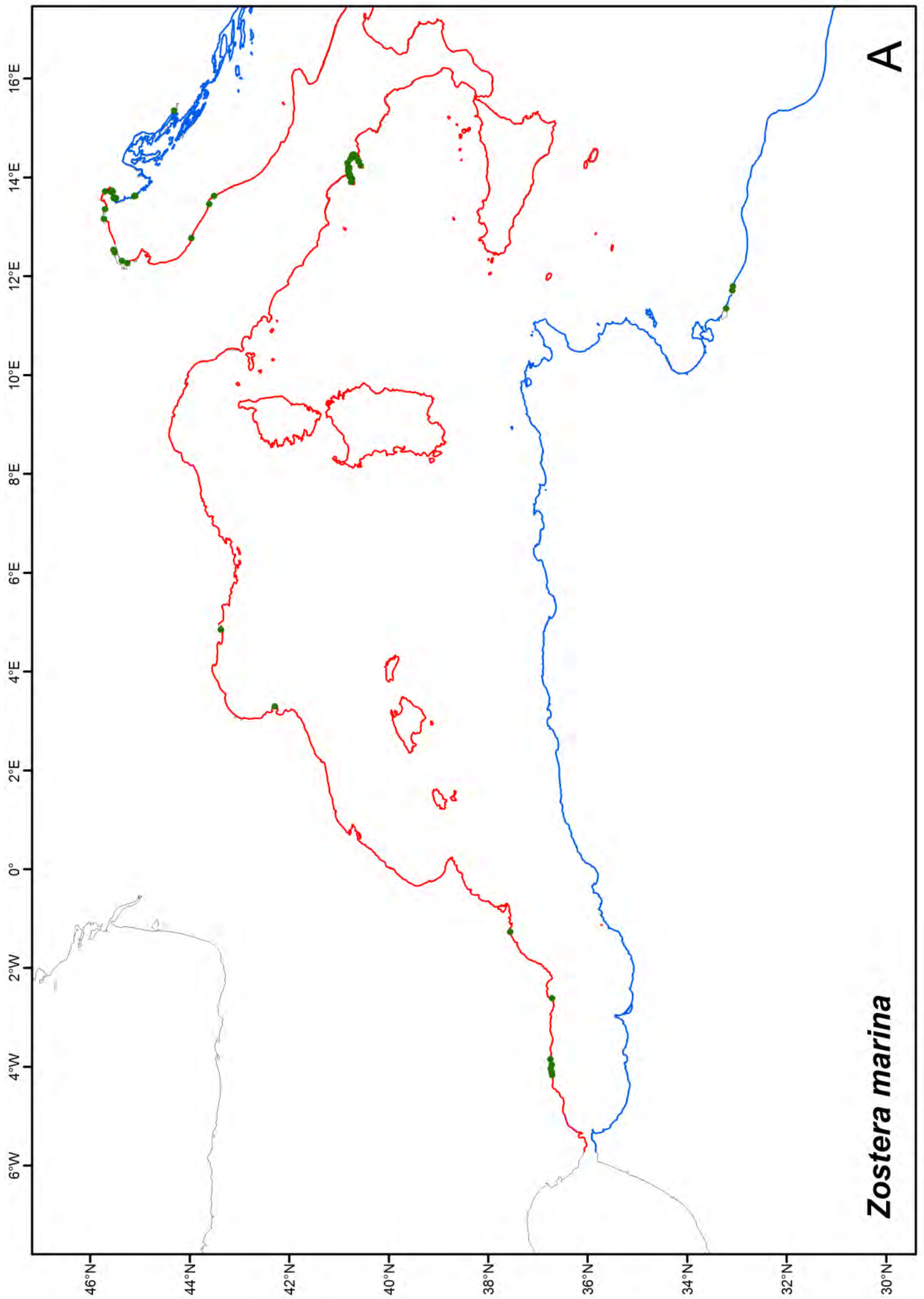


Fig. 1.1.17a. Current distribution of *Z. marina* in the Western part of Mediterranean Sea (green: presence; red: absence; blue: no data).

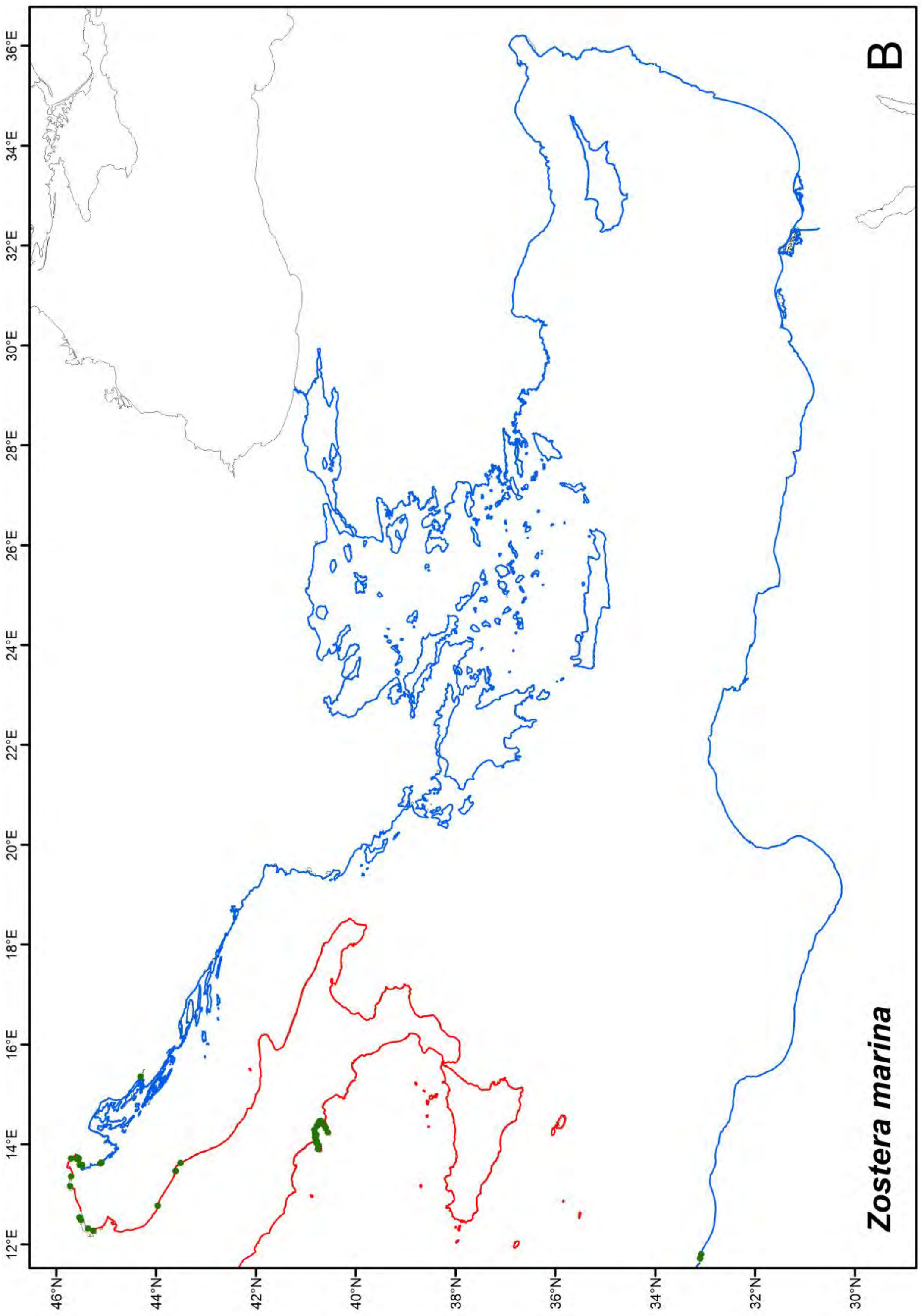


Fig. 1.1.17b. Current distribution of *Z. marina* in the Eastern part of Mediterranean Sea (green: presence; red: absence; blue: no data).

The current distribution of *Z. noltii* is shown in Fig. 1.1.18., the map represents "the state of art" of the actual knowledge being a significant improvement compared to the existing knowledge prior to this project. Figures 1.1.19a and 1.1.19b show the distribution for the Western and Eastern Mediterranean.

Existing information on *Zostera noltii* seems to be limited to scattered records in Aegean Sea, the lagoon systems of the east part of Ionian Sea, the north and the south part of the Adriatic Sea, limited areas along the Spanish coastline, the France coasts and the Tyrrhenian Sea. Records have been identified along the Lebanese coast in the Levantine (Fig. 1.1.18). Along the Eastern Mediterranean and African coastline information about *Z. noltii is* relatively scarce.

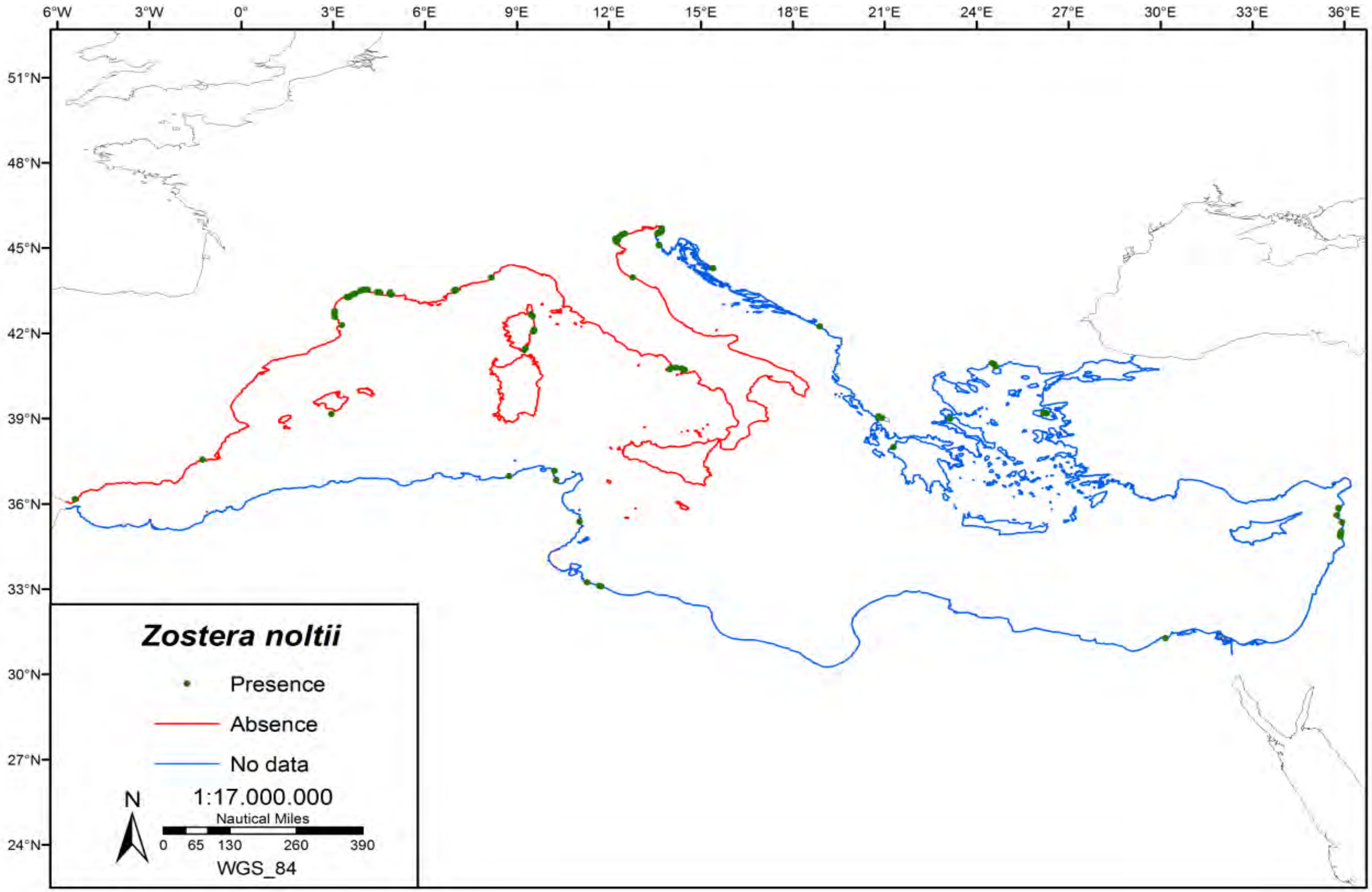


Fig. 1.1.18. Current distribution of *Z. noltii* across the Mediterranean Sea.

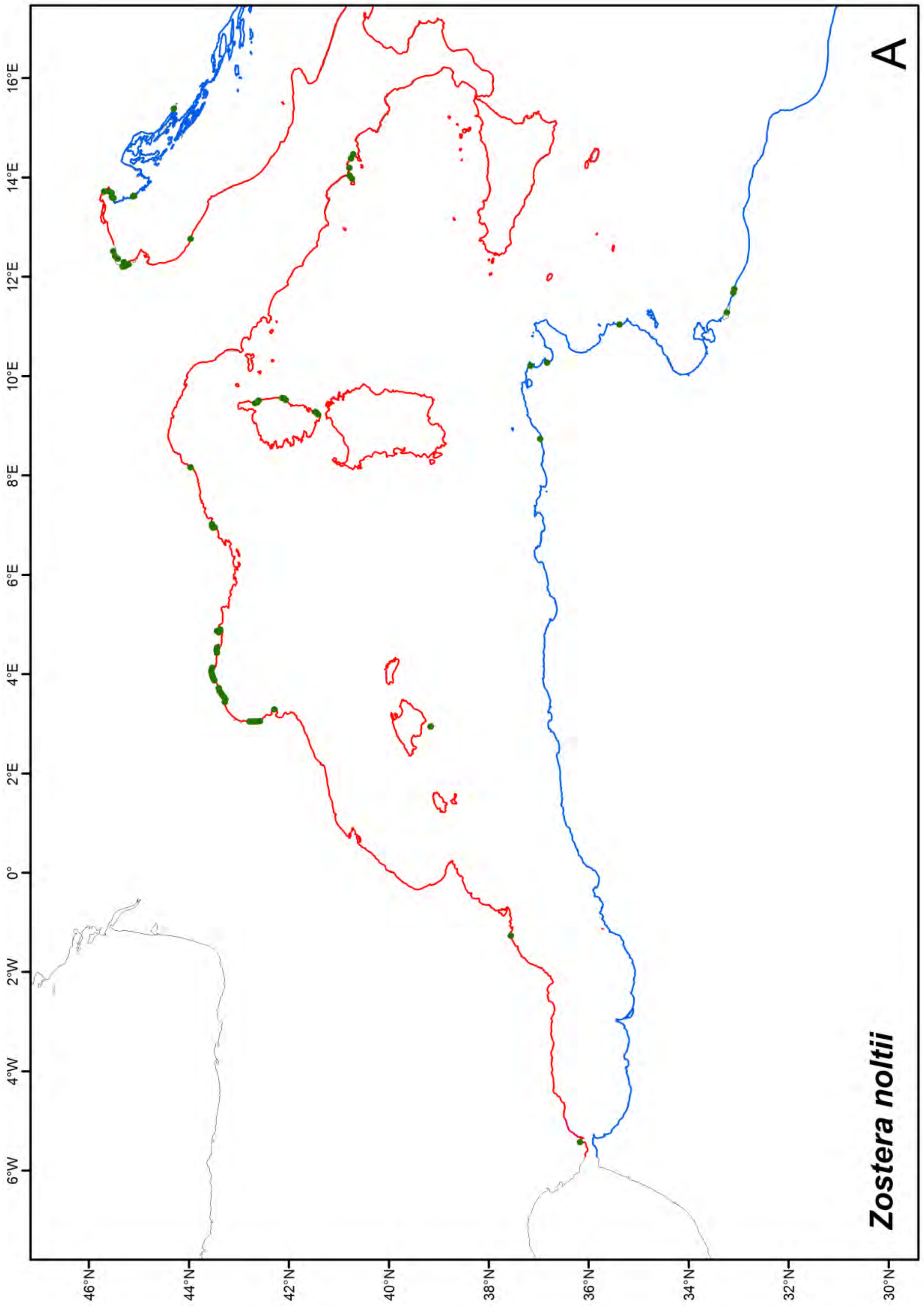


Fig. 1.1.19a. Current distribution of *Z. noltii* in the Western part of Mediterranean Sea (green: presence; red: absence; blue: no data).

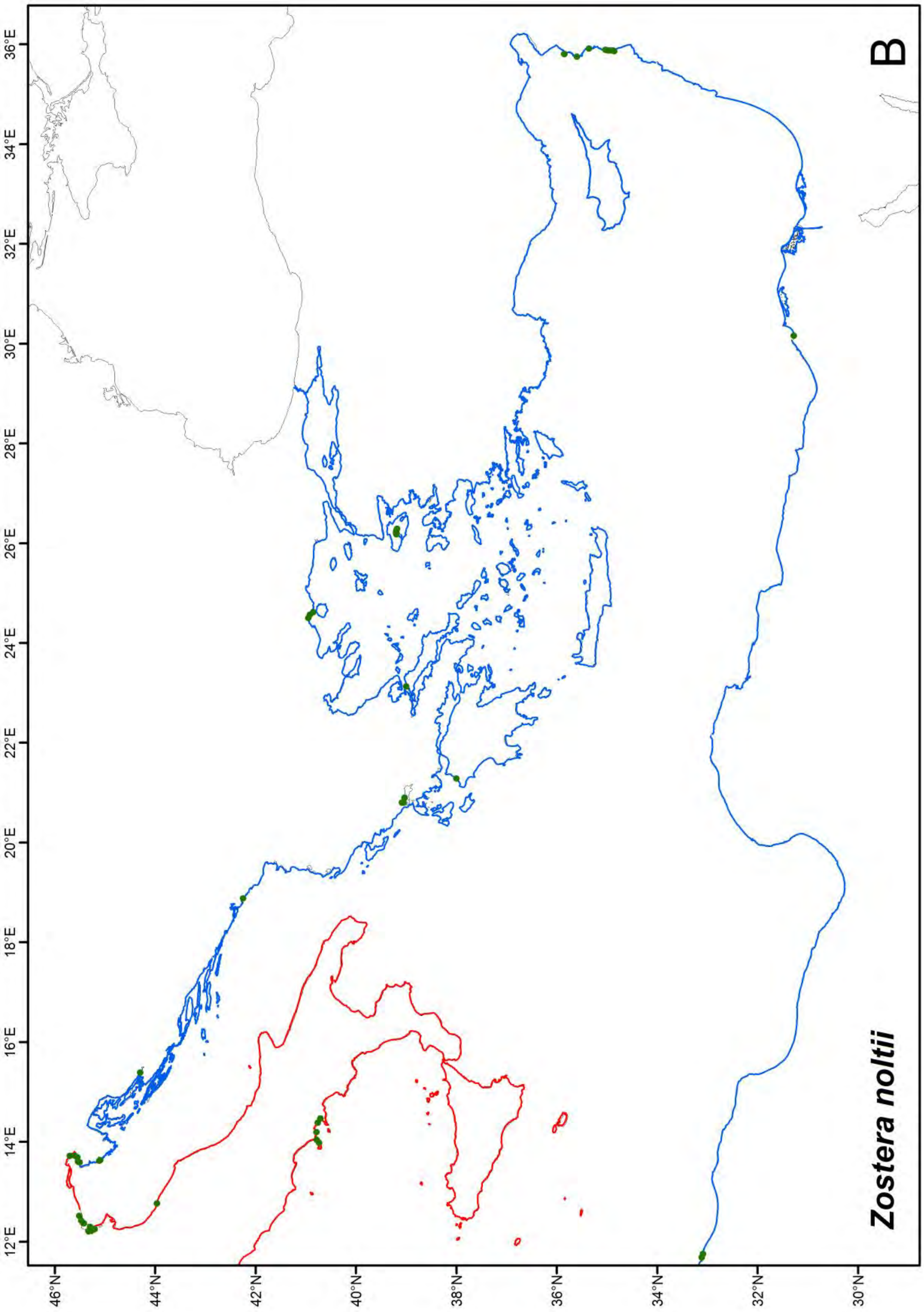


Fig. 1.1.19b. Current distribution of *Z. noltii* in the Eastern part of Mediterranean Sea (green: presence; red: absence; blue: no data).

Recently, the warm water seagrass species *Halophila stipulacea* has invaded the eastern Mediterranean and has reached the southern coasts of Italy. The species was introduced through the Suez Channel. Figure 1.1.20 shows the existing information on the distribution of this species based on projects results. The opening of the Suez Canal enabled it to enter the Mediterranean where it was first reported in 1894 (Fritsch, 1895). Since then, *Halophila stipulacea* has continued to advance, usually following prevailing currents (Galil, 2006). Fig 1.1.20 shows the existing information on the distribution of this species based on projects results. This map represents "the state of art" of the actual knowledge largely improving the available records compared to the situation prior to this project. Fig. 1.1.21a and 1.1.21b show the data for Western and Eastern Mediterranean.

Halophila is present along the coasts of Greece, Albania, Turkey, Cyprus, Syria, Lebanon, Israel, Egypt, Libya, Tunisia and the southern part of Italy. Along the most part of the Western Mediterranean, North-Western African and Adriatic coastline *H. stipulacea* is absent.

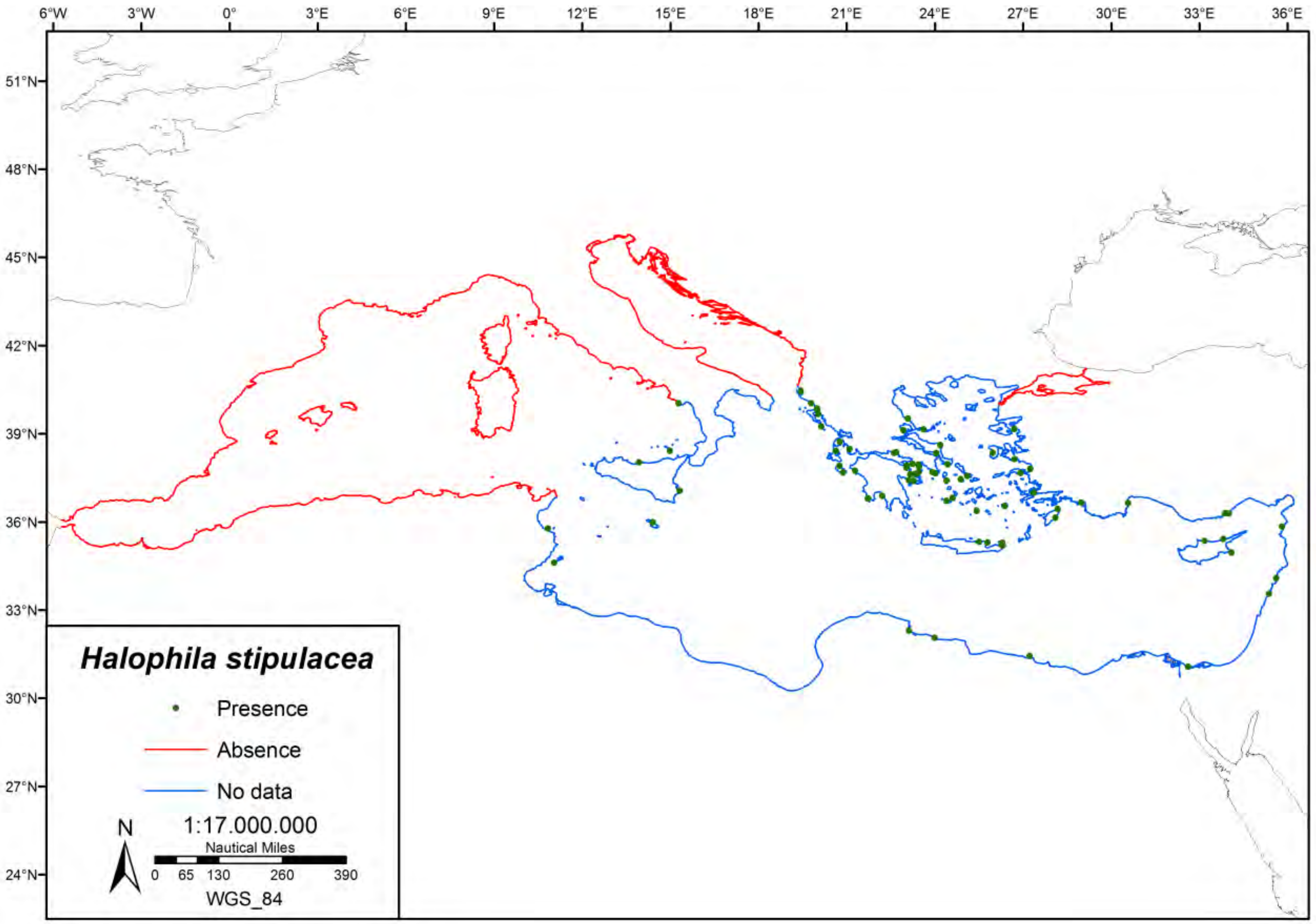


Fig. 1.1.20. Current distribution of *H. stipulacea* across the Mediterranean Sea.

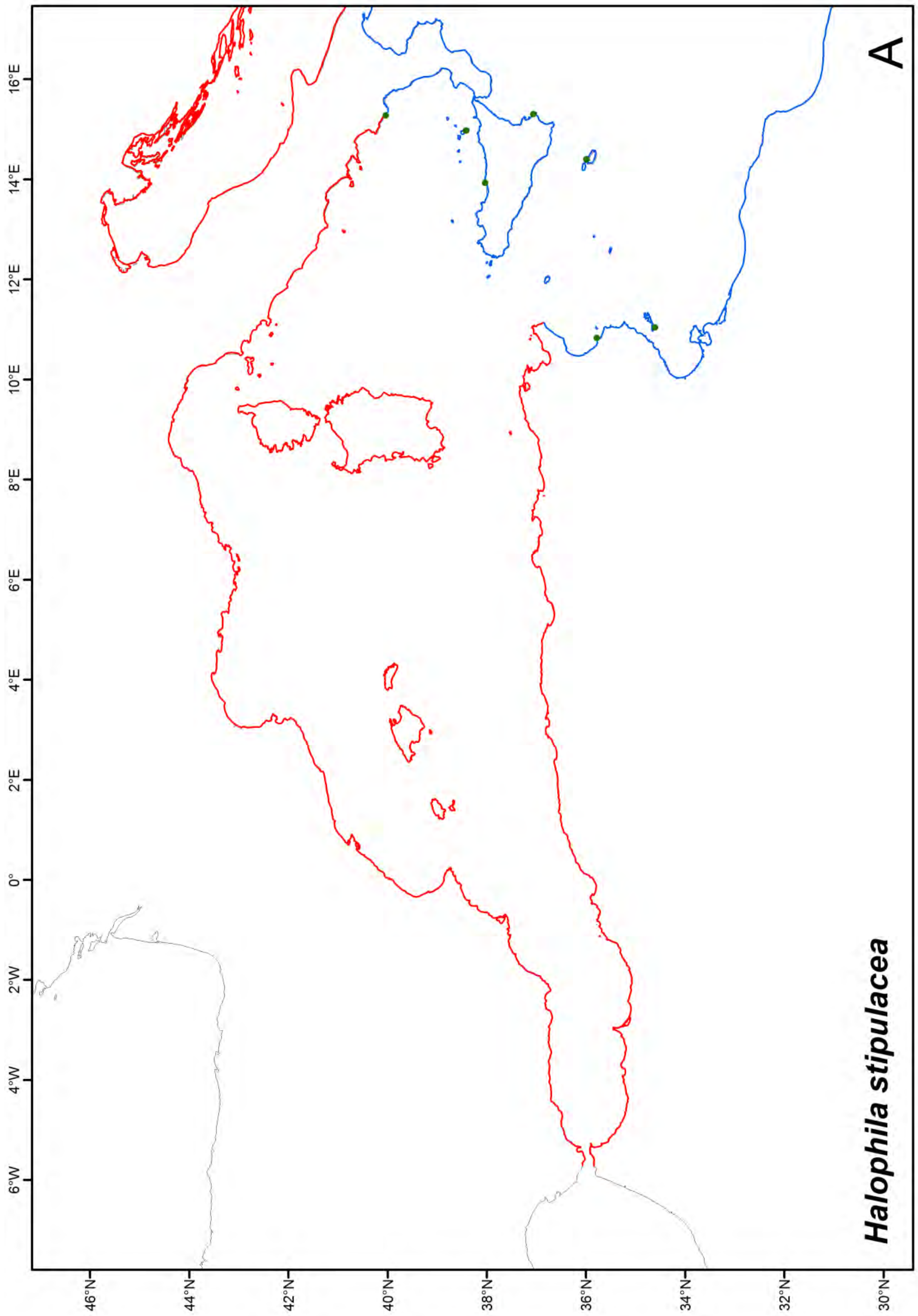


Fig. 1.1.21a. Current distribution of *H. stipulacea* in the Western part of Mediterranean Sea (green: presence; red: absence; blue: no data).

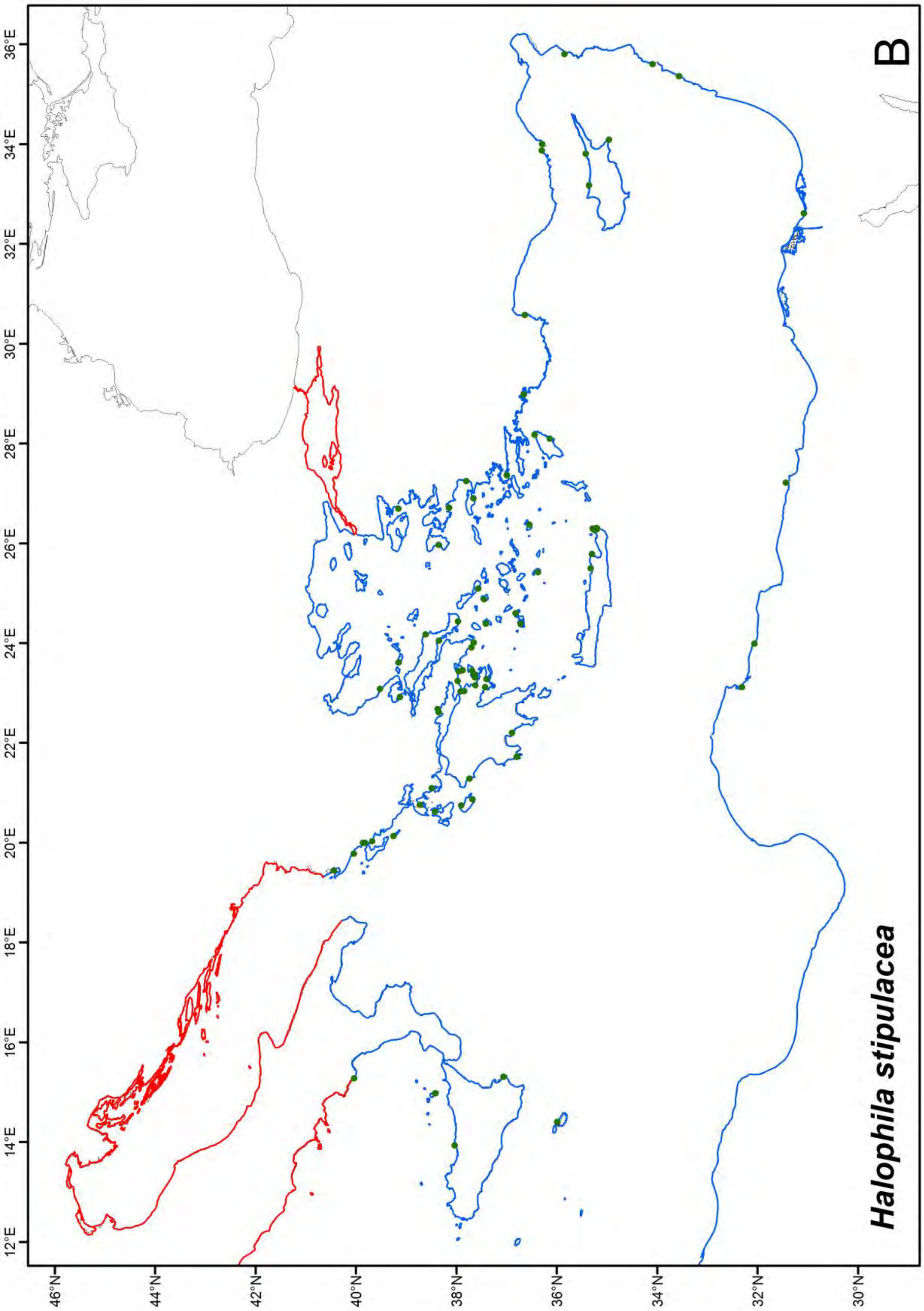


Fig. 1.1.21b. Current distribution of *H. stipulacea* in the Eastern part of Mediterranean Sea (green: presence; red: absence; blue: no data).

Ruppia spp. refers to *Ruppia cirrhosa* and/or *Ruppia maritima*. They can be found throughout the world, most often in coastal areas, where it grows in brackish water bodies, such as marshes or lagoons. The species can be extremely morphologically variable and therefore their identifications is often linked to differences in environmental conditions. *Ruppia* spp*.* are very euryhaline species and can withstand prolonged periods of desiccation. Existing information about the *Ruppia* spp*.* are limited to few data point from Aegean Sea, a limited area in the western part of Sicily, the Ionian Sea, the north and the south part of Adriatic Sea, a point from Spain, and the lagoon system of Tunisia and Egypt. Along the Eastern Mediterranean and African coastline information about *R. maritima* are relatively scarce and the distribution appears to be rather limited.

The current distribution of *Ruppia maritima* is shown in Fig. 1.1.22. Figures 1.1.23a and 1.1.23b show the data for Western and Eastern Mediterranean. These maps represent “the state of art” of the actual knowledge.

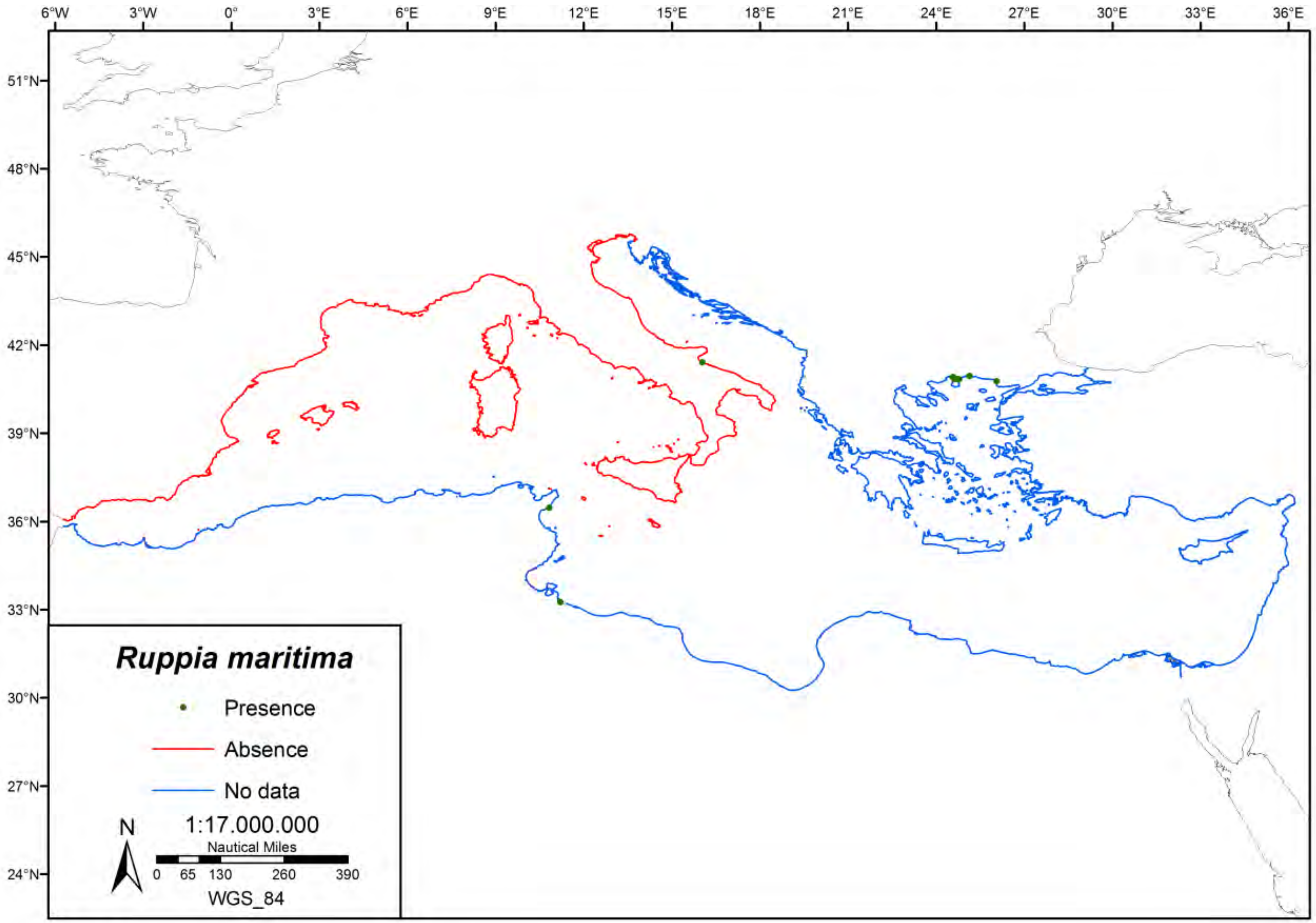


Fig. 1.1.22. Current distribution of *R. maritima* across the Mediterranean Sea.

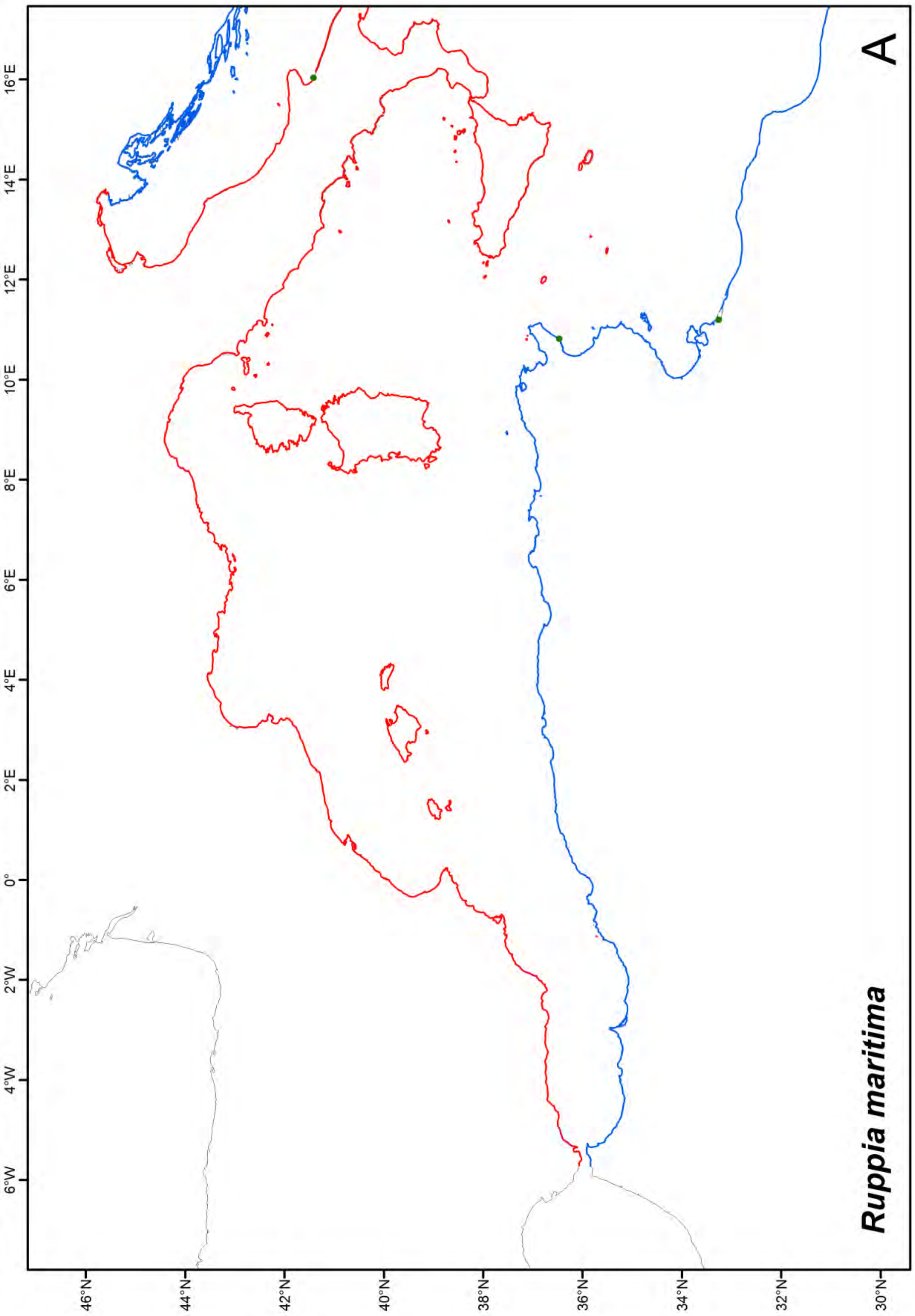


Fig. 1.1.23a. Current distribution of *R. maritima* in the Western part of Mediterranean Sea (green: presence; red: absence; blue: no data).

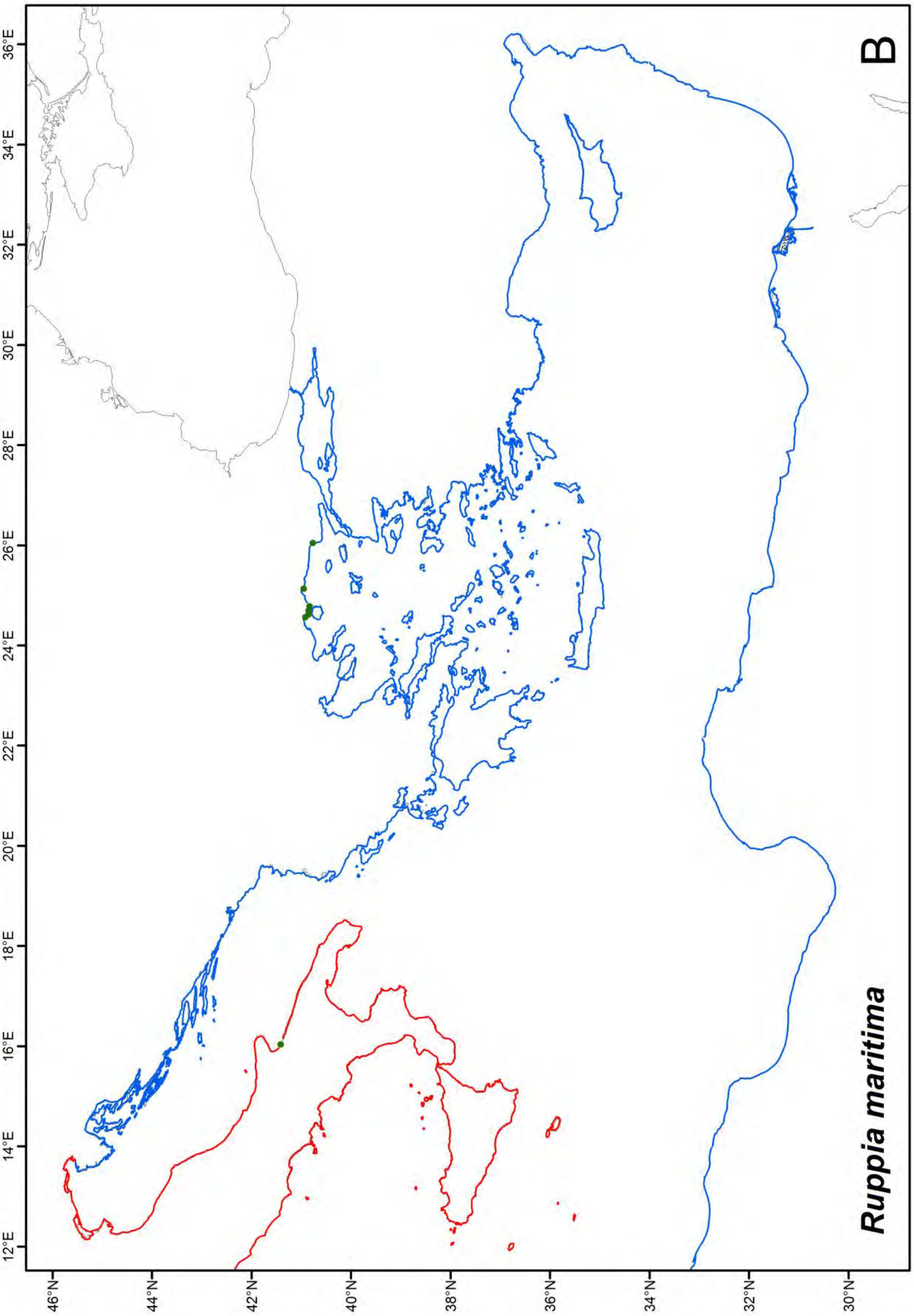


Fig. 1.1.23b. Current distribution of *R. maritima* in the Eastern part of Mediterranean Sea (green: presence; red: absence; blue: no data).

The current distribution of *Ruppia cirrhosa* is shown in Fig. 1.1.24. Figures 1.1.25a and 1.1.25b show the data for Western and Eastern Mediterranean. These maps represent “the state of art” of the actual knowledge.

Existing information on *Ruppia cirrhosa* seems to be limited to scattered records in the lagoon systems of the east part of Ionian Sea, the north part of the Adriatic Sea, limited areas along the Spanish coastline, limited areas in the western part of Sicily, a point from the coasts of Spain and the lagoon system of Tunisia. Along the Eastern Mediterranean and African coastline information about *R. cirrhosa is* relatively scarce.

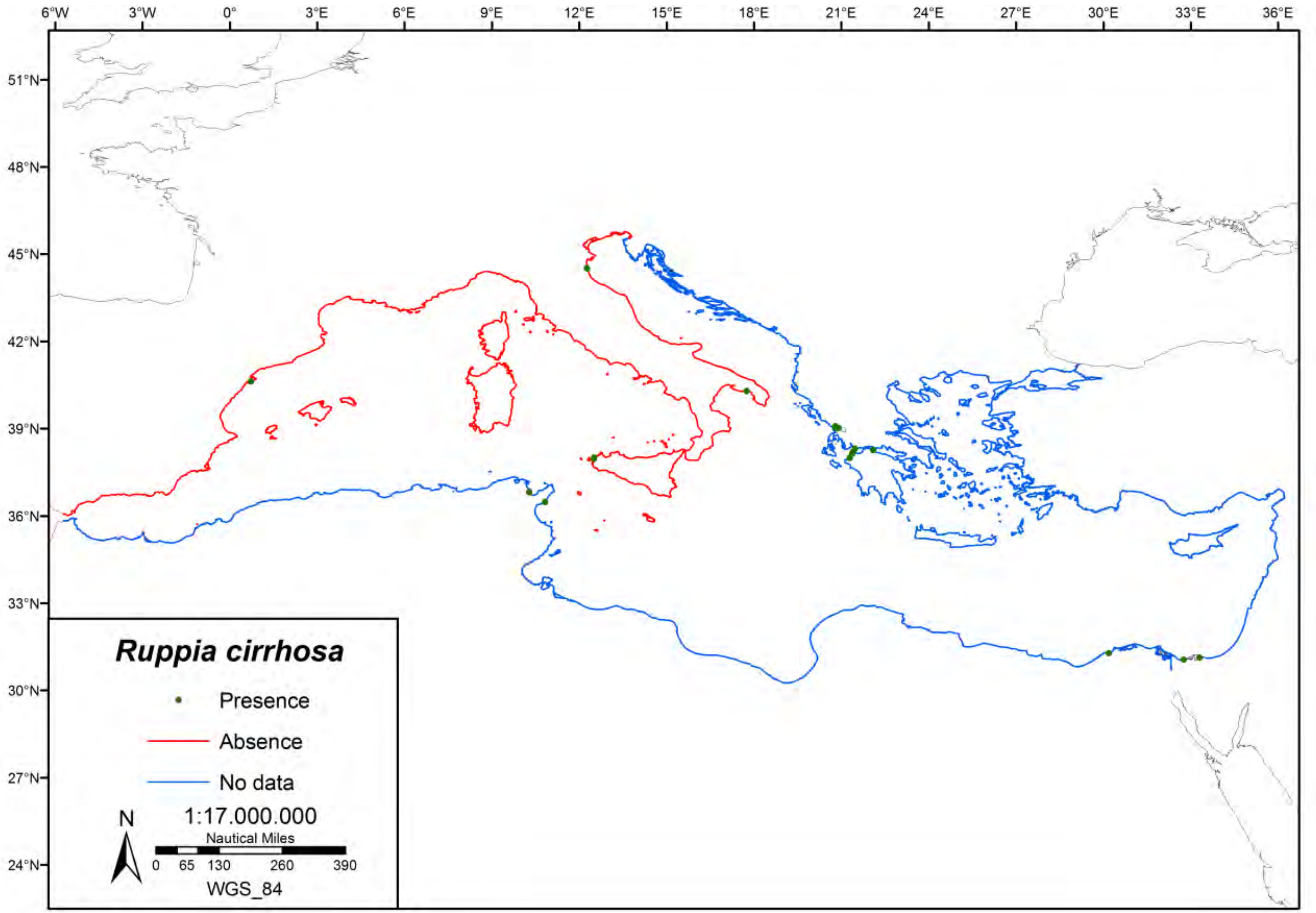


Fig. 1.1.24. Current distribution of *R. cirrhosa* across the Mediterranean Sea.

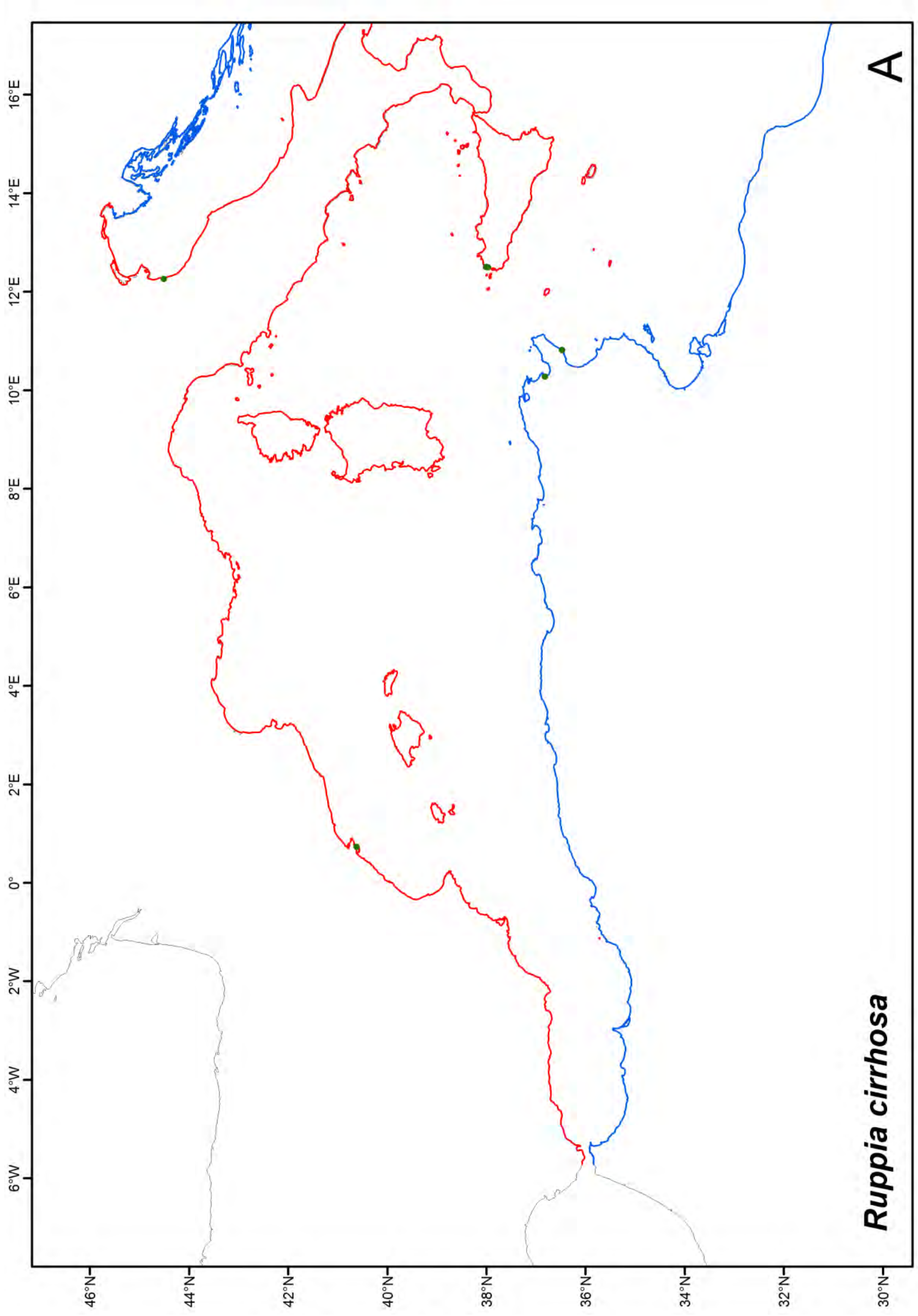


Fig. 1.1.25a. Current distribution of *R. cirrhosa* in the Western part of Mediterranean Sea (green: presence; red: absence; blue: no data).

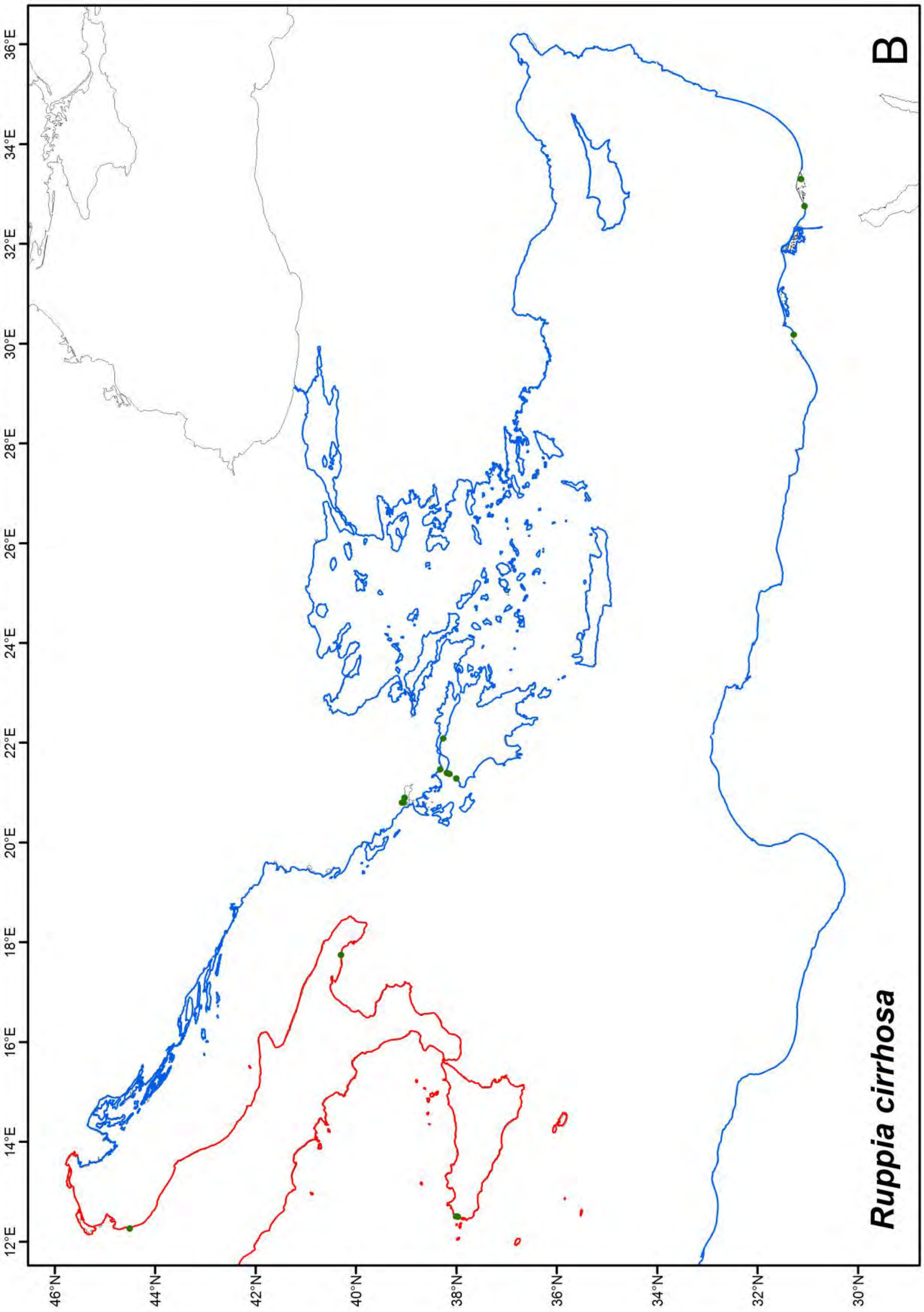


Fig. 1.1.25b. Current distribution of *R. cirrhosa* in the Eastern part of Mediterranean Sea (green: presence; red: absence; blue: no data).

An evaluation of data and information collected on the different seagrasses based on MEDISEH results is shown in Table 1.1.8.

Table 1.1.8. Reliability of the data collected (High: good knowledge on distribution; Medium: knowledge is not complete, some areas are poorly mapped; Low: poor level of knowledge).

Segrass species	Data reliability
Posidonia oceanica	High/Medium
Cymodocea nodosa	Medium
Halophila stipulacea	Medium/High
Zostera noltii	Low
Zostera marina	Low
Ruppia cirrhosa	Low
Ruppia maritima	Low

Historical data revision (M 1.1.1, D1.1.1)

The comparison of historical maps is considered a valuable tool for understanding the changes undergone by the meadows through time from a landscape and ecological point of view. This could allow us to obtain a picture of the historical *Posidonia* distribution and to identify these areas where Posidonia regression is dramatically ongoing.

Available historical data on the seagrassess beds from all areas (e.g the Iberian coast, the French coast, the Italian Tyrrhenian coasts, the north-western Ionian coasts, the Tunisian coasts) has been collected and evaluated. The reliability of historical maps was also evaluated. In those cases where a limited number of appropriate historical cartographic data are available, an appropriate bibliographic review has been conducted to obtain past records of the presence of Posidonia beds.

Historical data provided us an idea on the known *Posidonia oceanica* meadows that are under regressive phenomena in a determinate period of time. However, data were available only for certain countries, and not for the whole known distribution: Information is available for Italy (20-40% of known area), France/ Monaco (20-40% of known area), Spain (20-40% of known area), Tunisia (only locally), Egypt (only locally), Turkey (only locally) and Israel/Lebanon/Syria (only locally).

Detailed information is reported in the Table 1.1.9 where the percentage of regression (i.e. lost area compared to the total area) of the *Posidonia* meadows and the period that regression refers to, are summarize for each Country.

Table 1.1.9. *P. oceanica* percentage of regression and temporal period we refer for each Country across the Mediterranean Sea.

Country	Regression %	Temporal period
Spain	50%	2001-2011
France	15%	1980-2011
Italy (Liguria)	19%	1991-1995
Italy (Tuscany)	26%	1990-2000
Italy (Lazio)	38%	1990-1995
Italy (Puglia)	28%	1990-2005
Italy (Other regions)	_	1982-2009
Slovenia	_	2004
Croatia	_	2010
Montenegro	_	2004
Albania	16%	2007-2008
Malta	_	2002
Greece	_	2011
Turkey	_	2009
Cyprus	_	2008
Syria, Lebanon, Israel	_	2003
Egypt	_	2006
Libya	_	2011
Tunisia	2%	1972-2010
Algeria	_	2010
Morocco	_	_

The historical knowledge on the regressive phenomenon in the last 50 years for *Posidonia oceanica* meadows compared with the current distribution in the Mediterranean Sea are shown in Fig.1.1.26. It is important to highlight the geographical distribution of our knowledge. The main studies and data come from Spain, France and Italy, where Posidonia distribution maps are available from long time. In these Countries a long tradition of scientific activity on Posidonia meadows is carried out. Based on this we underastand that the regression of Posidonia meadows is a wide spread phenomenon, addressing most of the continental coasts and, to a lesser extent, the main islands (Sardinia, Sicily). Scattered information comes from some eastern Mediterranean countries, where large area of “dead matte” have been found from Tunisian researchers (EL Lakhrach et al., 2012).

In the next maps (Figs.1.1.27 to 1.1.29) we present some examples (Spain, France and Italy) of high resolution maps exported from our database, showing the current distribution and the area of regressionof *Posidonia oceanica* meadows along the Mediterranean coastline in the last 50 years.

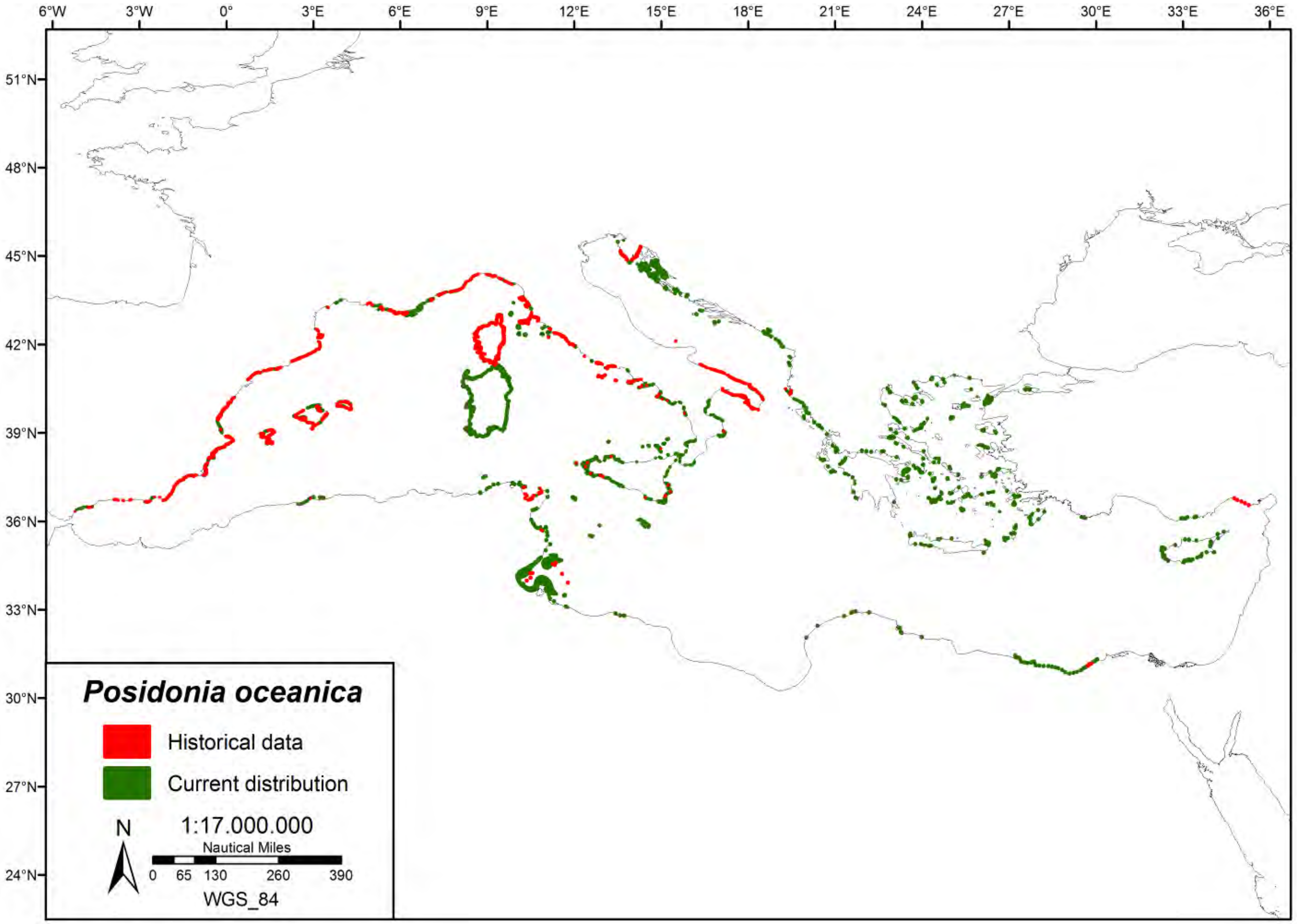


Fig. 1.1.26. Historical data: map highlighting the areas where *P. oceanica* is currently known that is in regression state (red areas).

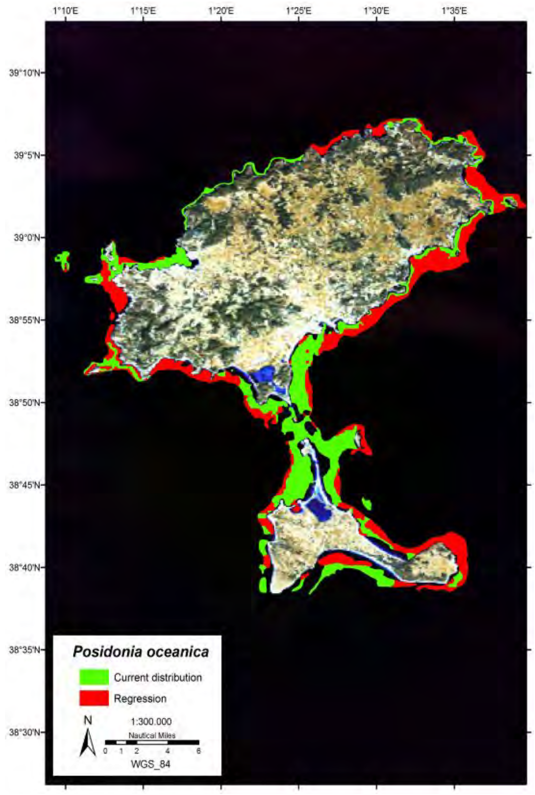


Fig. 1.1.27. *Posidonia oceanica* current distribution and regression along the coast of Ibiza and Formentera (*Spain*).

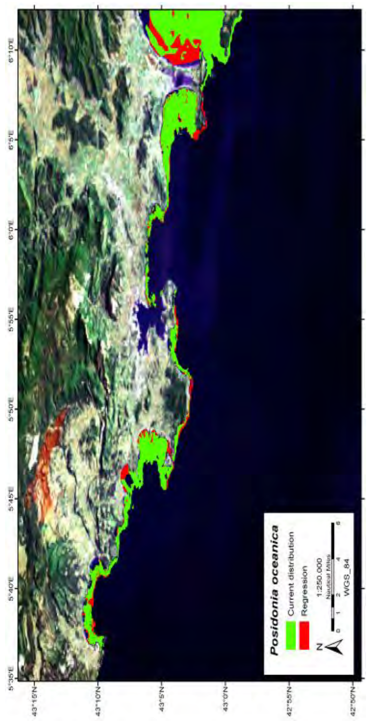


Fig. 1.1.28. *Posidonia oceanica* current distribution and regression between La Ciotat Bay and Gulf of Giens (*France*).

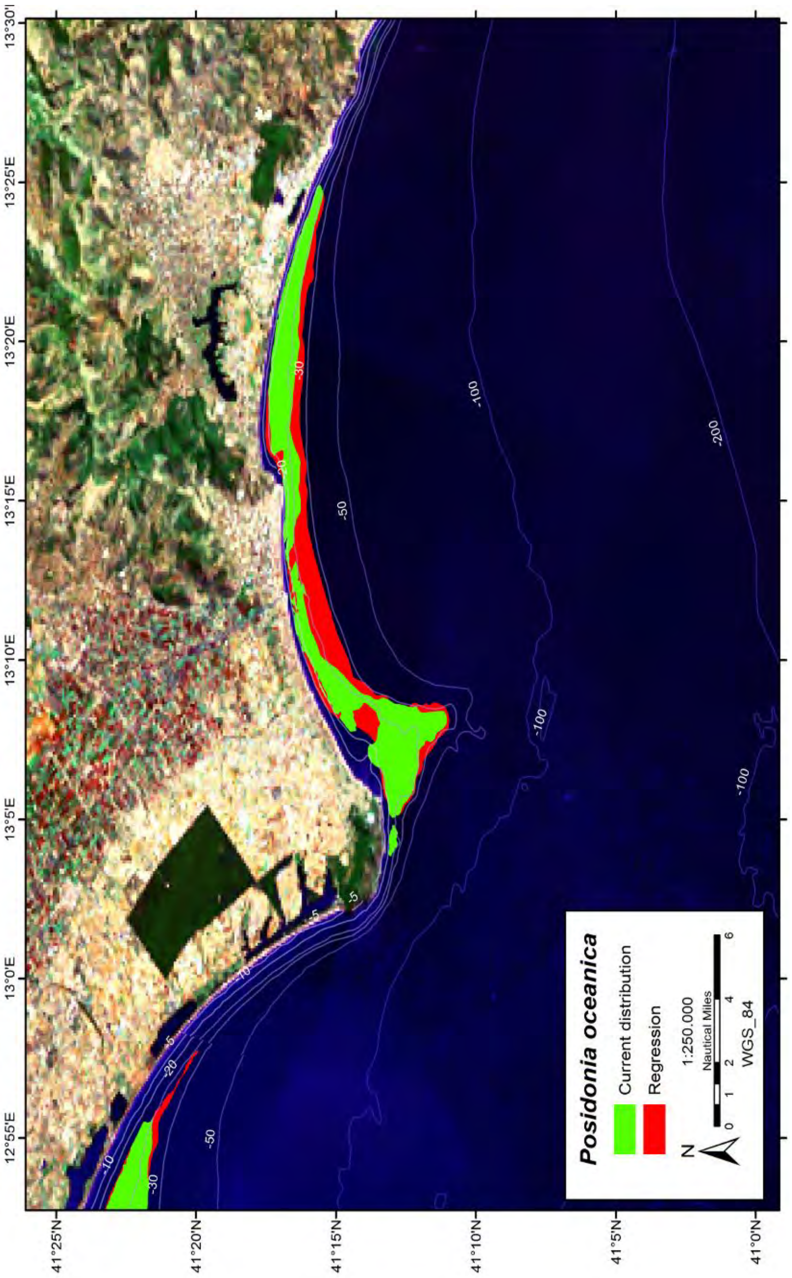


Fig. 1.1.29. *Posidonia oceanica* current distribution and regression between Circeo and Terracina (*Lazio region, Italy*).

Health status data

Data regarding health status are available mainly for *P. oceanica* and for certain countries: Italy, France, Monaco, Spain, Greece, Croatia, Albania, Tunisia (Table 1.1.10).

Tabel 1.1.10. Health status information presence for each Mediterranean Countries.

Country	**Health status information**
Spain	Y
France	Y
Italy	Y
Slovenia	N
Croatia	Y
Montenegro	N
Albania	Y
Malta	N
Greece	Y
Turkey	N
Cyprus	N
Syria, Lebanon, Israel	Y
Egypt	N
Libya	N
Tunisia	Y
Algeria	N
Morocco	N

Data collection evidences that these countries made substantial effort to monitor the seagrass meadows living along their coasts. In a very recent paper, Marbà et al. (2012) states that European countries are carrying out 42 monitoring programmes at European level, using a total of 49 seagrass indicators based on a total of 51 seagrass metrics used either alone or in various combinations of up to 14 metrics per indicator. Together with the classic indicators such as shoot density, biomass, or coverage a lot of more complex indicator are used, belonging to categories such as ''Processes'', ''Chemical constituents'', and ''Shoot characteristics'' that, according to Marbà et al. (2012) may respond faster to disturbance. Also other structural and physiographic descriptors can be present, for example: limit type (progressive, stable, regressive), lepidochronology and growing, production and productivity index. Table 1.1.11 reports an example of health status data for a certain area in Croatia (Bakran-Petricioli and Schultz, 2010).

The information available about the health status of *Posidonia* meadows along the Mediterranean Countries are the following (Marbà et al., 2012):

Distribution

- Depth limit
- Depth limit type
- Area

Abundance

- Shoot density
- Cover
- Dead matte cover

Shoot characteristics

- Shoot biomass
- Shoot leaf area
- No. of leaves per shoot
- Leaf width
- Leaf length
- Leaf necrosis
- Broken leaves
- Plagiotrophic rhizomes

Processes

- Leaf production
- Rhizome production
- Rhizome elongation
- Shoot recruitment
- Shoot mortality
- Flowering
- Shoot burial, rhizome baring
- Herbivore pressure

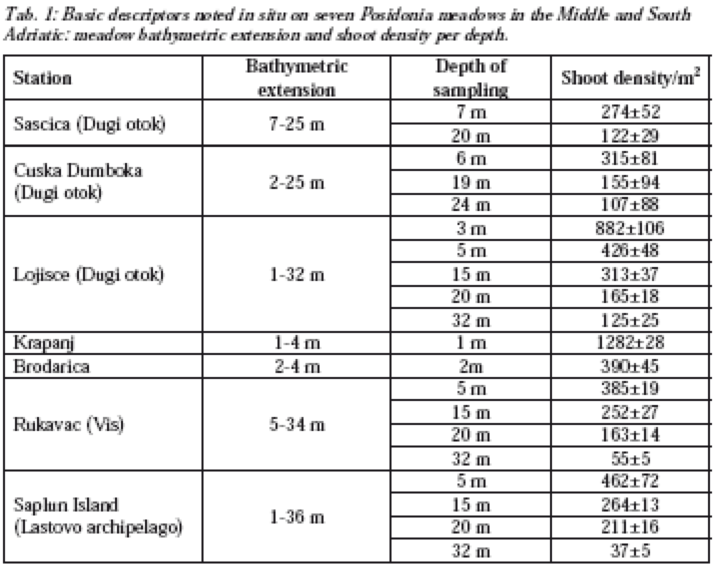
Chemical constituents

- Rhizome N
- Rhizome P
- Rhizome d15N
- Rhizomes d34S
- Rhizome sucrose
- Rhizome Cu
- Rhizome Pb
- Rhizome Zn

Associated flora and fauna

- Diversity
- Invasive sp. presence
- Epiphyte biomass
- Macrofauna abundance

Table.1.1.11. An example of the health status available for one area in Croatia.



Tab. 1: Basic descriptors noted in situ on seven Posidonia meadows in the Middle and South Adriatic: meadow bathymetric extension and shoot density per depth.

Station	Bathymetric extension	Depth of sampling	Shoot density/m^2
Sascica (Dugi otok)	7-25 m	7 m	274±52
		20 m	122±29
Cuska Dumboka (Dugi otok)	2-25 m	6 m	315±81
		19 m	155±94
		24 m	107±88
Lojisce (Dugi otok)	1-32 m	3 m	882±106
		5 m	426±48
		15 m	313±37
		20 m	165±18
		32 m	125±25
Krapanj	1-4 m	1 m	1282±28
Brodarica	2-4 m	2m	390±45
Rukavac (Vis)	5-34 m	5 m	385±19
		15 m	252±27
		20 m	163±14
		32 m	55±5
Saplun Island (Lastovo archipelago)	1-36 m	5 m	462±72
		15 m	264±13
		20 m	211±16
		32 m	37±5

Generally, the health status of meadows presents a wide heterogeneity along the Mediterranean coasts. The meadows are distributed between a few meters of depth to 45-50 m depth at maximum, mainly 35-40 m. The health situation is a very complex issue because it is linked to a great variety of local conditions (i.e. sea bottom morphology, hydrology, primary production, etc.), human impacts and, not the least, the variety of parameters considered.

Health status information collected is reported in Annex 1.1.1.

REGIONAL DETAILS

Spain

For the coasts of Spain we have good maps with the distribution of *Posidonia* (and scattered data for *Cymodocea*), information on the health status of meadows and spot data concerning the regression. *Posidonia* meadows are widely present along the continental coast and islands. The most extensive *P. oceanica* meadows are located in Murcia, Alicante and Balearic island regions. More than 58% of the Catalan coast and more than 52 % of Alicante coats are characterized by regression phenomena caused by natural processes and anthropogenic disturbances and stress. A study carried out on 29 *P. oceanica* meadows distributed on about 1.000 Km of the Spanish coast within 36"46' and 42"22' N latitude degree, shows that the meadows presenting good health conditions (in terms of biomass and density) are located in Andalusia region. However a general decline has been recorded in the main part of the surveyed meadows. (Marbà et al., 1996; Romero et al, 2007).

The main causes responsible for the regression of *P. oceanica* along the Spanish coast are: spills of wastewater; alteration of sedimentary dynamics due to the construction of infrastructure along the coast; beach nourishment; mechanical damage caused by trawling; input of organic matter produced by aquaculture facilities; discharges of brine spilled from desalination plants.

France

Distribution maps of Posidonia exist for the continental coasts of France, small islands and Corsica. Updated detailed data come mainly from Natura 2000 Network and EUSeaMap project. Information on the health status of meadows is available due to a standardized network that collects information from *Posidonia* monitoring projects. The French researchers have the oldest maps of *Posidonia* distribution in the

Mediterranean, and a lot of scientific papers testimony important regressive phenomena along the continental and insular costs. The causes are both human impacts and natural disturbances.

Italy

The current distribution of *P. oceanica* meadows along the Italian coasts is well known (Fig. 1.1.30). Distribution maps of *Posidonia* are available in shapefiles for most of the Italian coasts, and small islands. In some cases, maps are available also for long time period (Liguria, Tuscany, Lazio, and Puglia regions) (Figs. 1.1.31 and 1.1.32). Additionally, a significant amount of information on the health status of meadows is available. *Posidonia* is present along the Ligurian coasts (with few exception), the Tuscany costs (except the Magra, Ombrone mouths), and Tuscan Archipelago islands, the Latium coast (except Tevere, Garigliano and small river mouths), Campania, Calabria, Puglia (until the Gargano promontory). The health condition is very different from one area to another, but bad health status and regression areas are known and well studied along the continental coasts of Latium, Liguria and Puglia regions. *Posidonia* meadows are widely distributed along the Sardinia coast, and they generally are in good health conditions (except harbour areas).

The *P. oceanica* meadows along the Sicilian coasts are really well studied and described. Maps and relative shp files are currently available for the whole coastal area. *P. oceanica* meadows result mainly concentrated in west and south east sides of Sicily. In these areas probably due to the wide continental shelf and geological features of the sea bottom (calcarenitic substrates), *P. oceanica* meadows are particularly extended; especially in the west coast (from Mazara del Vallo at south to Egadi Island at north) where local meadows are considered to be some of the most wide ones for the whole Mediterranean sea. Although historical trends are not available, with the exception of *P. oceanica* meadows close to large urban (Palermo, Catania) and industrial centres (Milazzo. Augusta, Gela) health status of marine plants is generally good. However siltation from dumping sites and illegal activities of trawl fishing gears represent currently a serious problem for the *P. oceanica* biocenosis.

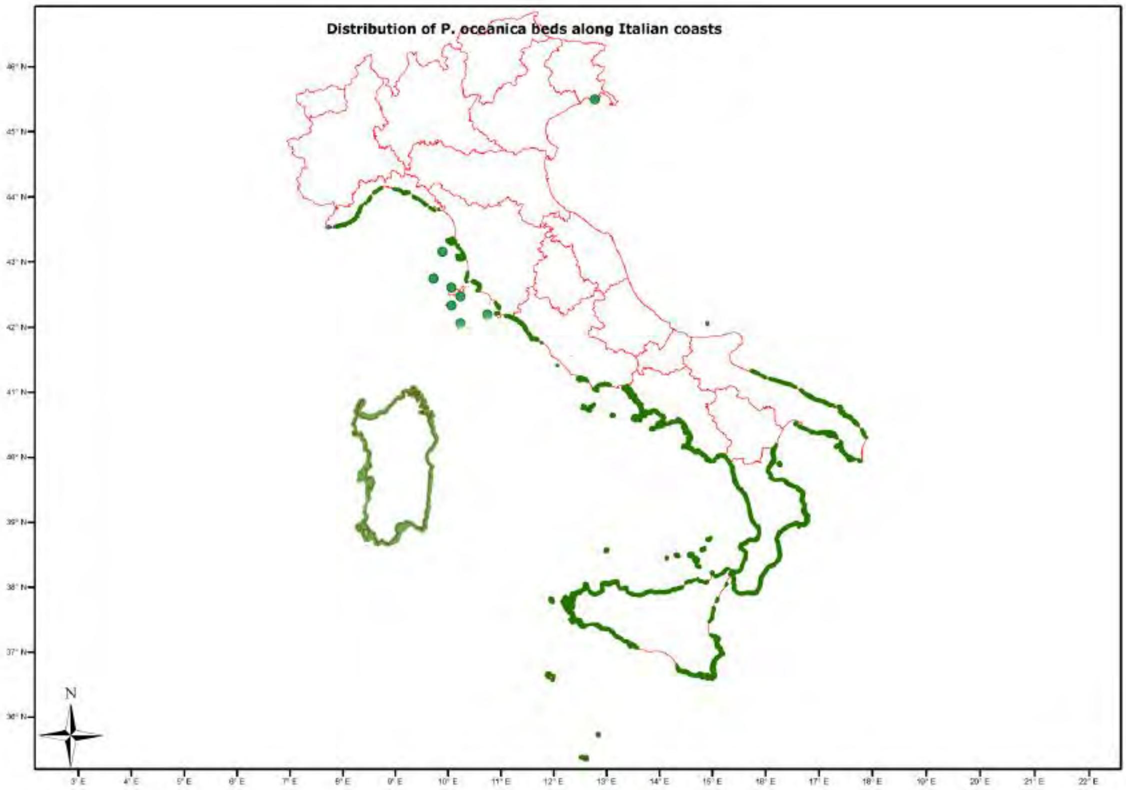


Fig.1.1.30 The actual distribution of *P.oceanica* beds along Italian coasts.

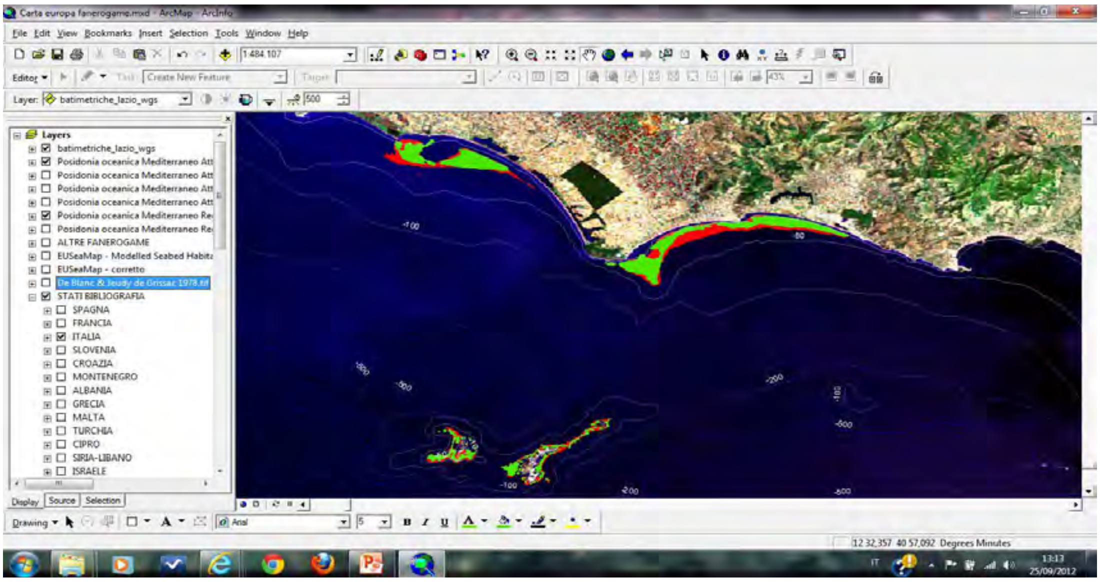


Fig.1.1.31 GIS example of *P. oceanica* current distribution (green) and lost area (red) between Circeo and Terracina (*Lazio region, Italy*).

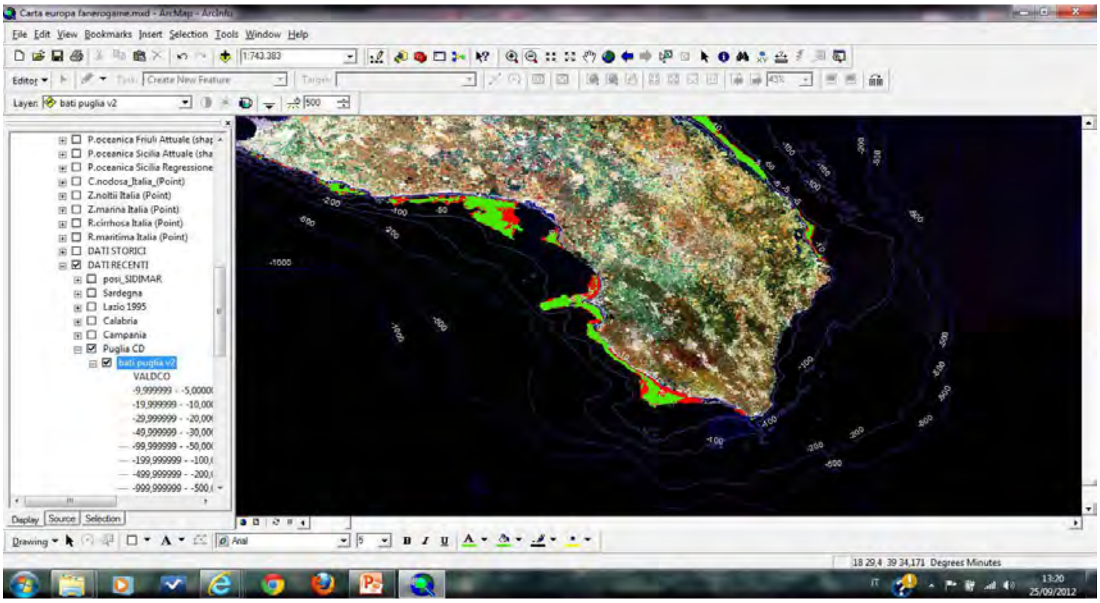


Fig.1.1.32 GIS example of *P. oceanica* current distribution (green) and lost area (red) along the southern coast of Puglia.

Greece

A large number of personal observations have been collected related to the occurrence of *P. oceanica* along the coasts of Greece.

This type of point data reflects years of experience and hundreds of diving all around the Country. The data have been provided by:

- P. Panayotidis: points from most of the Greek coasts;
- E. Apostolaki: some points from Crete Island.

However, all these personal observations highlight only the presence of the species without any information about extension and limits of the seagrass meadows; they were largely included in our database in order to heavily improve the model output (Task 1.3), as suggested by the modelers. As shown in Fig. 1.1.33 these personal points cover most of the Greek coastline complementing our official and unofficial data.

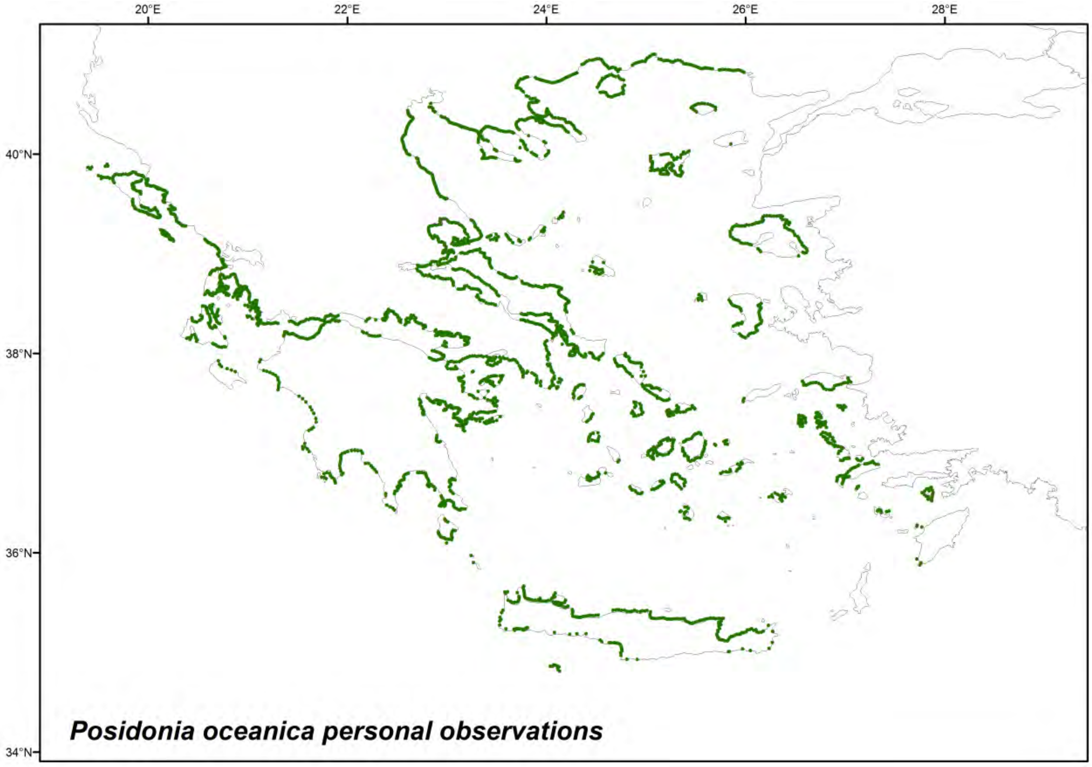


Fig. 1.1.33. *P. oceanica* personal observations along the coasts of Greece.

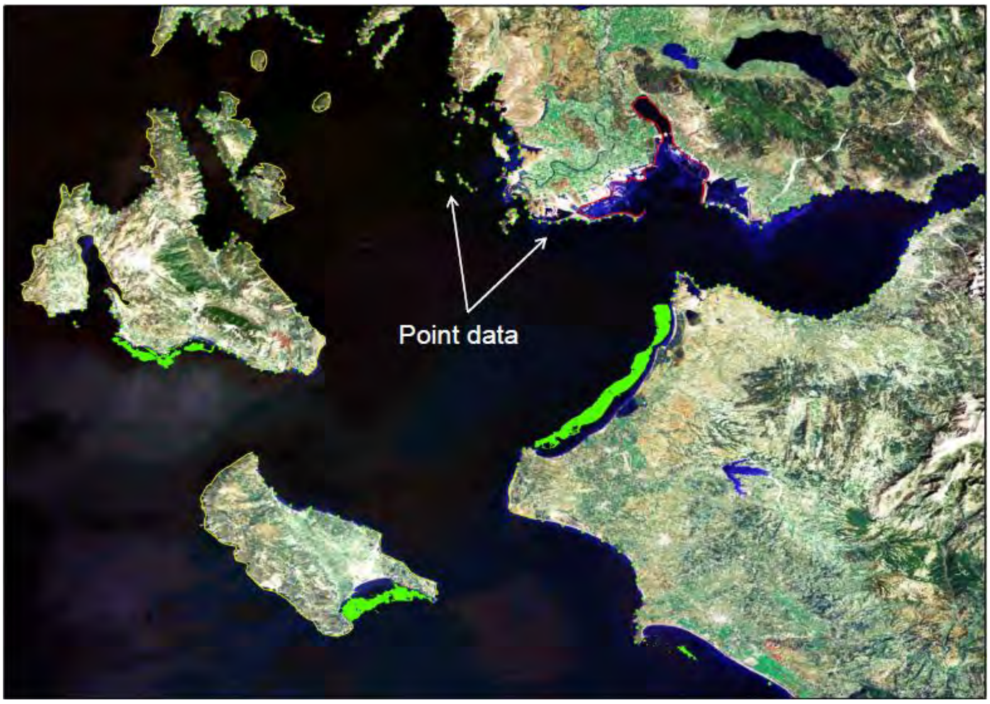
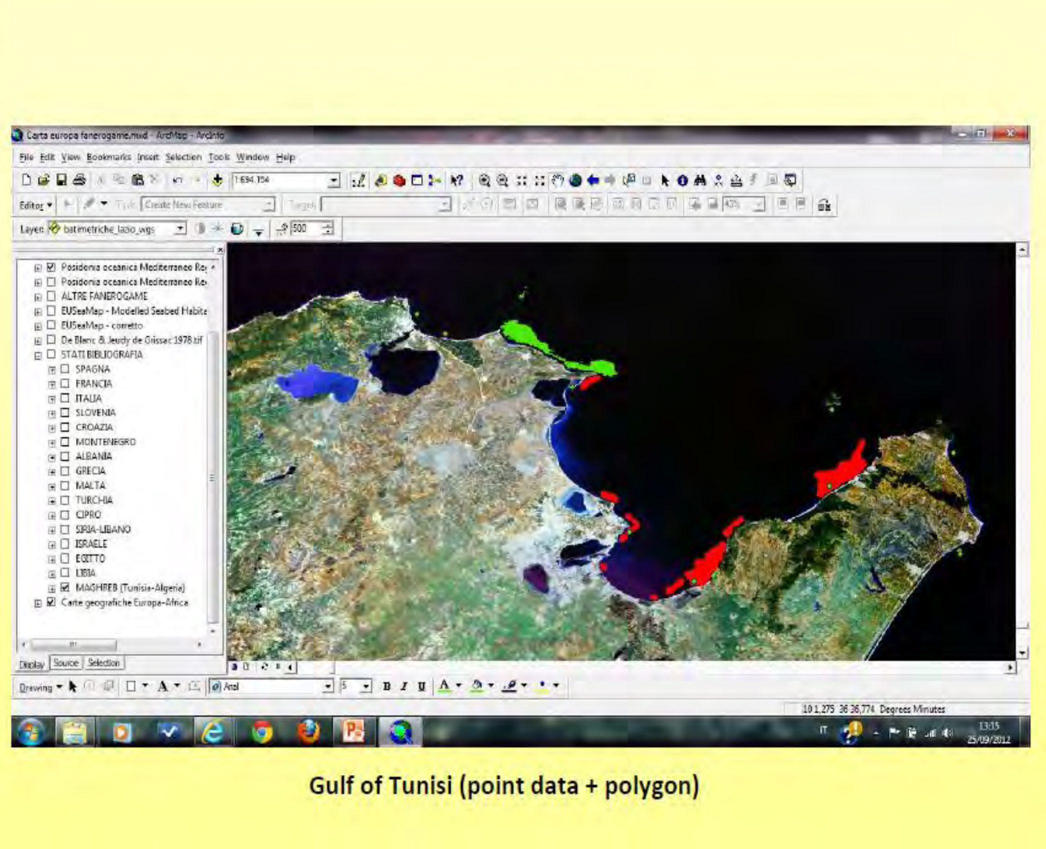


Fig.1.1.34. Some *P. oceanica* personal observation points (green) from the coasts of Greece.

Tunisia

Among the Maghreb countries, Tunisian coasts present the higher level of information on *P. oceanica* biology and spatial distribution. In the last two decades, several studies have produced useful data on the status of *P. oceanica* meadows, and a lot of meadows in regression are known. *Posidonia* maps are complete for the Gulf of Tunis, the Gulf of Gabes, Galite Archipelago and Zembra Island. Human impact on *P. oceanica* meadows is clearly described in Gulf of Gabes and several management plan have been proposed to protect the coastal area and, specifically, to slow down the *P. oceanica* regression. Many studies and projects are actually in progress in the Tunisian area, thus in a short time it will possible to refine and upgrade data collected and analyzed until now.



Gulf of Tunisi (point data + polygon)

Fig.1.1.35. GIS example of *P. oceanica* current distribution (green) and lost area (red) along the Tunisian coastline(Gulf of Tunis).

Malta

For Malta, *P. oceanica* distribution maps cover 100% of the coasts. Around the Island of Malta, a dense meadow on matte grows in the NE region between Saint Paul's Islands and Qawra Point and a dense meadow is interrupted between Qawra Point and Ras il-Qrejten. A relatively dense *P. oceanica* meadow characterizes the seafloor from Ras il-Qrejten to Saint Julian's bay. Further north-west *P. oceanica* reappears between Fomm ir-Riħ and Anchor bay, with patches growing on sand and rock. Around the Island of Gozo, *P. oceanica* is widely present along the north-eastern coast. Further west and up *Posidonia* is located in two small zones: one at Dwejra (with rare patches) and another just outside the Mgarr harbour. The channels between Gozo and Comino and Comino and Malta are covered by a dense *P.*

oceanica growing on matte. The meadow further continues close to the Maltese coast and St. Paul's Islands (Mifsud et al., 2006).

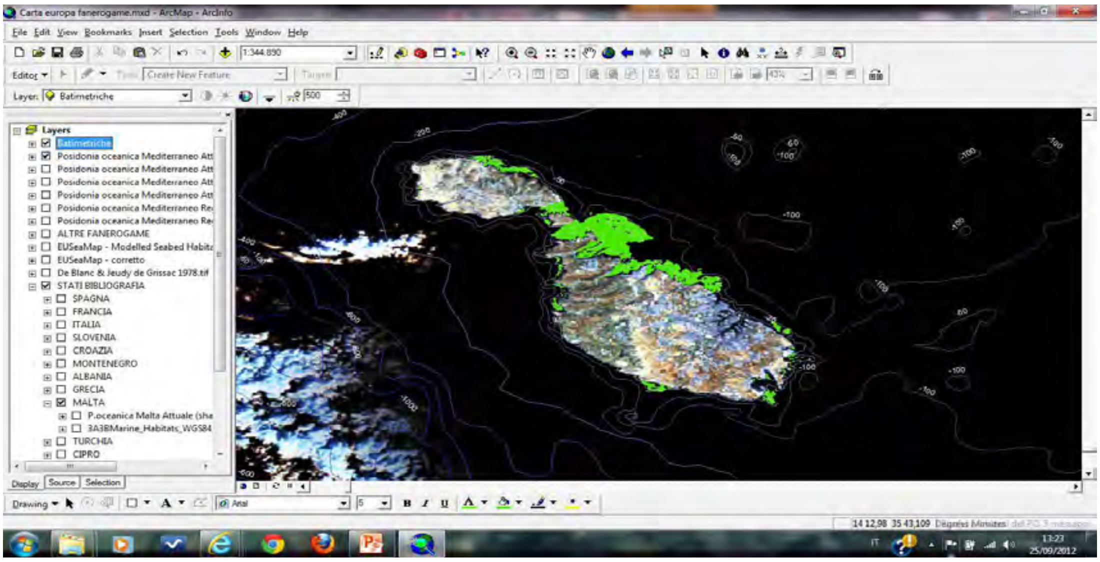


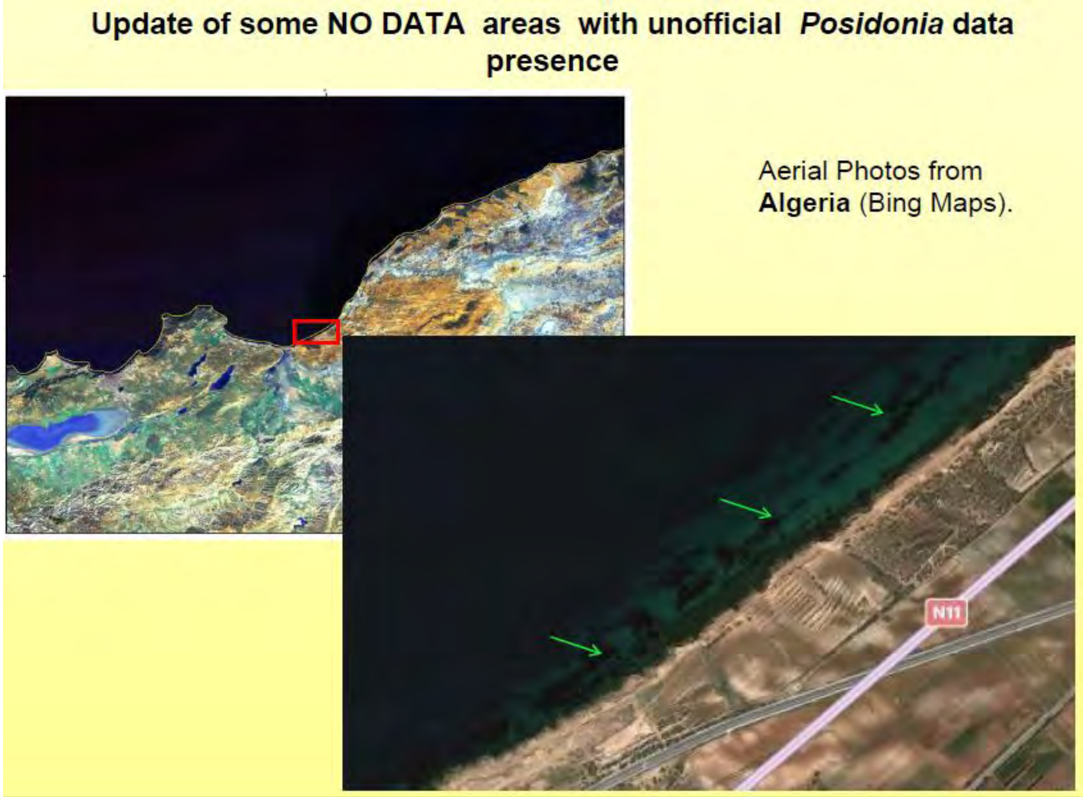
Fig.1.1.36. GIS example of *P. oceanica* current distribution (green) and lost area (red) along the Maltese coastline.

Other Countries

In the Eastern Adriatic Sea coasts only "presence points" of seagrasses are available for Slovenia, Croatia, Montenegro. In these Countries several coastal habitat mapping projects are still ongoing. Croatia is implementing the Natura 2000 marine Community Interest Sites, and Posidonia seems to be largely present.

Posidonia cartography is complete for Albania, where *Posidonia* is largely distributed. In this Country 2.837 ha of *Posidonia* meadows were mapped. Eleven meadows were identified between Cape Rodon (northern coast) and Cuke (southern coast).

The current distribution of *Posidonia oceanica* meadows along the western side of the African coasts is not well assessed. Information for Algerian and Moroccan coasts is rare and spotted. However, in the eastern side of Algeria qualitative studies describes *P. oceanica* meadows in a healthy status with a lower limit of around 35 m deep. The lack of human pressure in this wide area and the geomorphological structures of the coastal area let us imagine a wide coverage of meadows. Aerial photos from Bing Maps show the presence of seagrass along the coasts.



Update of some NO DATA areas with unofficial *Posidonia* data presence

Aerial Photos from **Algeria** (Bing Maps).

Fig.1.1.37. Aerial photo showing *P. oceanica* meadows presence along the Algerian coasts.

Information on the current spatial distribution of *P. oceanica* and other seagrass meadows along the Libyan coasts are very scattered and scanty. However, several studies carried out in coastal lagoons (Farwa, Garaboulli, Ain Al-Ghazala) describe *P. oceanica* meadows characterized by peculiar atoll-shape structures. Although information on the eastern Libyan coasts (Cirenaica region) are completely lacking, geological features of this area allow us to imagine presence of *P. oceanica* meadow.

Only localized knowledge is available about the distribution of *Posidonia* meadows in Egypt.

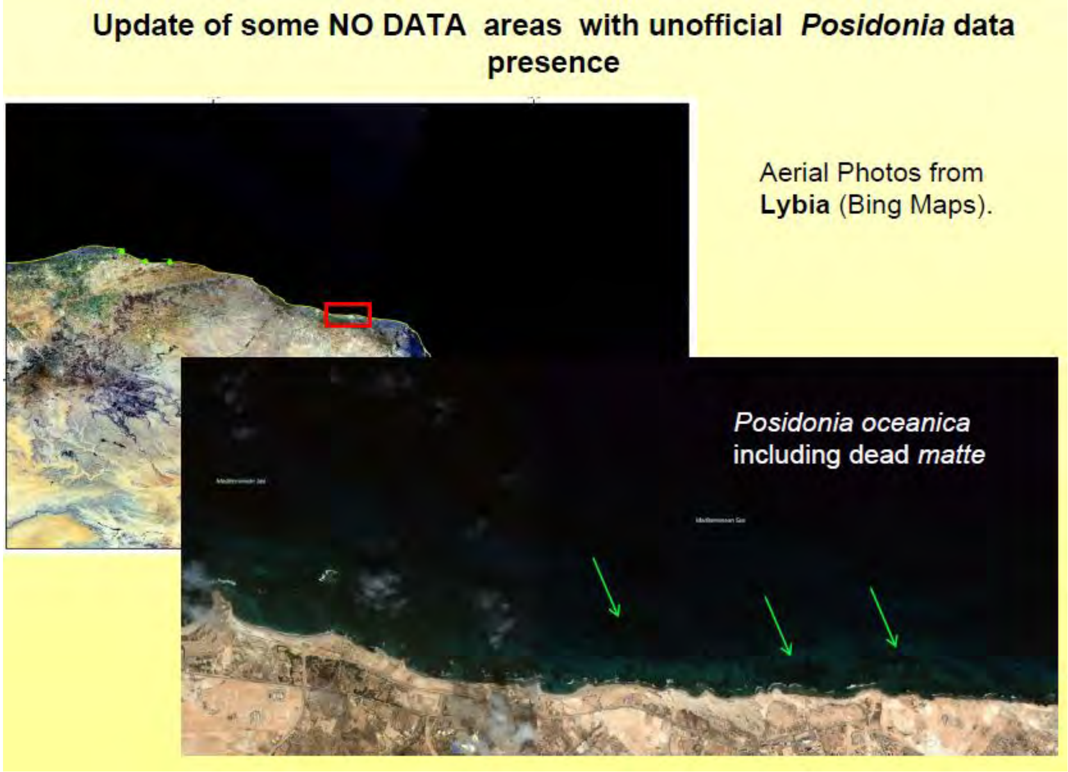


Fig. 1.1.38. Aerial photo showing *P. oceanica* meadows presence along the Libyan coasts.

Presence of seagrasses are confirmed along the Turkish Aegean coasts and in few localities along the southern coasts of Turkey.

Few data are available for Cyprus (some mapped areas deriving from Natura 2000 dataset), where *Posidonia* seems to be well present.

Difficulties encountered and remedial actions

The project collected the maximum of available information on the seagrass distribution in the Mediterranean Sea. The main problems encountered and solved were:

- The great amount of information that was available in different formats (i.e. scientific papers, reports, grey literature, websites, etc.) and the long time needed to collect it.
- The great heterogeneity in the scale of available maps (from 1:1.000 to 1:250.000) and the legends that use a suite of apparently not standardised symbols i.e., "*Posidonia*" is represented as *Posidonia* on matte, *Posidonia* on sand, *Posidonia* on rock, degradated *Posidonia*, *Posidonia* and isolated shoots, *Posidonia* and dead matte, dead matte, etc.
- Different geographical projection and datum in the available maps per Country, Region, Author.
- Lack of georeferenced information in many .doc or .pdf documents.

For all these problems different solutions were found. All available information was added into a bibliographic database and all the "geo-referenced" information into an ArcGis project, independently from the scale (this is the reason of the different resolutions in the restitution) and the legend (we consider the category "Posidonia" independently from the substrate or other). This work has requested considerable time to complete. To geo-reference the different geographic projections and datum in a unique format finally optimized our result.

Another problem was the lack of suitable data for certain areas. For the western Mediterranean basin we feel confident that the distribution map of *Posidonia* meadows represents the real distribution of *Posidonia*, for the eastern Mediterranean basin this is not the case. In most cases “absence area” actually corresponded to “non-available data”. This has been a hard job for the experts of the Consortium, involving reading of the available papers and reports and contacting local experts to obtain the right information.

A solution of “graphic type” has been adopted to solve the problem, highlighting the two different kinds of “absences”.

The main difficulty, however, was the lack of geo-referenced files in shapefile format for most countries. In fact, often the information is available only in the form of paper maps such as .jpeg file or text in .pdf or .doc. In certain cases the data owners have not agreed to provide us with .shp formats.

For some countries like Italy the problem concerned limited areas while for other countries, like France and Spain, the problem concerned very extensive areas. The problem was solved only in part using for the French coasts the information from the EUSeaMap project, but it remains for the northern coast of Spain. A time consuming solution to this problem involved the “manual digitizing” of the maps available in hard copy. For the Spanish coasts the problems concerned mainly the Catalonia Region. An effort has been directed to get additional information and greater cooperation with the RAC/SPA, under whose direction several projects of seagrasses mapping in the eastern Mediterranean basin are ongoing.

Another problem was related to the other segrassess species (*Cymodocea, Zostera* spp., *Ruppia* spp., *Halophila*) for which only point/ scattered information/ maps in paper are available. Therefore, the estimation of the real extension of their distribution grounds across the Mediterranean basin is not available. Gaps in knowledge per species and suggestions for improvement are cited in Table 1.1.12.

As far as the historical maps concern, despite the fact that there is a lot of information on the regression of *P.oceanica* around the Mediterranean basin, detailed geo-referenced and comparable maps are scarce. Thus we decided to proceed by analyzing "case studies" for those areas where information is available, and utilize only "graphical signs" for other areas.

Gaps in knowledge and suggestions for future actions

Table 1.1.12 reports the gaps in knowledge identified during the MEDISEH project.

Table 1.1.12. Gaps in knowledge

Gap	Proposal
Posidonia oceanica: Not completely known the distribution of meadows along the coast of Croatia, Greece, Libya, Algeria, Egypt and Tunisia due to the lack of investigation or diffusion of data, also if several project are locally ongoing.	Complete the *Posidonia* meadows mapping along the countries for which we have less information (eastern and southern coasts of the Mediterranean Sea) to confirm their presence or absence (historical absence too).
	Complete and confirm the personal observation along the coasts of Greece with ad hoc characterization surveys, to complete the map of the current real extension.
	Mapping of the *P. oceanica* meadows where it is not well known in order to propose the establishment of new marine protected areas (SCIs or MPAs) where appropriate

Gap	Proposal
	protection measures (Croatia) are not already taken.
Cymodocea nodosa: Limited map distribution for most of the Mediterranean countries	Increase the knowledge on the distribution of *Cymodocea nodosa* by characterization survey along the Med. coasts
Other seagrass: Only point data or very limited distribution maps for most of the Mediterranean countries. Many seagrasses are distributed mainly in coastal lagoons. Probably misunderstanding in species identification in many areas.	Increase the knowledge on the distribution of other seagrasses by characterization survey, especially inside coastal lagoons and closed waters.
	Monitoring the expansion of *Halophila stipulacea* in the western Mediterranean basin (mainly along the southern coasts of the Mediterranean and Tyrrhenian Sea).
Very abundant but locally sparse and not organized data (parameters, indices, etc.) on Posidonia meadows health status.	Creation of a Mediterranean standardized database to collect and elaborate information on health status of meadows
A large variety of known local cause of Posidonia meadows regression are available but lack of a large scale approach and of a coordinate plan at Mediterranean scale	Study on the health status of Posidonia meadows and regressive phenomena to understand, on a large scale, the actual extention of the problem.
	Monitoring the relationship between Posidonia (and other seagrass) distribution/regression and the diffusion of more competitive alien species (*Caulerpa* spp.).
	To improve the knowledge on the environmental factors that can influence Posidonia meadows regression
	To improve monitoring plans of the Posidonia meadows in the Mediterranean Sea.
Lack of historical data to evaluate the presence/status of Posidonia and other seagrasses during the time for many areas.	

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Task 1.2 Coralligenous and mäerl beds distribution along the Mediterranean coasts

(Scientific Responsible: Simonetta Fraschetti (CoNISMa), Partners involved: HCMR, CNR-IAMC, CNR-ISMAR, FCD (MSDEC), CIBM, CoNISMa)

Cited as: S. Fraschetti, M. Gristina, M. Salomidi, L. Knittweis, M.L. Pace, E. Punzo, A. Belluscio, G. Scarcella, F. Grati, F. De Leo, L. Rizzo, R. Cattaneo-Vietti, P. Povero, A. Cau, C. Piccinetti, V. Valavanis, C. Martin 2013. Coralligenous and mäerl beds distribution along the Mediterranean coasts *Mediterranean Sensitive Habitats* **(***MEDISEH) Final Report, DG MARE Specific Contract SI2.600741*

Background

Bioconstructors like coralligenous formations and mäerl beds are considered as a typical Mediterranean underwater seascape comprising coralline algal frameworks that grow in dim light conditions and in relatively calm waters (Ballesteros, 2006). They are the result of the building activities of algal and animal builders and the physical as well as biological eroding processes. Coralligenous is considered of great significance both for fisheries and CO_2 regulation. At present, results are showing that mechanical disturbance (Coma et al., 2004), sedimentation increase (Balata et al., 2005), species invasion (Baldacconi and Corriero, 2009), temperature increase (Garrabou et al., 2001) and water degradation (Giuliani et al., 2005) have all negative effects on species assemblages associated to coralligenous habitats. Those stressors can drive a decrease in species density and/or increase in mortality rates. Mäerl beds are biodiversity 'hot-spots' as they enhance biological and functional diversity of coastal sediments (BIOMAERL Team 1998; Bordehore et al. 2003; Steller et al. 2007). The same stressors potentially affecting coralligenous formations can be drivers of change of mäerl.

Regulation EC 1967/2006 defines these vulnerable habitats, upon which all destructive fishing practices should be banned as "coralligenous habitats", i.e. areas where the seabed is characterized by the dominant presence of a specific biological community named "coralligenous", or where such community has existed and is in need of restoration action, and "mäerl beds", i.e. areas where the seabed is characterized by the dominant presence of a specific biological community named "mäerl", or where such community has existed and is in need of restoration action.

Objectives

Task 1.2 aims at synthesizing historical and present knowledge on the distribution and status of coralligenous formations and mäerl habitats across the Mediterranean basin. Information on the past and current locations of coralligenous formations and maërl beds in different GSAs all over the Mediterranean basin will be stored into a common geodatabase according to a standardised format. The ultimate goal is an integration of data/maps deriving from ISI journals, reports, and grey literature, to establish an ongoing and consistent Mediterranean database of coralligenous and mäerl data able to document distribution, and, if possible, trajectories of changes over time.

Specifically, the objectives of Task 1.2 are summarised as follow:

- Review of historical and current data on the locations and the status of coralligenous formations and maërl beds in different GSAs all over the Mediterranean basin.
- Integrate and present the aforementioned information through a web-based GIS viewer with an associated geo-referenced database that will operate as a consulting tool for spatial management and conservation planning.
- Following the revision of the knowledge base, to identify gaps and suggest future research priorities.

In order to meet these objectives within the framework of MEDISEH an expert team was composed within the MAREA Consortium from scientists with long term expertise on coralligenous and mäerl beds, habitat modeling, spatial statistics and GIS expertise working at different areas in the Mediterranean basin. The team for the execution of the project covers the majority of institutes within the EU countries of the Mediterranean with a strong reputation in this field. The participating Institutes/Entities operate in the Western, Central and Eastern part of the Mediterranean basin that guarantees the familiarity with the geographical areas that are related to the specific tendering. Moreover, a large number of scientists outside the MAREA Consortium collaborated on a volunteer basis with data and input. Details on the list of experts and external collaborators one can see below at Table 1.2.1. For CV details check MAREA expert web-site *http://www.mareaproject.net/*.

Table 1.2.1. Expert list involved in WP1, Task 1.2.

Participant	Participant affiliation
S. Fraschetti	CoNISMa
A. Belluscio	CIBM
M. Gristina	CNR-IAMC
M. Salomidi	HCMR
C. Martin	HCMR/ Current affiliation: UNEP-WCMC (Cambridge, UK)
L. Knittweis	FCD - MSDEC, Malta
M.L. Pace	FCD - MSDEC, Malta
G. Scarcella	CNR ISMAR
E. Punzo	CNR ISMAR
F. Grati	CNR ISMAR
F. De Leo	CoNISMa
L. Rizzo	CoNISMa
R. Cattaneo-Vietti	CoNISMa
P. Povero	CoNISMa
A. Cau	CoNISMa
C. Piccinetti	CoNISMa
V. Valavanis	HCMR, Input from WP3

Moreover, for organisation purposes responsibilities for Coralligenous/Maërl Data Collection were allocated per partner and area based on the scheme below

HMCR (M. Salomidi) for GSAs: 20, 21, 22, 23, 24, 25, 26

CNR-IAMC (M. Gristina) for GSAs: 1, 2, 3, 4, 5, 6, 12, 13, 14, 15, 16

CIBM (A. Belluscio) for GSAs: 7, 8, 9

CNR-ISMAR (G. Fabi, E. Punzo, G. Scarcella) for GSA: 17

CONISMA (S. Fraschetti, F. De Leo, L. Rizzo, A. Terlizzi, R. Cattaneo-Vietti, P. Povero, A. Cau, C. Piccinetti) for GSAs: 9, 10, 18, 19

A number of colleagues were finally contacted across the Mediterranean Sea to get information and data: E. Cebrian and E. Ballesteros (Spain), G. Bavestrello (Italy), B. Mikac (Croatia, Palermo), V. Macic (Montenegro), B. Ozturk (Turkey), J. Ben Souissi (Tunis).

Deliverables and Milestones foreseen

The following table describes the Task Deliverables and Milestones as foreseen by the proposal.

Table 1.2.2. Task Deliverables and Milestones based on the proposal.

Deliverable	Description	Timeframe
M1.2.1	Revision of existing information of past coralligenous and mäerl beds along the Mediterranean coast.	Month 6
M1.2.2	Revision of existing information of current coralligenous and mäerl beds along the Mediterranean coast.	Month 6
M1.2.3	Production of GIS files indicating the position of past and current coralligenous and mäerl beds along the Mediterranean coast.	Month 8
D1.2.1	Georeference database covering all revised information on coralligenous beds spatial distribution	Month 6
D1.2.2	Georeference database covering all revised information on mäerl beds spatial distribution	Month 6
D1.2.3	Integrated maps presenting the known spatial distribution of coralligenous habitats and mäerl beds across the Mediterranean	Month 8
D1.2.4	GIS compatible file for input to WP3	Month 8

Progress achieved

Within the framework of Task 1.2 and according to MEDISEH proposal four meetings were held to follow the progress achieved by the project. Specifically:

A one day workshop took place following the kick-off meeting of the project that was held in Heraklion (Crete) in October 2011, in order to standardise the work among the partners involved, standardise the input data format in order to be suitable for modeling. In addition an introduction on the modeling techniques that could be applied was made. In the meeting have been involved: Eugenia Apostolaki, Vasilis Gerakaris, Vessa Markantonatou, Maria Salomidi, Nadia Papadopoulou, Chris Smith and Vassilis Valavanis (Greece), Leyla Knittweis (Malta), Gianna Fabi, Fabio Grati, Michele Gristina, Andrea Belluscio (Italy) and the task coordinator Simonetta Fraschetti (Italy).

A two days workshop was held within the second meeting of the MEDISEH at Palermo (Sicily) in February 2012 along with Task 1.1. The aim of this workshop was to define environmental and/or anthropogenic variables to be tested for habitat modeling depending on data availability. The first session on Monday 6th February involved presentations by S Fraschetti (general introduction plus data on GSA 18-19, M. Salomidi on Eastern (and partly Central) Mediterranean (GSA 20,21,22,23,24,25,26,27,28), G. Scarcella on the Adriatic Sea (GSA 17), M. Gristina on Sicily (GSA 16). On Tuesday 7th and Wednesday 8th February (Workshop) the discussion focused on the problems of modeling. The general discussion that followed mainly addressed the difficulties encountered. On Tuesday 7th and Wednesday 8th February (Workshop) the discussion focused on problems related to habitat modeling**.**

A two days workshop was organized within the third MEDISEH meeting in Rome (Italy) in September 2012 along with Task 1.1. and Task 1.3. The aim of this workshop was to evaluate habitat model input for coralligenous and mäerl along with initial modeling results and discuss in collaboration with Task 1.3 ways to improve models. The first session involved presentation of the status of knowledge by the time of the meeting by S. Fraschetti (CONISMA) and modeling results by C. Martin (HCMR). In a subsequent step experts from Task 1.2 and Task 1.3 examined carefully, area by area, modeling results along with the quality of input data in each area and inproved input dataset. The discussion continued in the third day focusing on the available variables used for modeling, the spatial and temporal resolution available and on the possible ways to improve.

A two days workshop was organized within the fourth MEDISEH meeting in Heraklion (Greece) in January 2013 along with Task 1.1. and Task 1.3. During the workshop an update on data input from the Western Mediterranean was presented. The workshop focused on the evaluation of the modeling results per area as presented from colleagues working in Task 1.3. A thorough discussion followed on ways to improve in results certain areas along with some further modeling trials. The planning of work in order to finalize and optimize the modeling approach was also discussed and agreed.

Meetings agenda are cited in the annexes and MEDISEH website. Moreover, details on the progress achieved towards the Task deliverables and milestones of the project are cited below.

Sources of data

A lot for information has been derived from three critical sources: the first is the Action plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea by the UNEP-MAP-RAC/SPA (2008) followed by the report in the State of knowledge of the geographical distribution of the coralligenous and other calcareous bio-concretions in the Mediterranean by UNEP (2009). Together with these two initiatives, at present, there are other projects carried out at national and international scale focusing on bioconstructions, their distribution and the driving forces affecting their structure and function. Among the others:

- EuSeaMap (http://jncc.defra.gov.uk/page-5020) (2010)
- EMODnet (http://bio.emodnet.eu)
- Med Sea (http://medsea-project.eu) (2011-2012)
- MEDCHANGE (http://sudek.esil.univmed.fr/medchange/spip/) (2007-2012)
- Biomap (http://www.biomapping.it/index/) (2011-2012)
- Synthesis of the cartographic information on the coralligenous assemblages and other biogeniccalcareous formations in the Mediterranean Sea (web site not available) (2008)
- MoBioMarCal (http://www.regione.calabria.it/ambiente/index.php?option=com_content and task=view and id=130 and Itemid=67) (2005-2009)
- Biodiversità del Canale di Sicilia (web site not available) (2010)
- Maërl (web site not available) (2010)
- CoCoNet (2012-2016) web site is available http://www.coconet-fp7.eu
- www.ambienteinliguria.it (www.remare.org/) data are available on coralligenous mapping of the Ligurian Sea
- CONISMA-ISPRA: Uso del ROV (Remotely Operated Vehicle) nella definizione applicativa di piani di gestione per il corallo rosso (*Corallium rubrum*). Strategie gestionali per la conservazione della specie e valutazione della compatibilità della risorsa con un potenziale sfruttamento commerciale lungo le coste italiane del Tirreno centro-settentrionale. Responsabile G. Bavestrello. (2012-13)

In addition, we need to thank a number of colleagues outside the MAREA consortium that were contacted across the Mediterranean Sea and provided us information and data on the spatial distribution of coralligenous and mäerl:

- **E. Cebrian and E. Ballesteros (Spain),**
- **G. Bavestrello (Italy),**
- **C. Venier (Italy)**
- **A.R. Zogno (Italy)**
- **S. Rizzardi (Italy)**
- **L. Faresi (Italy)**
- **B. Mikac (Croatia, Palermo),**
- **V. Macic (Montenegro),**
- **B. Ozturk (Turkey),**
- **J. Ben Souissi (Tunis),**
- **I. Benamr (Libya)**
- **M. Aplikioti (Cyprus).**

As already stated in the case of *Posidonia* meadows, several habitat mapping efforts for coralligenous formations and mäerl have been carried out through different national and international initiatives without the use of a common spatial and temporal resolution.

Here, an inventory of the available maps on the distribution for coralligenous formations and mäerl have been carried out together with a review concerning existing information on the complex suite of biological and environmental factors associated with these habitats. All the relevant maps have been gathered and standardized within a geodatabase system for spatial data storage and management according to a common format. This analysis allowed the identification of those areas where the information about distribution and spatial features of the coralligenous formations and mäerl are more consistent and that can be used as case study areas for the development of species distribution models (suitability models). At the same time, this analysis will help to define geographical areas with scarce knowledge that would require data integration and the identification of areas suitable for coralligenous formations and mäerl. A systematic analysis of human impacts will also be needed to increase our understanding of how multiple pressures influence biogenic habitats, and to identify priority issues and focal areas for conservation action.

Detailed tables of the references used are reported as supplementary Excel tables in Annex 1.2.1 at the respective folder of the ftp (http://mareaproject.net/FTPMareaProject/#15/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.2/ Annex 1.2.1/Deliverables 1.2.1_1.2.2.xls)

Results

A total of 798 scientific documents have been collected up to now, together with 43 shapefiles, 1492 polygons and 641 data points for coralligenous formations, 47 polygons and 124 data points for maërl, and 39 bathymetric maps within the framework of MEDISEH project. Even though proving information about *absence data* for both coralligenous and mäerl can be extremely difficult, an attempt has been made and 584 polygons have been included for coralligenous formations and 935 for maërl data. Detailed information for these two habitats is now available on about 15% of the Mediterranean coastal area.

Additional to the foreseen deliverables we revised and formed a list of 2339 taxa (the geographic information specifying where data are available at species level can be found in MEDISEH_wp1.2 Supplementary Tables and in the Species_List_Report) related to coralligenous/ maërl. This information can be further analysed to show specific patterns at assemblage level. This can be interesting from an ecological perspective and useful for modeling purposes.

Figure 1.2.1 shows the knowledge existing prior to MEDISEH project (i.e. from the effort of UNEP / RAC SPA of 2009). From inspection of Figure 1.2.2, it is clearly evident the progress reached through MEDISEH MAREA. Despite the fact that the scientific information is still unevenly distributed (much more studies dealing with the western Mediterranean), areas previously totally unknown are now better covered. Also, critical information has been collected for the eastern Mediterranean Sea in terms of habitat presence. The discussion on this data set arrived to the conclusion that coralligenous formation is much more widespread than the scientific community could even figure out. Basically, bioconstructors such as coralligenous can be very common from 18 - 20 down to 100 meters and more. The knowledge about mäerl is far behind, but also for this habitat considerable update has been achieved. Collected information shows a high heterogeneity in term of:

- Data (points source, shapefiles, georeferred data)
- Scales: from 1:4000 to 1:250000
- Legends: coralligenous formations and maërl are represented with a suite of apparently not standardized symbols

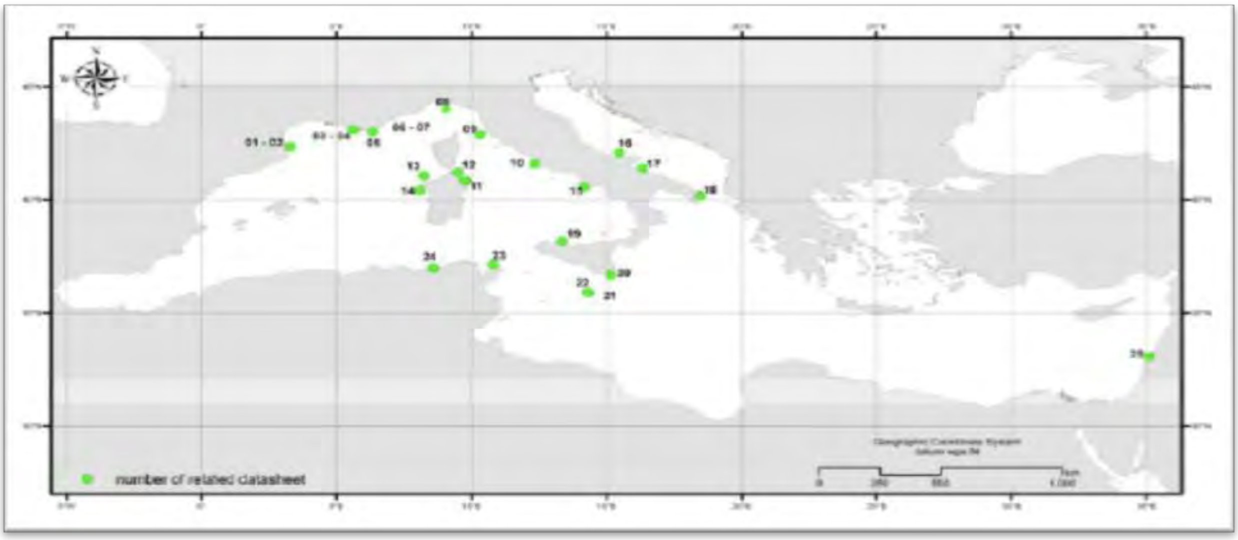

Fig. 1.2.1. Knowledge existing before this project (From the effort of UNEP / RAC SPA of 2009).

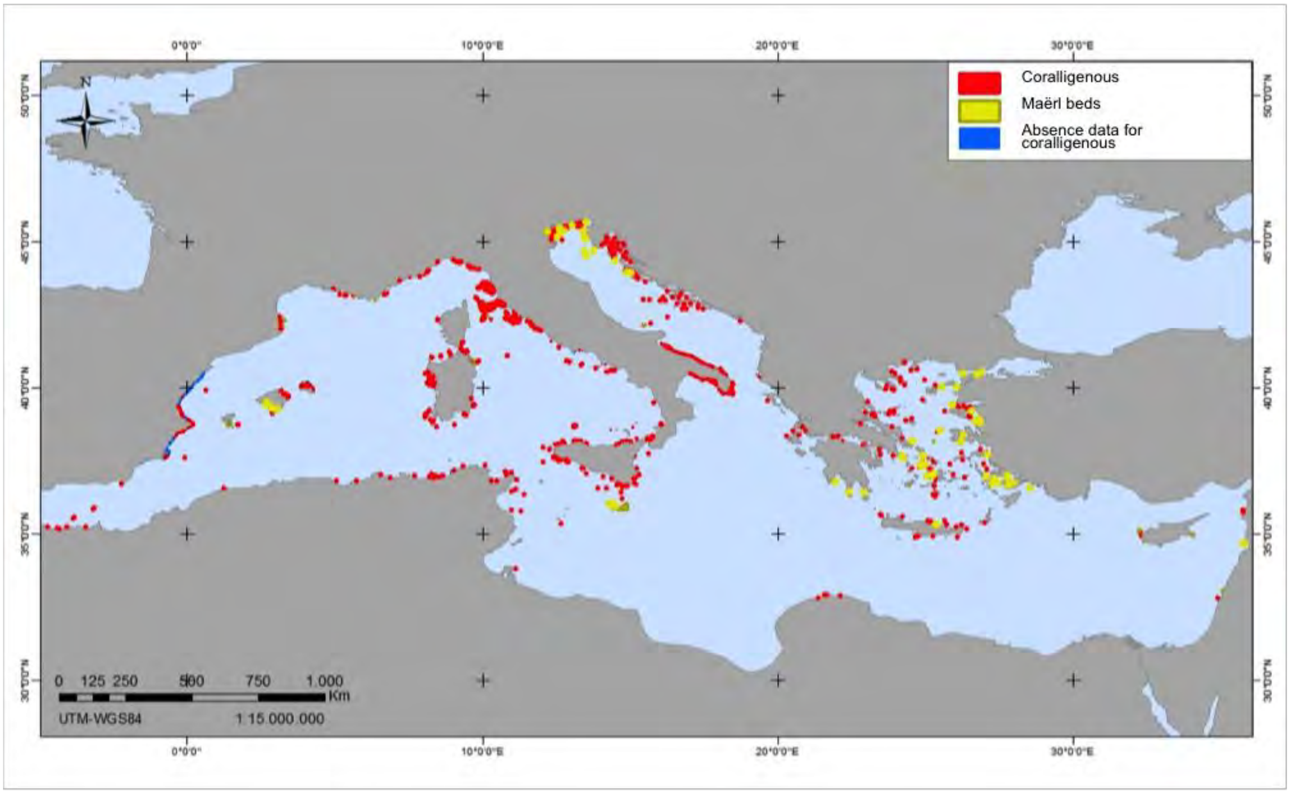

Fig. 1.2.2. The figure represents "the state of art" on the distribution of these two habitats at basin scale and it is a step forward of the knowledge existing before this project (seen in Fig. 1.2.1), especially as far as the eastern Mediterranean. It combines different sources of informations. In the legend, the information on *absence data* refers to those areas where the inspection of detailed cartographic informations showed the absence of coralligenous (Map in detail at http://mareaproject.net/mediseh/viewer/med.html).

One of the Countries where knowledge is quite good is Italy. Here, distribution maps of bioconstructions are available in shapefiles for several Italian coasts (Ligurian Sea, Tyrrenian Sea, Apulia, Sicily) (Fig. 1.2.3). Apulia, Toscana, Sicily and Liguria are, so far, the regions where mapping activities have been carried out more systematically, and, in general, Italy has demonstrated a strong interest towards this habitat also in terms of the effects of different sources of stress.

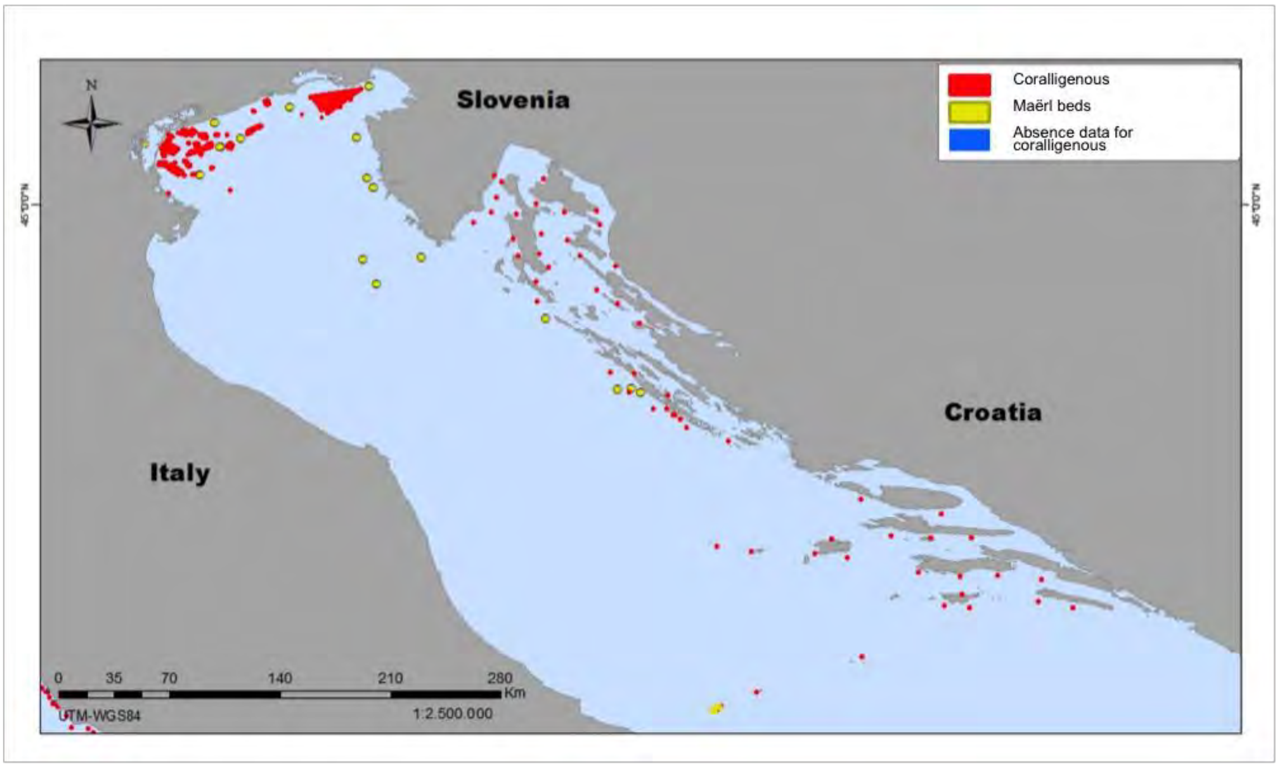

Fig. 1.2.3. Distribution of bioconstructors in the northern and southern Adriatic Sea (more details are provided in the text).

In the northern Adriatic Sea several “points” of coralligenous-maërl are available for the coasts of Italy. In this area, an effort has been carried out to map peculiar formations called *tegnùe*, *trezze presure* or *grebeni*, submerged rocky substrates of biogenic concretions irregularly scattered in the sandy or muddy seabed and containing extraordinary zoobenthic assemblages (Casellato and Stefanon, 2008). Recently, a study of macroalgal assemblages of this area revealed important differences with the coralligenous assemblages found in other areas of the Mediterranean Sea. For Croatia only point data sources are available, even though it is clearly evident that coralligenous might be largely present in this area. Very few data refer to maërl. Some information is available for Albania while no information is officially available for Montenegro, even though there are internal reports referring to the presence of bioconstructions (Fig. 1.2.4). In Apulia, there are a lot of data on the presence of bioconstructions (as the map shows) and this information will be refined through the on-going project BIOMAP (see project list), since the continuous distribution suggested by this map is just a rough assessment of the real distribution. Good quality data are instead available for the three Marine Protected Areas (Archipelago Tremiti, Torre Guaceto, Porto Cesareo) where the available resolution is at 1:5000.

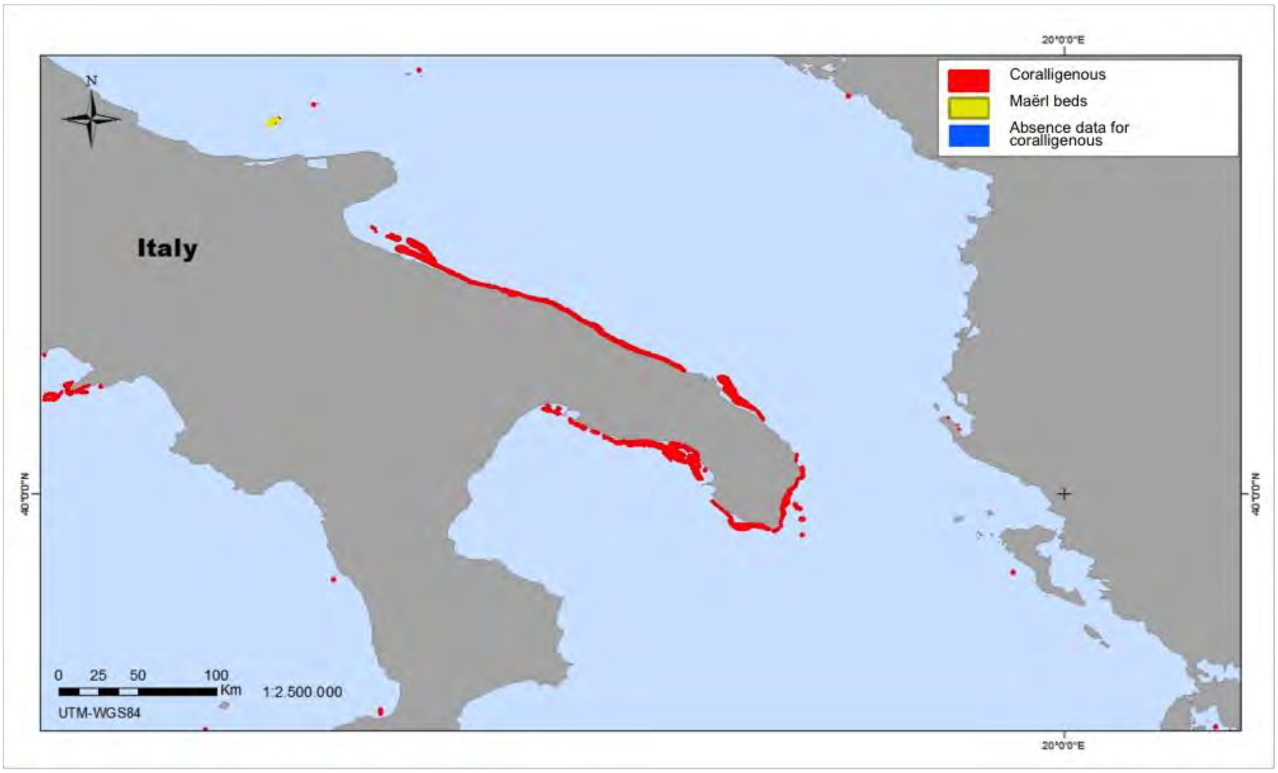

Fig. 1.2.4. Details on the southern Adriatic Sea.

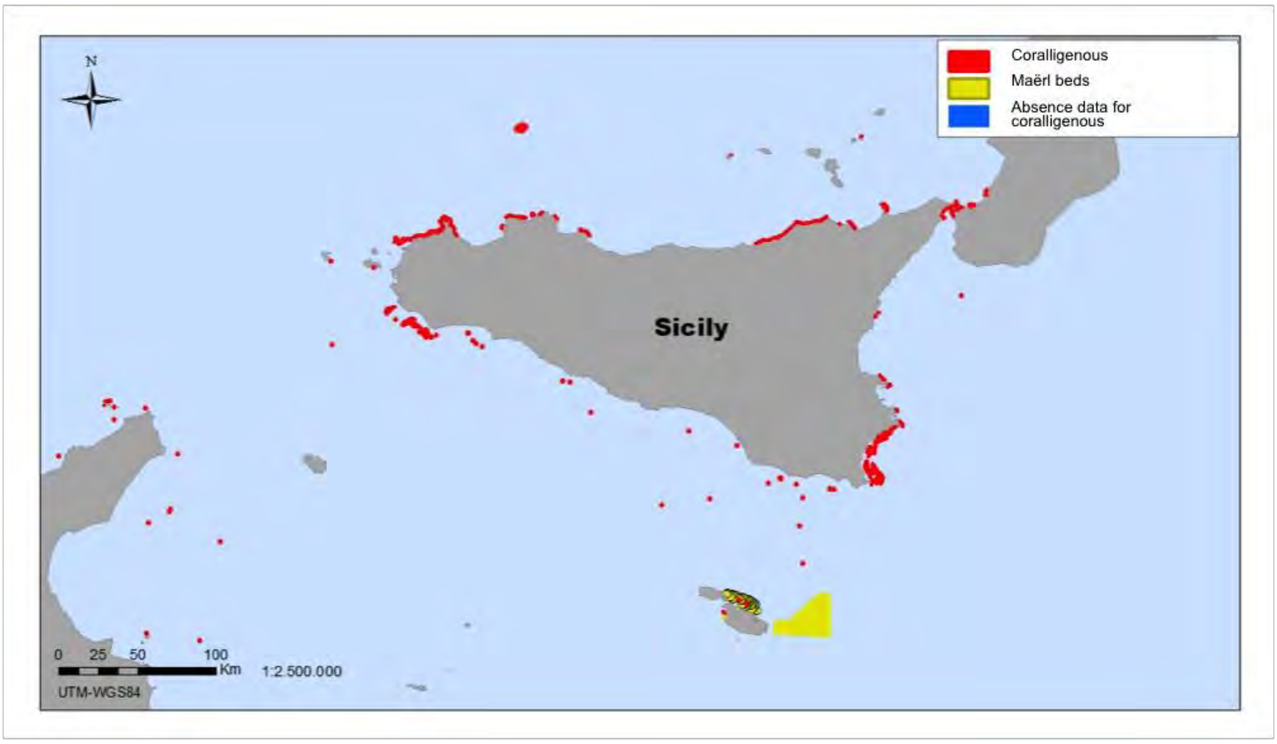

Fig. 1.2.5. Details on Sicily (Italy), Malta and Tunisia (more details later on in the text).

Limited information has been included for Calabria region, even though several projects have been carried out in this area (see the project MoBioMarCal). Specific studies referring to these projects have been included in the analysis of the literature. It is a common opinion, that while the Thyrrenian portion of the region is featured by large extension of this habitat, it might be nearly absent in the Ionian portion of it. In Sicily, it is evident the effort that has been done to analyze the distribution of this habitat and the ongoing project

MEDCHANGE, involving several partners across the basin, will surely increase present knowledge. For Malta, all the information available on the location of mäerl habitats is given in this map. Only the eastern part of Malta has waters shallow enough to support maërl habitats (Malta Bank) (Fig. 1.2.5). Whilst the mäerl bed located to the northeast of Malta has been mapped in detail (Sciberras et al. 2009), data on the precise location of the mäerl bed to the southeast of Malta (yellow polygon) is lacking and the current extent of the mäerl bed is based on a rough extrapolation of several points where mäerl fragments have been located (Dimech at al. 2007).

A set of "points data" are only available for Tunisia (less than 10% of coverage) (Fig. 1.2.6), however personal communication with Tunisian colleagues allowed us to assume that it is largely represented northern of Tunis.

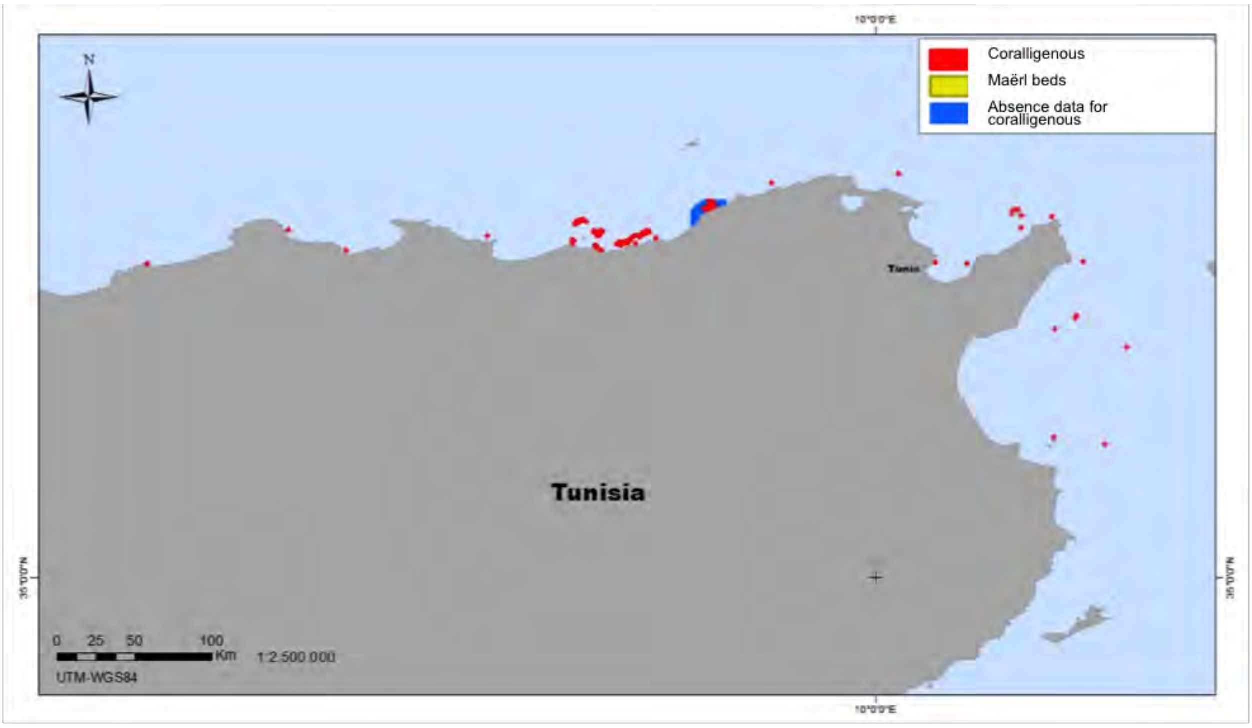

Fig. 1.2.6. Details for Tunisia. Also in this case, *absence data* are derived from the inspection of detailed cartographic information.

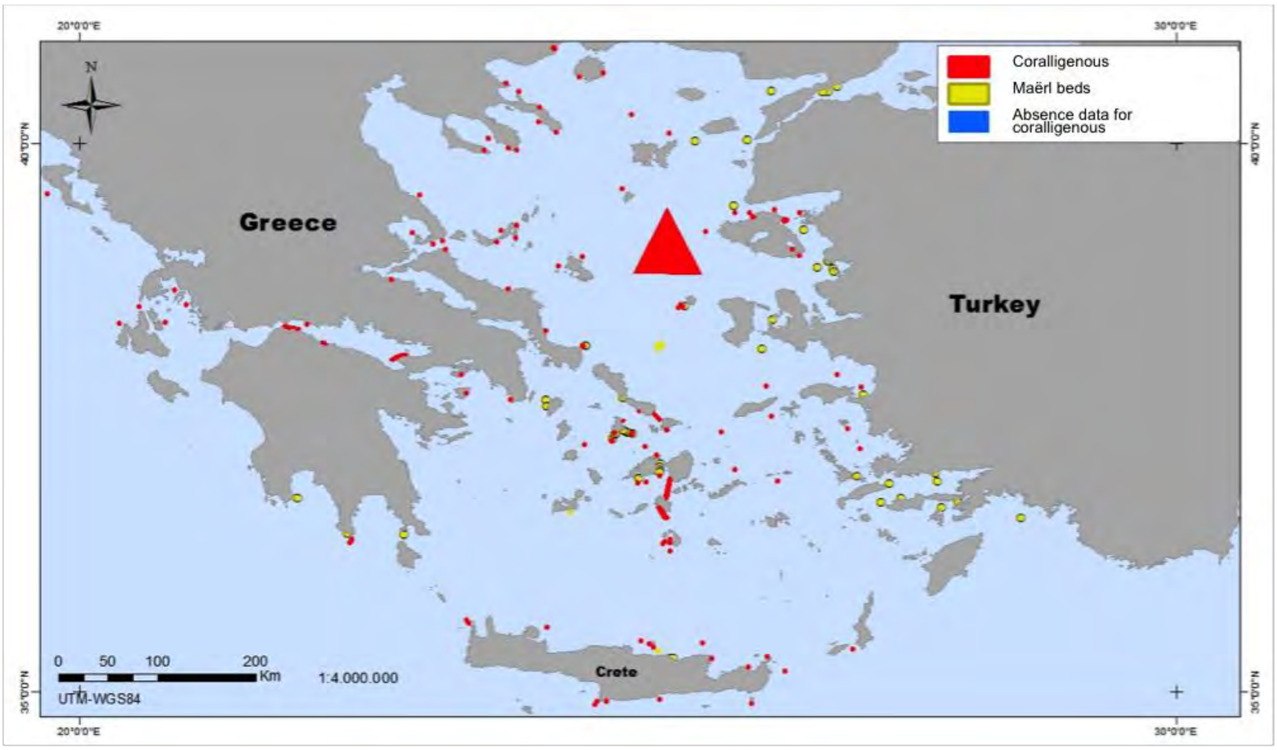

Fig. 1.2.7. Details of the Eastern basin: Greece and Turkey.

Fig. 1.2.8. Data for Cyprus, Syria, Lebanon and Israel.

In Greece, a lot of information is available even though present in the form of point source data (Fig. 1.2.7). Knowledge is very limited for N. Levant basin as far as Cyprus, Syria, Lebanon and Israel (Fig. 1.2.8); only few point data gathered from very few references. However, also in this case, it is clearly evident that coralligenous formation should be largely present. No information is available from Egypt. Ballesteros (2006) concludes that coralligenous buildups are common all around the Mediterranean coasts, with the possible exception of those of Lebanon and Israel (Laborel, 1987). According to Laborel (1961), the best developed formations are those found in the Aegean Sea, although the most widely studied banks are those of the northwestern Mediterranean.

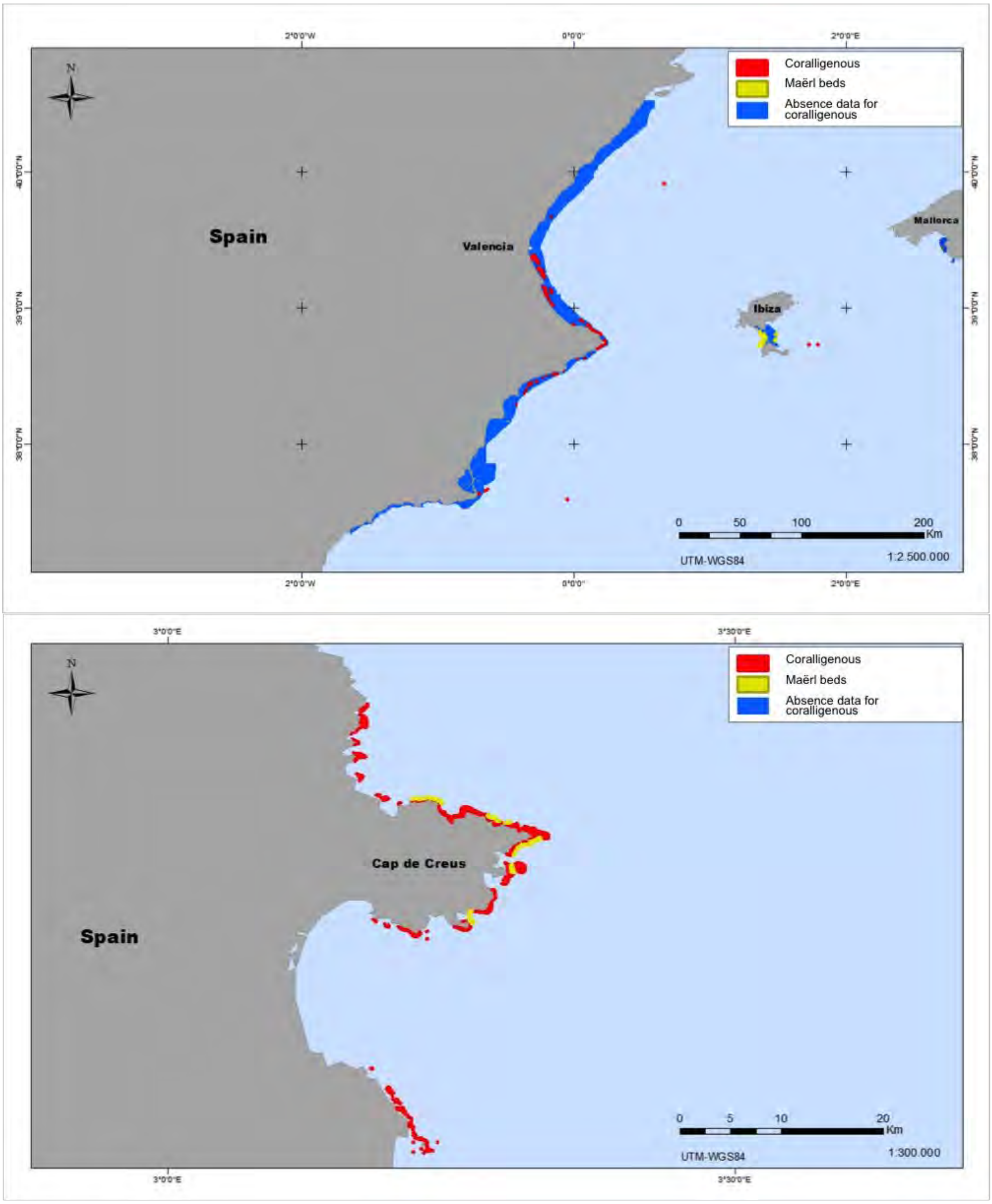

Fig. 1.2.9. (Upper): Coralligenous in Spain, including absence data. (Lower): a particular for Cap de Creus

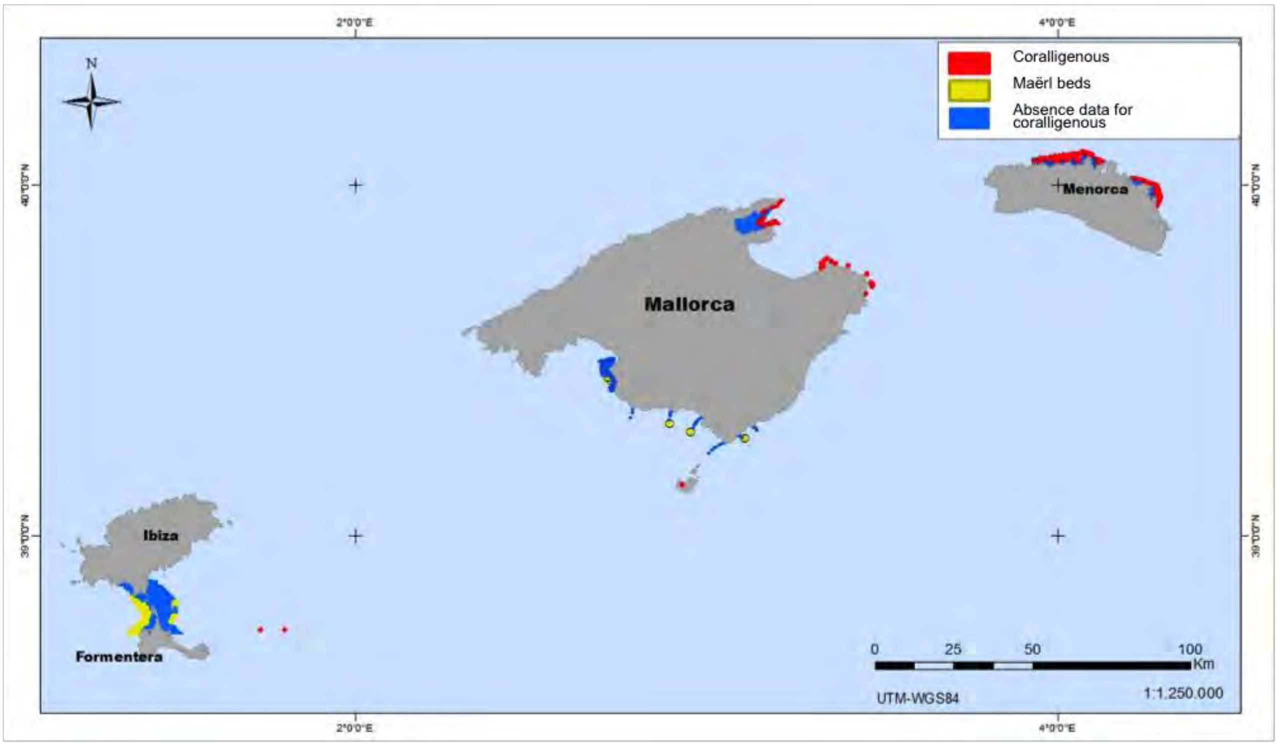

Fig. 1.2.10. (Upper): Coralligenous in the islands of Mallorca, Minorca, Ibiza and Formentera

Improved information is available for the coasts of Spain (Figs. 1.2.9 and 1.2.10) including the islands of Mallorca, Minorca, Ibiza and Formentera. This represents a considerable step forward if compared with the information provided by RAC/SPA (2009). In addition, recently, along the coast of Spain a lot of effort has been done to analyze the impact of climate change on coralligenous communities dominated by gorgonian species. This should allow us to understand better the impact of climate change as well as to reveal the underlying biological and genetic factors involved in the resistance of populations exposed to severe disturbances such as those related to climate change. However, the distribution of bioconstructions in the two countries can be easily assessed since all points deriving from publications focusing on these two regions have been included in this report. The same argument is valid for distribution maps of bioconstructions of France and the island of Corsica, even though several projects have been carried out for these stretches of coast (see for instance MEDCHANGE) (Fig. 1.2.11).

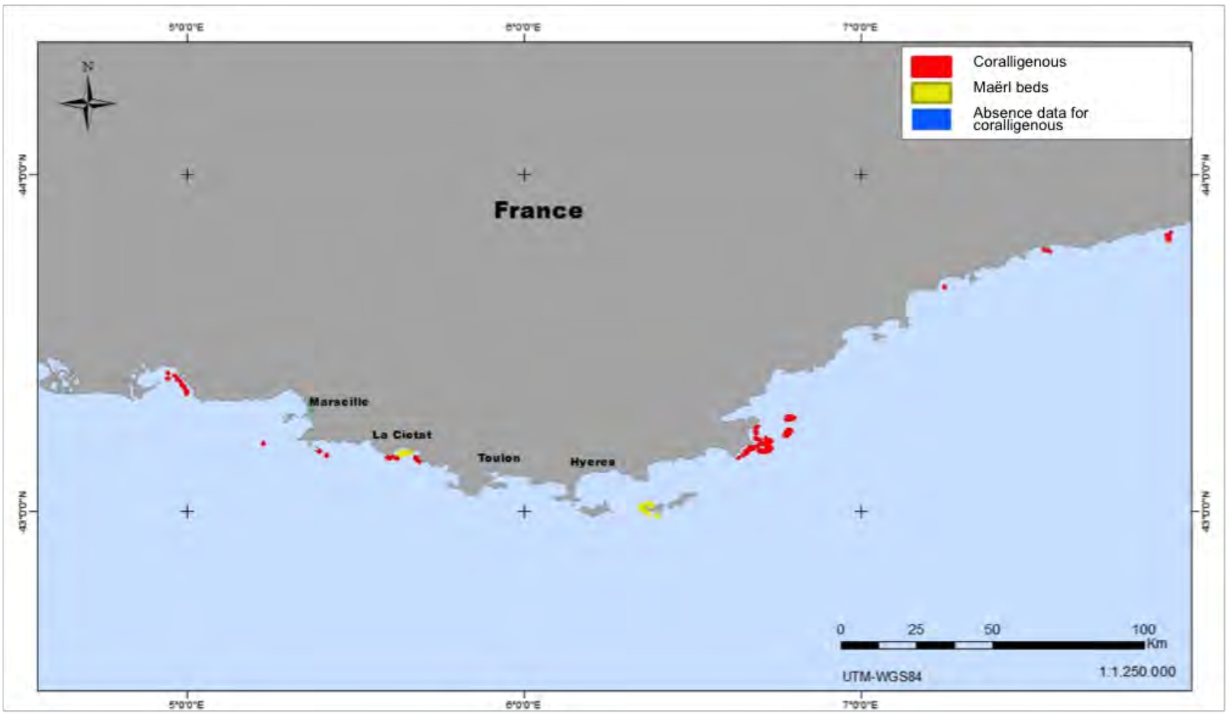

Fig. 1.2.11. Details for the France country.

In France, the information is still extremely limited. The same conclusion for Course, where, instead, this habitat should be largely represented.

In the Liguria Sea, the information, on the contrary, covers a relevant portion of the coast. Here, Marine Protected Areas have been mapped quite accurately. The Region made an important effort in this direction and studies have been also carried out to analyze the current conservation status of the habitat (fig. 1.2.12). The Ligurian Sea coralligenous reefs are highly endangered because of the occurrence of severe mass mortality events affecting benthic populations since 1999. The degradation of coralligenous reefs during massive necrosis is a major and underestimated threat, as most of these organisms have a very slow growth rate (0.006 - 0.83 mm/year). Unprecedented large-scale mass mortality events were recorded in 1999 and 2003, affecting about 30 benthic species over hundreds of kilometers of the NW Mediterranean coast. These mass mortality events coincide with great (3º- 6ºC above the usual) thermal anomalies during the summer and autumn stages, with an abnormal continuous inexistence of thermocline up to 45m depth and in consequence no water mixing and higher water temperature (up to 22ºC at 40m depth). Besides the two large scale episode in 1999 and 2003 mass mortality events occurred in 2005, 2006, 2008 and 2009 in the Ligurian Sea and are expected to occur more frequently in the near future representing a huge threat for the integrity of this precious reef habitat. In addition, coralligenous reefs in the Ligurian Sea are further endangered by several human activities insisting on the coastal zone including fishing, boating and scuba diving. These catastrophic events struck other sessile species belonging to anthozoans (*Cladocora caespitosa, Corallium rubrum*), sponges (mainly horny sponges), bivalves (*Spondylus gaederopus*) and ascidians (*Microcosmus* spp) on February 1985, October, 1993, September 1999, and July 2003.

The red coral *Corallium rubrum*, which is listed in Annex V of the European Union Habitats Directive, and commercial sponges like *Spongia officinalis* and *S. agaricina* have been also severely affected.

Considering the coastal surface colonized by gorgonians, it covers a belt of about 0.5 km^2 (from 30 to 50 m depth and with a density of about 10 colonies/m^2), and it is possible to estimate a loss of hundreds of thousands of colonies only along the Ligurian coastline after the 1999 and 2003 warmest events. Mass mortality events mainly affect suspensivore sessile organisms like sponges, tunicates, molluscs, echinoderms, coralline algae and mostly gorgonian species.

The most affected groups are those so called “engineering species” or “foundation species”, the “constructors” and those with important structural roles inside the community as coralline algae, sponges, bryozoans and gorgonians, especially *Paramuricea clavata*, the most affected gorgonian. Their occurrence enhances local biodiversity creating high heterogeneity in several environmental conditions like light, water movement, sedimentation and food dispersal. When foundation species disappear there is a shift from a highly diverse assemblage to a poor one, leading to a general loss of biodiversity.

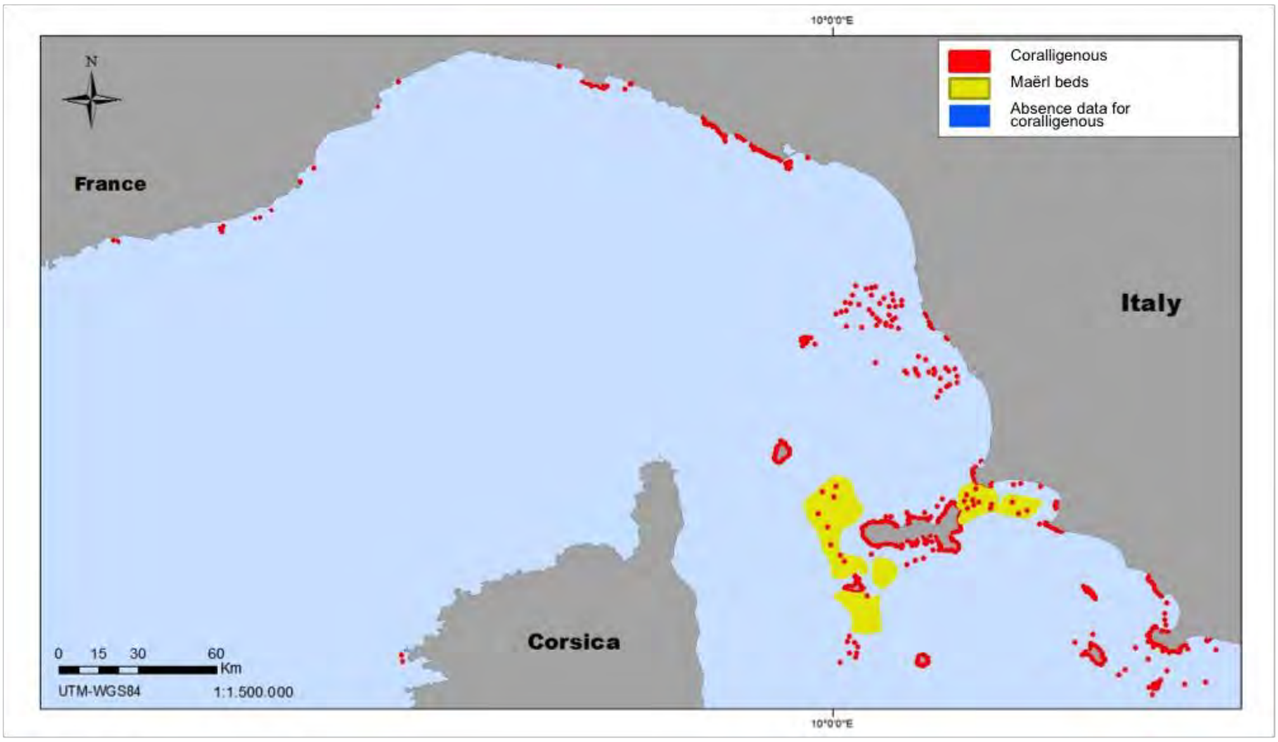

Fig. 1.2.12. Details from the Ligurian Sea and the Archipelago Toscano.

The Archipelago Toscano is featured by a lot of effort in terms of habitat mapping (Fig. 1.2.12). Here, experimental studies on the quantitative effects of different sources of impacts (from sedimentation to invasive species) are also available.

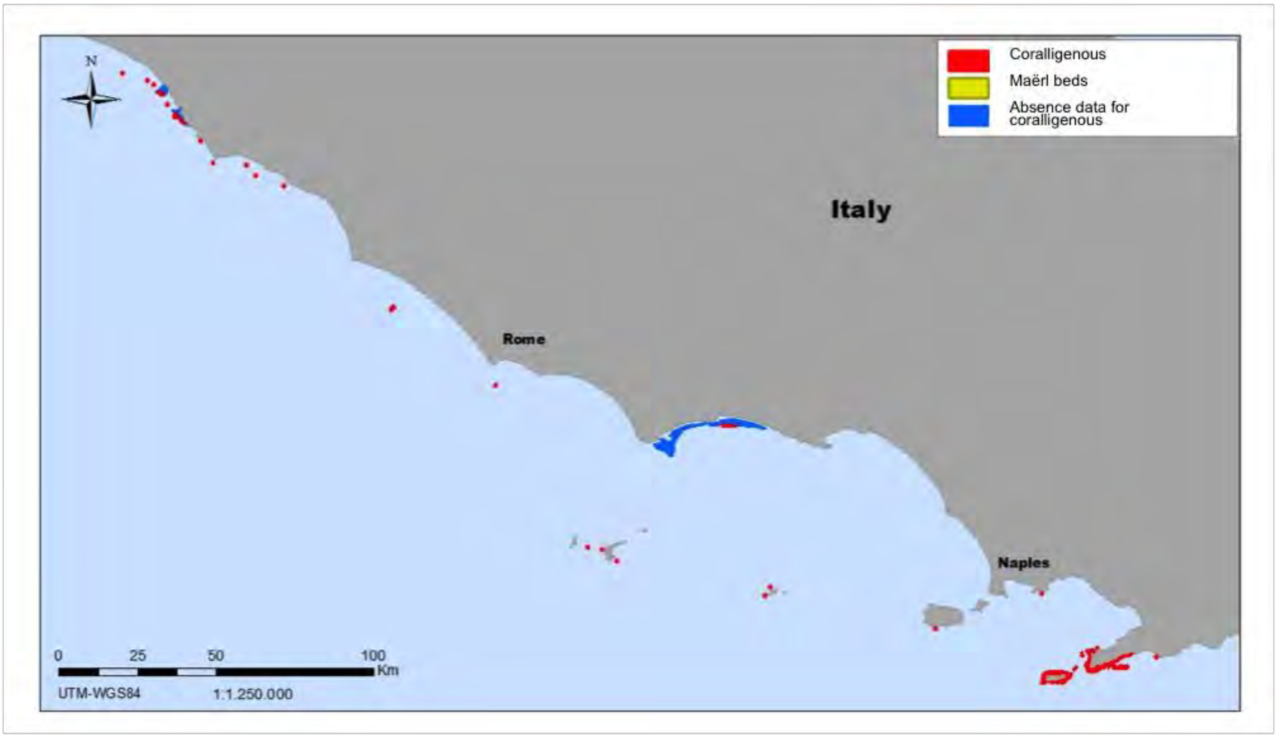

Fig. 1.2.13. Details from Lazio and Campania (Italy). Also in this case, *absence data* were available from inspection on local detailed carthography.

In Lazio, the information is still extremely limited (Fig. 1.2.13) even though improved in this last report, thanks to additional information both on presence and absence of coralligenous from local colleagues. Also in Campania the information should be improved. However, here, areas such as Capri have been mapped in detail (Fig. 1.2.14).

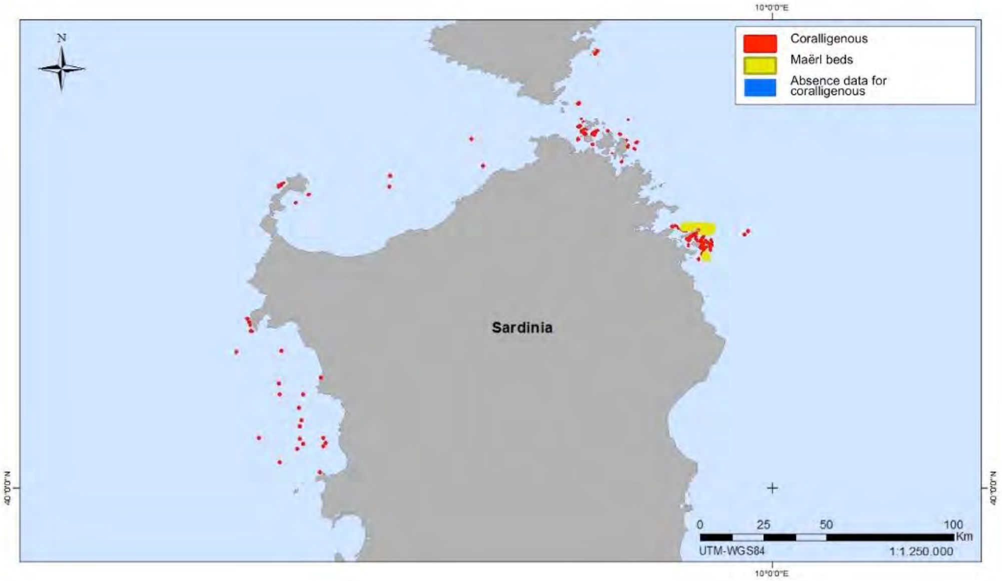

Fig. 1.2.15. Details from Sardinia.

In Sardinia, several stretches of coast have been systematically mapped (MPAs included).

From the above description it is evident that data on coralligenous formation and maërl habitat have largely increased in the last twenty years and several projects have been funded in order to analyze spatial distribution and extent of this habitat. This analysis confirms that coralligenous is present everywhere in the Mediterranean Sea. Figs. 1.2.16 and 1.2.17 show how the collected information is distributed across GSAs and geographical regions.

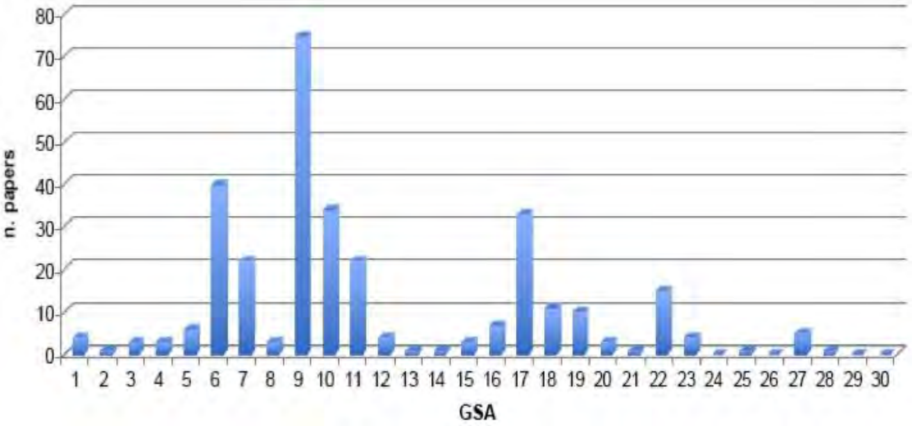

Fig. 1.2.16. Number of papers collected in the GSAs of the Mediterranean Sea.

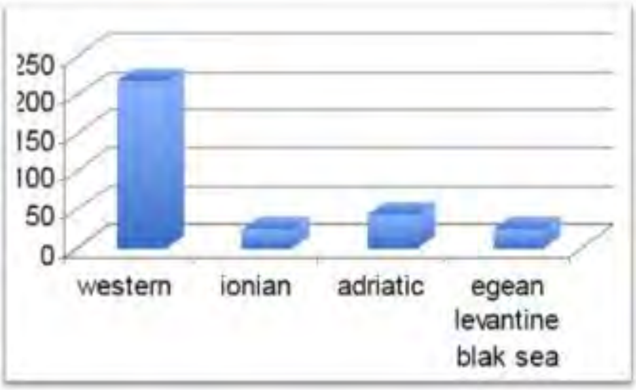

Fig. 1.2.17. Number of papers from different regions of the Mediterranean Sea.

The number of publications is still higher in the western Mediterranean compared to the Eastern part. However, recent efforts are trying to fill the gaps in the knowledge in the eastern Mediterranean Sea.

Recent basin wide efforts assessed how multiple pressures distribute and combine to influence Mediterranean marine ecosystems and biodiversity. These analyses showed distinct spatial patterns in the distribution of cumulative human impacts, identifying which stressors exert the greatest impacts on the marine ecosystems and biodiversity. Looking at these results, more efforts should be directed to map these vulnerable habitats especially in those areas (i.e. Spain, Gulf of Lions, north-eastern Ligurian Sea, Adriatic Sea, Aegean Sea, south-eastern Turkey and regions surrounding the Nile Delta and north-west African coasts) where strong interactions have been found between areas of high biodiversity and threats.

The collection of the list of species associated to different location across the Mediterranean Sea will be analysed to quantify compositional differences in coralligenous assemblages at regional scale complementing the information about habitat mapping. The list includes the information across all GSAs. Also a check for species name has been carried out, with a specific focus on sessile taxa.

An effort to find the environmental variables potentially associated to the presence of this habitat has been done in order to facilitate the modeling work of Task 1.3. They have been largely discussed in the two meetings held in Heraklion (Crete) and Palermo (Sicily).

A synthetic table on the status of knowledge and data availability on coralligenous is reported in Table 1.2.3. Quantitative assessments relative to what is known and what is not known about the spatial distribution and extent of the two habitats compared to the total Mediterranean extension is very difficult. Also, in many areas, most information is under the form of point source data. Thus the work needed to obtain an idea of the percentage of marine landscape actually occupied by these habitats becomes challenging. However, on the basis of the collected data it is possible to conclude that detailed information is now available on about 5% of the Mediterranean Sea. Thus, Table 1.2.3 reports on the percentage of data collected until now compared to data that we presume are still to be included in the online GIS viewer. This is a very rough assessment and does not involve evaluations about what we presume is still to be mapped at Mediterranean scale.

Collected data have been added in the database and will be presented in the MEDISEH online GIS viewer (http://mareaproject.net/mediseh/viewer/med.html).

Table 1.2.3. Status of the actual situation of data availability on coralligenous and maërl habitats in the Mediterranean Sea.

Country	**Data collected**	**Available file type**	**Information about habitat status**
Italy	100 %	Polygon data/ point data//jpg	Y
France/Monaco	It might be refined	point data /jpg	Y
Spain	It might be refined	point data /jpg	Y
Greece	≈100%	Polygon data/ point data	Y
Turkey	≈100%	Polygon data/ point data	scarce
Croatia	It might be refined	point data	scarce
Albania	100%	Polygon data	Y
Morocco	100%	Polygon data/ point data	scarce
Malta	≈100%, it might be refined	Polygon data, point data	Y
Cyprus	100%	Polygon data/ point data	scarce
Algeria	100%	point data	scarce
Tunisia	≈100%	point data	scarce
Libya	≈100%	point data	scarce
Egypt	-	-	-
Israel, Syria, Lebanon	≈100%	Polygon data/ point data	Y

Table 1.2.4. Table indicating the state of art for each deliverable: the percentage of foreseen results and the possibility to reach the 100% of the foreseen results (continues).

Deliverable	Description	% of foreseen results	Timeframe to reach 100% of results
M1.2.1	Revision of existing information of past coralligenous and mäerl beds along the Mediterranean coast.	100%	Done
M1.2.2	Revision of existing information of current coralligenous and mäerl beds along the Mediterranean coast.	100%	Done
M1.2.3	Production of GIS files indicating the position of past and current coralligenous and mäerl beds along the Mediterranean coast.	100%	Done
D1.2.1	Georeference database covering all revised information on coralligenous beds spatial distribution	100%	Done
D1.2.2	Georeference database covering all revised information on mäerl beds spatial distribution	100%	Done
D1.2.3	Integrated maps presenting the known spatial distribution of coralligenous habitats and mäerl beds across the Mediterranean	100%	Done
D.1.2.4	GIS compatible file for input to WP3	100%	Done

There is no potential to refine our analyses with quantitative, historical data. Long-term information is available only in the Ligurian Sea, in the continental NW Mediterranean coast (i.e Catalonia and Provence coasts) and in two Mediterranean islands (i.e. Corsica and Balearic Islands). These studies specifically refer to mass mortality events occurring in the Mediterranean coralligenous communities supposedly linked to global warming of the NW Mediterranean Sea.

Difficulties encountered and remedial actions

The main problems encountered were:

- the great amount of information, available in different formats (i.e. scientific papers, reports, grey literature, websites, etc.) and effort needed to collect it.
- the great heterogeneity of the restitution scale of maps (from 1:4.000 to 1:250.000) and the legends.
- different geographical projections depending on maps referring to different Countries and Regions.

These issues have been partially solved by adding all available information in the bibliographic database and all the “georeferenced” information into the ArcGIS software, independently from the scale and the legend. Thus we obtained different information for different geographical areas and kept the original information, without any interpretation, addressing coralligenous and mäerl as one entity.

Another issue (already described for *Posidonia* meadows) is the lack of electronic georeferenced files (shapefile format) in most countries. In fact, often the information is available only in the form of paper maps in .jpeg file or text in .pdf or.doc. For the countries of the Eastern Mediterranean basin the problem concerns limited areas (and basically the shapefiles are very limited), while for other countries, like France and Spain, the problem concerns very extensive areas (and shapefiles for these areas do exist). As a final effort, we digitalized all the RAC/SPA information, together with additional data from Spain, France, and Tunisia not included in the previous reports.

Even though a large effort has been made putting together all available information, we still stress the need to plan systematic mapping activities across the Mediterranean Sea. This study has shown that detailed information is available for only 5% of the coast and this cannot be considered an efficient platform for future management and conservation decision.

Gaps in knowledge and suggestions for future actions

Data needs

The project collected most of the information available on the coralligenous and mäerl habitats across the Mediterranean Sea. The analyses of our results clearly show that the GIS information on coralligenous formations and mäerl has largely increased in the last ten years. The full recognition of the relevant contribution of bioconstructions to the Mediterranean biodiversity has fuelled increasing efforts to assess their functional role, spatial distribution, assemblage composition, effects of threats and potential for connectivity. Understanding how this information can be incorporated into conservation planning is critical to reverse the present trajectories of change and degradation. Despite this increased recognition, available information still mostly relies on shallow waters from 20 to 30 meters depth (Fig. 1.2.18). Data on deeper areas are still too scarce and this gap of information should be filled through systematic surveys.

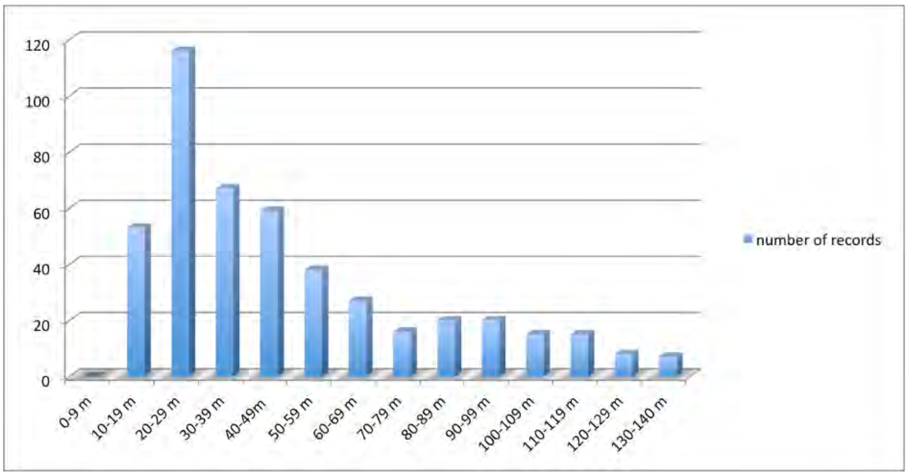

Fig. 1.2.18. The figure shows depths where studies on coralligenous and mäerl were mainly carried out in the Mediterranean Sea.

In addition, for the north Adriatic Sea, Sardinia, and Calabria, Corsica, France, Spain, Croatia and Montenegro surely there is space for refinement with the inclusion of additional information. For some of those areas (e.g. France), the information is available through different projects. Access to these datasets was outside the potential of the MAREA Consortium but in a future step, it is advisable to incorporate data from European and national institutions operating in these areas.

Taken together, these results stress that much information on the distribution of bioconstructions is already available for the Mediterranean Sea but it should be better framed within basin-scale coordinated efforts involving both EU and non EU countries. Systematic mapping should be carried out at basin scale, since there are extensive areas where gaps of knowledge limit the potential for setting conservation priorities.

Threats

Limited knowledge exists on the effects of threats on bioconstructors. Fishery, temperature anomalies and species invasions have been the focus of several, quantitative studies. Most information derives from descriptive, small-scale studies. The lack of historical trajectories and the inadequate data about the synergistic relationships among the various threats for this type of habitat, largely prevent the planning of mitigation interventions. Basic research on the ecology of these habitats together with systematic, large scale efforts to document the effects of multiple stressors are critical to successfully advance the conservation and the management of this valuable habitat.

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Task 1.3 Modeling of protected habitats using predictor variables

(Scientific Responsible: Michele Scardi (CoNISMa), Partners involved: HCMR, CNR-IAMC, CNR-ISMAR, CIBM, CoNISMa)

Cited as: M. Scardi, C.S. Martin, V. Valavanis, S. Fraschetti, A. Belluscio, M. Gristina, M. Salomidi, E. Punzo, P. Panayotidis, M. Giannoulaki 2013. Modeling of protected habitats using predictor variables, Mediterranean Sensitive Habitats **(***MEDISEH) Final Report, DG MARE Specific Contract SI2.600741*

Introduction

A good knowledge of the geographical distribution of species and their habitats is vital in conservation biology and environmental management. To protect a threatened species, it is essential to know where the species or its habitat can be found. The data required to tackle this issue typically consist of geo-referenced occurrence localities for a species (e.g. the seagrass *Posidonia oceanica*), or group of species (e.g. those species communities present in coralligenous formations or in mäerl beds). At best, species absence records are usually only available at a limited number of sites, because the absence of a species is only ascertained when a given site has been exhaustively explored.

Comprehensive species presence records, and possibly absence ones, are typically not available across large geographical expanses such as regional seas, meaning that knowledge on species distributions remains approximate and limited to well-sampled areas. Habitat suitability modeling based on predictor variables, or descriptors, is an effective way to fill spatial information gaps on the distribution of a species. Models are able to predict the location of habitats that are likely to be suitable for a species, or group of species, to live. Examples of predictor variables that can be used for this purpose include those of environmental and/or physical nature, such as water temperature, salinity, depth, nutrient concentrations, seabed types, and many others. Data on these variables tend to be comparatively easier and cheaper to measure or estimate across wide geographical regions of interest.

Depending on the modeling approach chosen (see Franklin, 2009, for a review), a more or less direct relationship of causality between species occurrence and the model's predictor variables may be needed, or not. In the former case, the model intends to explain patterns of occurrence in relation to the predictor variables, as part of an "explanatory" or "functional" approach. In the latter case, the causality link between species occurrence and predictor variables is irrelevant, the aim being to best predict species occurrence (i.e. its habitat distribution) across a wide geographical area of interest. Indeed, many such variables might be relevant, in terms of causality, at the local scale or as part of experimental studies (e.g. phosphate concentration), whilst this link might be lost at the larger-scale, for instance when modeling spatial occurrence for a regional sea.

The type of habitat modeling undertaken for Task 1.3 was of the "predictive" type, i.e. well-suited for modeling at the broad scale, and suitable for situations when species absence records are limited, or even unavailable. Furthermore, because this approach does not rely on a clear direct link of causality between predictor variables and species occurrence, and instead uses gradients and shapes of the predictor variables at the regional scale, a whole variety of variables, beyond the typical environmental/physical ones, could be used to predict species occurrence.

Objectives

The overall aim of Task 1.3 was to develop models relating to sensitive Mediterranean habitats. The models would be used to predict species (or group of species) occurrence at poorly-sampled and un-sampled areas, thereby leading to the production of continuous habitat maps for these species (*P. oceanica*), or groups of species (those present in coralligenous formations, and mäerl beds), across the

Mediterranean Sea. Mapped predictions based on these models would help identify areas of the Mediterranean basin where these species' habitats would be likely to be found, and where they would be likely to be absent.

Specifically, the objectives of Task 1.3 were to:

- develop habitat suitability models for *P. oceanica*, coastal coralligenous formations, and mäerl beds, and
- create continuous distribution maps (and associated "GIS" layers) of associated habitats, based on the models being used in predictive mode.

Deliverables and milestones

All milestones (M) were successfully achieved, and deliverables (D) produced, within the originally proposed timeframe (Table 1.3.1).

Table 1.3.1. Milestones and deliverables for Task 1.3.

	Description	Timeframe
M1.3.1.	Inventory of potential predictor variables	Month 8
M1.3.2	Revision and evaluation of presence and absence records from Tasks 1.1 and 1.2, on *Posidonia oceanica*, coastal coralligenous formations, and mäerl beds. Collection and standardization of predictor variables, revision and choice of the best approach for habitat suitability models	Month 10
M1.3.3	Habitat specific model fitting and validation	Month 14
M1.3.4	Production of GIS layers with predicted habitat	Month 15
D1.3.1	Habitat suitability model for *P. oceanica*	Month 14
D1.3.2	Habitat suitability model for coastal coralligenous formations	Month 14
D1.3.3	Habitat suitability model for mäerl beds	Month 14
D1.3.4	GIS layers for the predicted habitats	Month 16

Partners involved

In order to reach these objectives within the framework of the MEDISEH project, an expert team was established within the MAREA Consortium, with experts in habitat modeling, spatial ecology and Geographic Information Systems (GIS). This team (Table 1.3.2) worked in close collaboration with the biologists from Tasks 1.1 and 1.2, to bring in existing knowledge on the modelled habitats (e.g. local, on-the-ground, knowledge of species distributions, information on the biology and habitat preferences of the species concerned, etc). Partners involved in this task are listed in Table 1.3.1, and CVs can be found on the MAREA Expert Web site at http://www.mareaproject.net/.

Table 1.3.2. Partners involved in Task 1.3.

Participants	Affiliations
M. Scardi	CoNISMa
C. Martin	HCMR/ Current affiliation: UNEP-WCMC (Cambridge, UK)
M. Giannoulaki	HCMR
V. Valavanis	HCMR, Input from WP3
S. Fraschetti	CoNISMa, Input from Task 1.2
A. Belluscio	CIBM, Input from Task 1.1
M. Gristina	CNR-IAMC, Input from Task 1.1, Task 1.2
M. Salomidi	HCMR, Input from Task 1.2
E. Punzo	CNR-ISMAR, Input from Task 1.1
P. Panayotidis	HCMR, Input from Task 1.1

Project workshops

A number of workshops took place during the course of the project, as planned in the initial proposal.

Heraklion (Greece, October 2011): A one-day workshop took place as part of the project's kick-off meeting, in order for partners to discuss data-related issues (for both species and predictor variables), and standardise the approach followed. Potential habitat modeling techniques were presented and discussed.

Palermo (Italy, February 2012): A two-day workshop was held as part of the project's second meeting in Palermo. The aim of this workshop was to select potential predictor variables to be tested during the modeling procedure, based on data availability. A practical session was carried out during these two days, including initial modeling attempts on *P. oceanica* dataset using two machine-learning techiques. The discussion also focused on several issues relating to habitat modeling.

Rome (Italy, September 2012): A two-day workshop was organized as part of the project's third meeting, with the participation of partners from Tasks 1.1 and 1.2. The aim of this workshop was to evaluate habitat models for *P. oceanica*, coralligenous formations and mäerl beds. Predicted maps were discussed, along with ways to improve models (i.e. choice and temporal/spatial resolution of predictor variables, input data to the models).

Heraklion (Greece, January 2013): A two-day workshop was organized as part of the project's fourth, and final, meeting. There, the final models were evaluated and discussed, with key contributions from Tasks 1.1 and 1.2 partners. Work for finalizing and optimizing outputs from Task 1.3 was agreed.

Methods

Modeling techniques based on input data having presence and absence species records are inherently more powerful and accurate than those only based on presence records. Hence, two separate habitat modeling approaches were followed: "presence-absence" habitat modeling for *P. oceanica*, and "presence-only" habitat modeling for coralligenous formations and mäerl beds. This was due to the unavailability of suitably sufficient absence records for coralligenous and mäerl, whilst these were available for *P. oceanica*.

P. oceanica data used as input into the models

Partners from Task 1.1 provided a Mediterranean-wide dataset for *P. oceanica*, with both presence and absence records, which were either published, or unpublished ("personal observations"). Presence records included some from areas where *P. oceanica* was known to have occurred, but where the beds had regressed.

Data were provided in the form of polygon and point shapefiles, and were used to create one raster layer with four pixel classes: presence (pixel value 1), absence (pixel value 2), "no data" (pixel value 3) and land (pixel value 4). Obviously, "no data" pixels included only pixels in which *P. oceanica* could potentially occur, i.e. pixels whose average depth was shallower than 50 m, or pixels with at least one neighboring pixel whose depth was shallower than 50 m (a pixel may have an average depth larger than 50 m, but still contain a shallower sub-pixel area: this condition is very likely to happen at the deep end of the *P. oceanica* distribution). The habitat model would then be used to predict *P. oceanica* presence or absence at the locations corresponding to pixel value 3 (i.e. "no data" areas).

The *P. oceanica* layer was formatted identically with the predictor layers, in terms of geographical extent, resolution, and coordinate system (see below). For modeling purposes, each non-land pixel was converted to an array containing all the values for the predictive variables as well as the *P. oceanica* class (present/absent/unknown). All the arrays were then sequentially saved to a comma-delimited (.csv) file to be used as input into the modeling procedure (see below). In total, the *P. oceanica* potential distribution stretched over 1,198,514 pixels: 96,658 of them were presence records (Fig. 1.3.1), 609,472 were absence records, and 492,384 were flagged as "no data".

A total of nine test zones were drawn (Fig. 1.3.1). Presence and absence data points within these zones would be excluded from model development, but would be used to independently test the performance of the model. This dataset will be referred to as "test set", as opposed to the "training set" used in model development. All nine test zones were located in the western Mediterranean, i.e. in the only subregion where both presence and absence information were widely available, and represented about 6.8% of the full dataset (48,287 pixels, 19,965 presence records and 33,322 absence records). Test areas were not defined according to a random selection: on the contrary, they were selected in order to represent different types of western Mediterranean meadows across the widest range of environmental conditions.

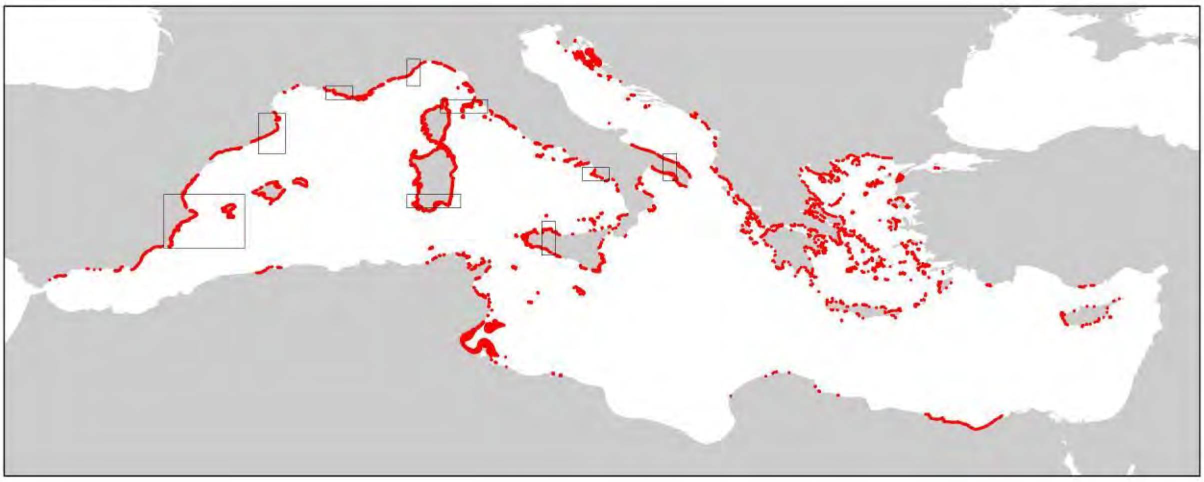


Fig. 1.3.1. Occurrence dataset (points, red colour) for *P. oceanica*, used as input into the modeling procedure. For clarity, absence records, and areas with "no data" are not shown. Black-lined boxes correspond to test areas.

Coralligenous formation and mäerl bed data used as input into the models

For both coralligenous formations and mäerl beds, partners from Task 1.2 provided Mediterranean-wide occurrence data (published, or unpublished "personal observations") in the form of one polygon shapefile and one point shapefile each. For coralligenous formations, occurrence data in the Po estuary were removed from the dataset since they are related to a specific type of coralligenous called tegnue, which has very unique and particular habitat preferences.

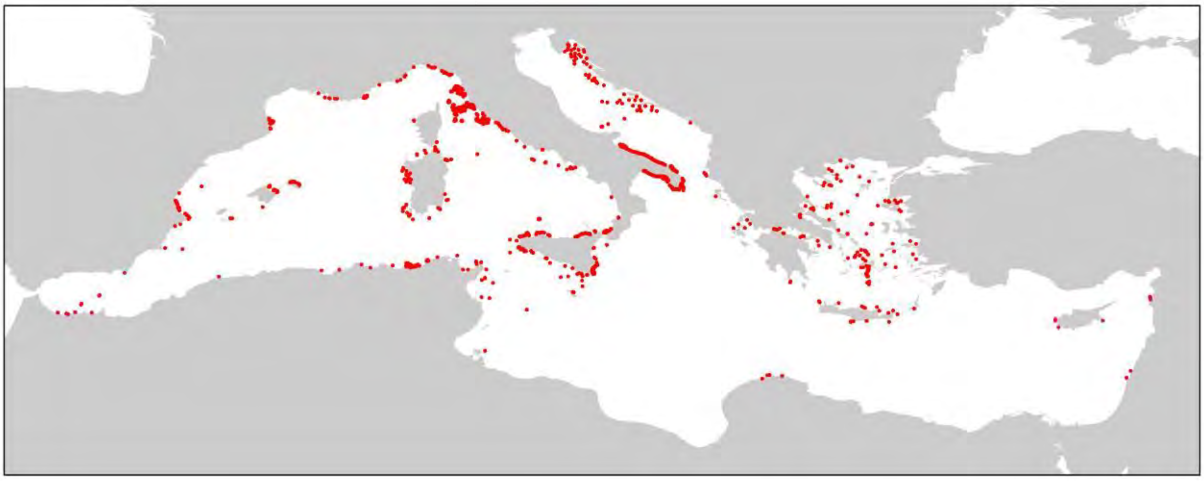


Fig. 1.3.2a. Occurrence dataset (points, red colour) for coralligenous formations, used as input into the modeling procedure.

The polygon shapefile was converted to a point shapefile, such that the result would have a similar number of occurrence points as the point shapefile. Both point shapefiles were merged into one, thereby producing one occurrence dataset of 6,213 points for coralligenous (Figure 1.3.2a), and one of 1,431 points for mäerl (Fig. 1.3.2b). Both were saved in comma-delimited (.csv) format for use as input into the modeling procedure (see below).

Fig. 1.3.2b. Occurrence dataset (points, red colour) for mäerl beds, used as input into the modeling procedure.

Predictor variables used as input to the models

A total of 36 predictor variable layers were prepared (Table 1.3.3). Beyond actual availability, predictor variables were selected if they had a complete coverage, i.e. if they could be mapped continuously at the scale of the Mediterranean basin. Predictor variables ranged from physical and environmental ones (e.g. bathymetry, salinity), to anthropogenic ones (e.g. pollution), including GIS calculations based on other layers (e.g. distance to ports). Some were based on *in situ* measurements (e.g. silicate concentration), some were remotely-sensed (e.g. sea surface temperature), whilst others were modelled (e.g. human impact to marine ecosystems).

All layers were standardized to raster format (using ArcGIS 10, ESRI), with the same geographical extent (the Mediterranean basin), coordinate system (WGS 1984), and resolution (pixel/cell size of 0.004166 decimal degrees, i.e. about 460 m along the north-south axis, and about 350 m along the west-east one). This working resolution was obviously much finer than the native resolutions of most predictor variables (bathymetry excluded). For predictor variables with coarser native resolutions, the resolution was artificially made finer without re-interpolating the data, so that they would be kept at their native resolution. However, this choice of working resolution, albeit artificial, allowed for a better fit along the coastlines (i.e. minimal gaps between the end of the predictor layers and the start of land). This was particularly important for *P. oceanica*, given that this species is very coastally distributed, in relatively shallow waters. Areas with "no data", if any, were coded to have the value -9999.

Table 1.3.3. Predictor variables available mapped at the scale of the Mediterranean basin.

	Name	Source	Abbreviated name
1	Artisanal fishing	Halpern et al., 2008	artfish
2	Aspect of the seafloor	GIS calculation based on variable 3 (bathymetry)	gebasp
3	Bathymetry	EMODNet Hydrography Portal, 2013	emodnet
4	Bottom salinity	Boyer et al., 2005	botsalin
5	Bottom temperature	Boyer et al., 2005	bottemp
6	Bottom type	Halpern et al., 2008	bottype
7	Calcite concentration	Tyberghein et al., 2012, based on Feldman and McClain, 2010	calcite
8	Chlorophyll *a* concentration (mean)	Tyberghein et al., 2012, based on Feldman and McClain, 2010	chmean
9	Chlorophyll a concentration (annual range)	Tyberghein et al., 2012, based on Feldman and McClain, 2010	chrange
10	Climate change (sea surface temperature)	Halpern et al., 2008, based on Casey et al., 2010	climsst
11	Climate change (UV)	Halpern et al., 2008, based on McPeters et al., 1998	climuv
12	Diffuse attenuation coefficient	Tyberghein et al., 2012, based on Feldman and McClain, 2010	dacmean
13	Dissolved oxygen concentration	Tyberghein et al., 2012, based on Boyer et al., 2009	dissox
14	Distance to 200 m isobath	GIS calculation based on variable 3 (bathymetry)	dist200m
15	Distance to coast	GIS calculation based on Wessel and Smith, 1996	distcoast
16	Distance to ports	GIS calculation based on NG-IA, 2011	distport
17	Distance to river mouths	GIS calculation based on ESRI, 2012, and Wessel and Smith, 1996	distriver
18	Euphotic depth	Feldman and McClain, 2010	zeumean
19	Human impact to marine ecosystems	Halpern et al., 2008	impact

	Name	Source	Abbreviated name
20	Nitrate concentration	Tyberghein et al., 2012, based on Boyer et al., 2009	nitrate
21	Nutrient input (fertilizers)	Halpern et al., 2008	nutrient
22	Ocean acidification	Halpern et al., 2008	oceacidif
23	pH	Tyberghein et al., 2012, based on Boyer et al., 2009	ph
24	Photosynthetically available radiation	Tyberghein et al., 2012, based on Feldman and McClain, 2010	parmean
25	Phosphate concentration	Tyberghein et al., 2012, based on Boyer et al., 2009	phosphate
26	Pollutants (inorganic)	Halpern et al., 2008	inorpol
27	Pollutants (organic)	Halpern et al., 2008	orgpol
28	Pollution (ocean-based)	Halpern et al., 2008	pollution
29	Population pressure	Halpern et al., 2008	popress
30	Salinity	Tyberghein et al., 2012, based on Boyer et al., 2009	salinity
31	Sea surface current (mean)	AVISO, 2013	sscmean
32	Sea surface temperature (mean)	Tyberghein et al., 2012, based on Feldman and McClain, 2010	sstmean
33	Sea surface temperature (annual range)	Tyberghein et al., 2012, based on Feldman and McClain, 2010	sstrange
34	Shipping intensity	Halpern et al., 2008	shipping
35	Silicate concentration	Tyberghein et al., 2012, based on Boyer et al., 2009	silicate
36	Slope of the seafloor	GIS calculation based on variable 3 (bathymetry)	gebslo

Modeling approach for *P. oceanica*

P. oceanica modeling was carried out taking into account both presence and absence records and therefore the range of potentially useful modeling methods was very wide. Preliminary tests were performed on a subset of data in order to select the best approach among Classification Trees (both using CRT and CHAID algorithms), Artificial Neural Networks (multilayer perceptions) and Random Forests. While all the above mentioned methods provided acceptable results, Random Forests performed significantly better than other methods.

Comparative tests were then performed between Random Forests and Maximum Entropy, focusing on the nine Western Mediterranean test areas. As the latter method is based on presence information only, it was not surprising that the best results were obtained by the Random Forests.

Random Forests are an ensemble technique based on a set of Classification Trees. Conventional single classifiers, including Classification Trees, suffer from over-fitting in many data classification problems, including those that deal with species or habitat distribution. Therefore, to improve the performance of single classifiers, various *ensemble* techniques have been proposed. Ensemble techniques use various methods to select the training data, to train the classifier, and to predict the class of an instance (e.g. presence or absence of species or habitats) with the ensemble.

Bagging, from bootstrap aggregating (Breiman, 1996), is an ensemble technique used to improve stability and accuracy of any classifier. Given a training data set D of size N , a number of training (sub)sets of size N'≤ N are created by randomly sampling cases from D, with replacement. Obviously, some instances in each training subset may be duplicated because of sampling with replacement. For large data sets, the number of cases included in the training subsets may be smaller than that of the original data, while in small data sets it is usually the same as in whole original data set. Each training subset is used to build a classifier of the same type and all the individual classifiers in the ensemble are then combined by taking the most frequent of their outputs (as a majority vote).

The Random Forests (Breiman, 2001) utilize the bagging and the random subspace (Ho, 1998) to construct the individual classification trees in the ensemble. The class of each case in the training set or of any other case (e.g. from new data sets) is then predicted using majority voting or a similar criterion (e.g. based on a threshold value different from 50% of the votes). This process is sketched in Figure 1.3.3.

Given a set of N training cases and p predictive variables (i.e. features), the Random Forest algorithm first builds several (k = ensemble size) training subsets by randomly sampling N cases with replacement from the training data. Then, each training subset is used to build a classification tree. During the training of each classification tree, only some predictive variables (p'<< p) are randomly picked at each node of the tree and the best split is calculated using the training subset and the selected variables. The value of p' is held constant during the forest growing. Each tree in the Random Forest is fully grown, as its terminal nodes, or leaves must be pure, i.e. they must not contain cases belonging to different classes. Therefore, the trees in a Random Forest cannot be pruned (single classification trees are usually pruned to avoid overfitting and therefore to improve generalization). An example of building a single classification tree in a Random Forest is shown in Figure 1.3.4.

According to Breiman (2001), Random Forests are very effective, as they can build an ensemble classifier very quickly from large databases containing a many records as well as many predictive variables. Moreover, they provide information about the role that predictive variables play in the classification as well as information about the relation between the predictive variables and the classification (*prototypes*). It also computes *proximities* between pairs of cases that can be used to locate outliers or to run clustering or ordination procedures. As Random Forests are able to select the most important predictive variables out of the whole set of available variables, they are not affected by variables that are completely uncorrelated to the target variable (i.e. to irrelevant inputs). Finally, as the best split at the nodes of each tree is selected from a random subsets of predictive variables, correlations between the latter does not impair the efficiency of the Random Forest.

However, while single classification trees are very easy to interpret, the inner structure of a Random Forest is nearly impossible to disentangle. As for the role of predictive variables, although Random Forests are not sensitive to correlation among them, if the data contain groups of correlated predictive variables of similar relevance for the output, then smaller groups of variables are favored over larger groups (Toloşi and Lengauer, 2011).

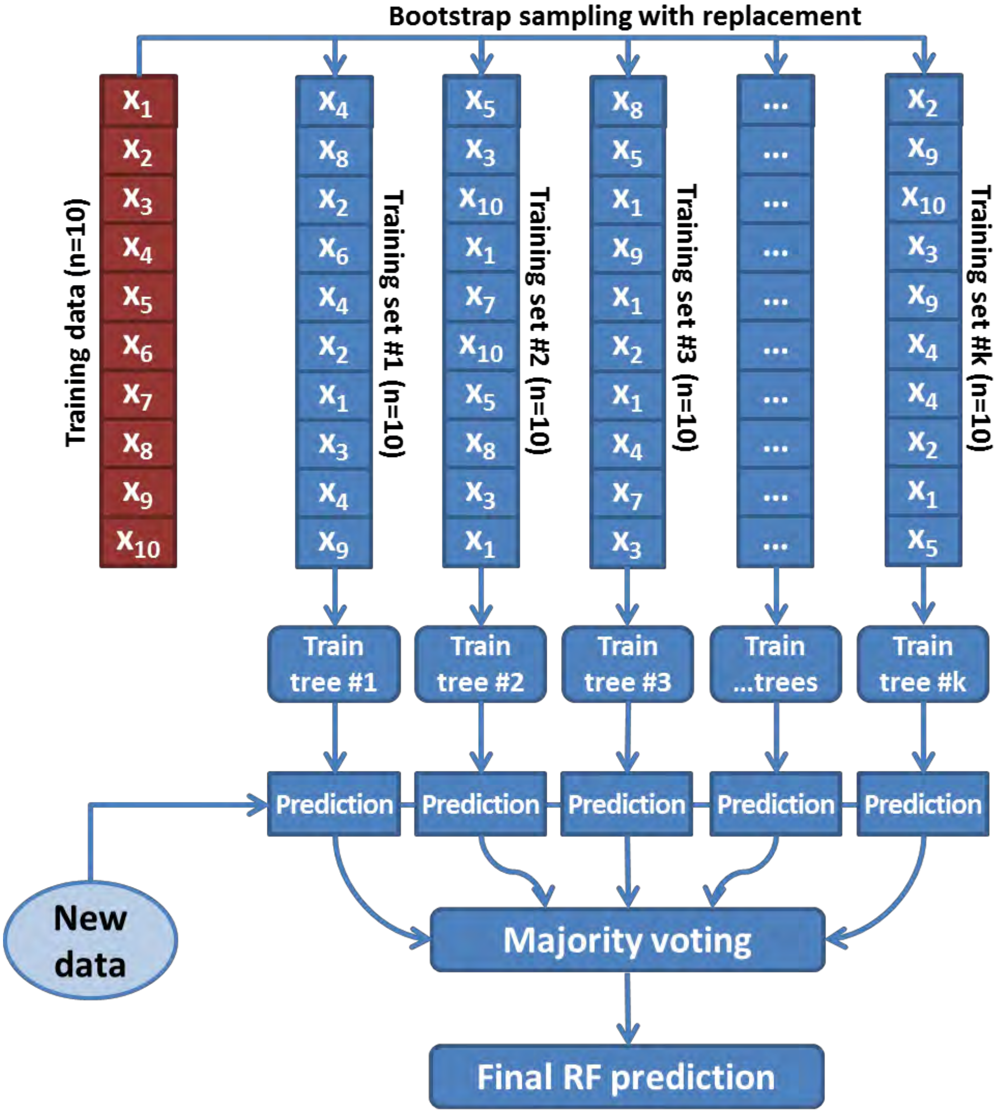
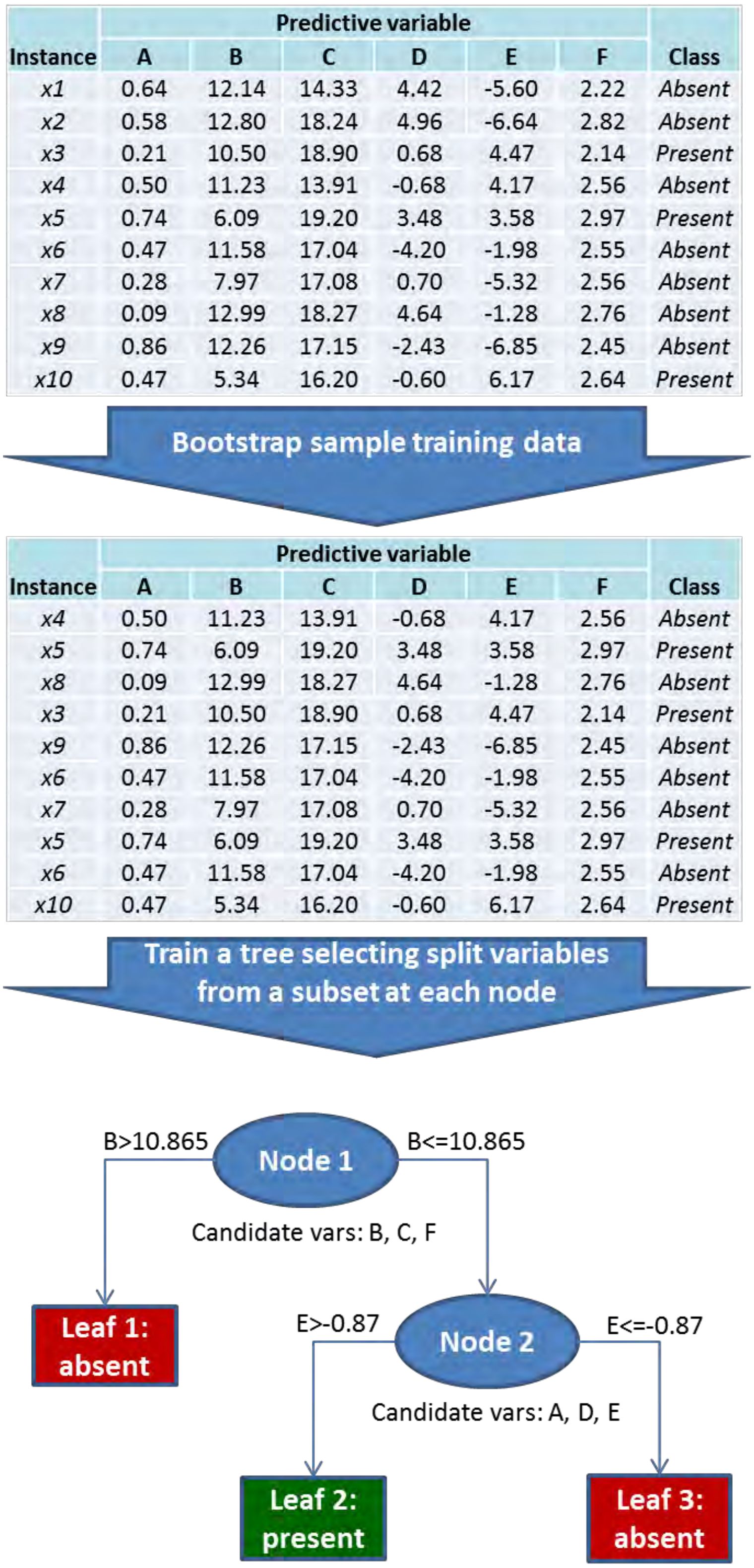


Fig. 1.3.3 A. Random Forest is an ensemble technique based on a set of classification trees, which are trained using different bootstrap samples obtained from the training data set. All the trees "vote" for the final Random Forest prediction.



Instance	Predictive variable						Class
	A	B	C	D	E	F	
x1	0.64	12.14	14.33	4.42	-5.60	2.22	*Absent*
x2	0.58	12.80	18.24	4.96	-6.64	2.82	*Absent*
x3	0.21	10.50	18.90	0.68	4.47	2.14	*Present*
x4	0.50	11.23	13.91	-0.68	4.17	2.56	*Absent*
x5	0.74	6.09	19.20	3.48	3.58	2.97	*Present*
x6	0.47	11.58	17.04	-4.20	-1.98	2.55	*Absent*
x7	0.28	7.97	17.08	0.70	-5.32	2.56	*Absent*
x8	0.09	12.99	18.27	4.64	-1.28	2.76	*Absent*
x9	0.86	12.26	17.15	-2.43	-6.85	2.45	*Absent*
x10	0.47	5.34	16.20	-0.60	6.17	2.64	*Present*

Instance	Predictive variable						Class
	A	B	C	D	E	F	
x4	0.50	11.23	13.91	-0.68	4.17	2.56	*Absent*
x5	0.74	6.09	19.20	3.48	3.58	2.97	*Present*
x8	0.09	12.99	18.27	4.64	-1.28	2.76	*Absent*
x3	0.21	10.50	18.90	0.68	4.47	2.14	*Present*
x9	0.86	12.26	17.15	-2.43	-6.85	2.45	*Absent*
x6	0.47	11.58	17.04	-4.20	-1.98	2.55	*Absent*
x7	0.28	7.97	17.08	0.70	-5.32	2.56	*Absent*
x5	0.74	6.09	19.20	3.48	3.58	2.97	*Present*
x6	0.47	11.58	17.04	-4.20	-1.98	2.55	*Absent*
x10	0.47	5.34	16.20	-0.60	6.17	2.64	*Present*

Fig. 1.3.4. Bootstrap sampling and split variable selection in a single classification tree of a Random Forest.

The importance of each predictive variable is assessed by Random Forests on the basis of the misclassification rate for the out-of-bag records, i.e. for records that are not selected as members of the bootstrap sample used for training a classification tree of the Random Forest. For each predictive variable, values in the out-of-bag records are randomly permuted, and the modified records are then used to get new predictions. The difference between misclassification rates for original and modified out-of-bag data is regarded as an estimate of the importance of each predictive variable.

To evaluate the performance of the Random Forests (as well as those of other methods that have been tested) the Correctly Classified Instances (CCI) were computed only for descriptive purposes, while the Kappa statistics (Cohen, 1960) was considered as the main criterion for selecting the best model.

Modeling approach for coralligenous formations and mäerl beds

Data exploration (Zuur et al., 2007) was carried out on the coralligenous, mäerl and predictor variable datasets, using the R software (R Development Core Team, 2009), so as to detect potential outliers. Habitat modeling techniques are often sensitive to multicollinearity among the predictor variables used. The 36 predictor variables were hence tested for multicollinearity using variance inflation factor and spearman's rank correlation, resulting in a subset of 12 mostly uncorrelated predictor variables[1]: bathymetry (3), bottom salinity (4), bottom temperature (5), bottom type (6), distance to ports (16), distance to river mouths (17), euphotic depth (18), nutrient input (21), phosphate concentration (25), sea surface current (31), silicate concentration (35), slope of the seafloor (36).

Maximum entropy, a well-known approach in machine-learning, is widely used to model species geographical distributions (i.e. their occurrence) in the terrestrial and marine environments, using for instance museum collections that only record the locations of species presence. Here, the software Maxent (Phillips et al., 2006; Phillips and Dudik, 2008) was used to develop habitat models for coralligenous formations and mäerl beds, based on the 12 predictor variables listed above. The algorithm used in Maxent aims to find the largest spread, or maximum entropy, in a geographic dataset, in relation to a set of "background" variables. The geographic dataset was the presence records of coralligenous or mäerl, whilst the background variables were the 12 predictor variables.

For each of the two models being developed, Maxent started with a uniform distribution of occurrence probability values over the entire Mediterranean basin, the "background", and conducted an optimization routine that iteratively improved model fit, measured as the gain. The gain was the likelihood (deviance) statistic that maximized the probability of presence in relation to the background data, corrected for the case where the probabilities of all pixels were equal (uniform distribution).

Modeling was restricted to the 0-200 m depth zone, based on data exploration suggesting that > 90% of occurrence records fell into this range. Of the several feature types available in Maxent, hinge features were selected (Elith et al., 2011). In contrast to *P. oceanica*, where the test set was geographically selected, the test sets for coralligenous and mäerl were randomly selected by Maxent, to represent 25% of the full datasets.

Response curves were created (though they will not be shown), to help understand how the predicted relative probability of occurrence depended on the value of each predictor variable. Based on the estimates of relative contributions of the predictor variables to the Maxent model, variables contributing the least to the model were removed (usually if they contributed less than 5%, or based on expert judgement), and the final model re-run without them. The importance of each predictor variable was then measured through a jackknife test of variable importance, by training with each predictor variable first omitted, and then used in isolation.

Based on the final models used in predictive mode, rasters showing the logistic probability (ranging from 0 to 1) of occurrence for coralligenous formations, and for mäerl beds, were produced. Given that the models were intended to predict occurrence in areas where there was no information, known

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[1] The numbers in brackets correspond to those in Table 1.3.3.

areas of presence were then added (to have the value 1) to the corresponding raster, whilst known areas of absence were removed (to have the value 0, only for coralligenous).

Results

P. oceanica

The distribution of *P. oceanica* meadows has been modelled at first focusing on a small set of point-records that were extracted from areas where *P. oceanica* presence and absence were already known. The preliminary results were acceptable with all the methods tested, but those obtained from Random Forests were by far the best. Therefore, all subsequent modeling was performed by means of Random Forests.

When the coverage of the *P. oceanica* records was nearly complete (input from Task 1.1), a new Random Forest model was developed for the whole Mediterranean Sea. The results were excellent relative to the known meadows in training areas, and very good in the test areas, which were scattered over the whole western Mediterranean, i.e. in the only subregion where both presence and absence data were available almost everywhere.

The analysis of the predicted *P. oceanica* distribution obtained from the first version of the Random Forest model allowed finding subregions where more information about *P. oceanica* presence or absence would be needed in order to improve the accuracy of the prediction. On the basis of a thorough revision of the available data a second Random Forest was then trained, improving the predictive ability of the first version by about 1.5% Correctly Classified Instances (CCI), from 76.8% to 78.3%. The value of Kappa statistics increased from 0.518 to 0.535 and the resulting model was more conservative with respect to the prediction of *P. oceanica* presence than the first version (less false positives, but slightly more false negatives).

The final Random Forest was based on 250 trees whose “leaves” were set to contain at least 50 records (i.e. no further splits were allowed if a leaf contained less than 50 records). This limit allowed shrinking the size of the Random Forest structure down to 1/3 of the original size (about 200 Mb). In the final Random Forest the number of variables that were randomly selected to define each split was set to 4.

The confusion matrices for the training and test data set are shown in Table 1.3.4. The CCIs in the test set were 78.1%, while Kappa was 0.420. Results were obviously much better for the training set (97.9% CCIs, Kappa=0.901).

Table 1.3.4 Confusion matrices for the *P. oceanica* Random Forest.

		Training set **Observed**				**Test set** **Observed**	
		Present	*Absent*			*Present*	*Absent*
Predicted	*Present*	73161	5417	**Predicted**	*Present*	6474	2082
	Absent	8532	571003		*Absent*	8491	31240
		CCI = 97.9%				CCI = 78.1%	
		Kappa=0.901				Kappa=0.420	

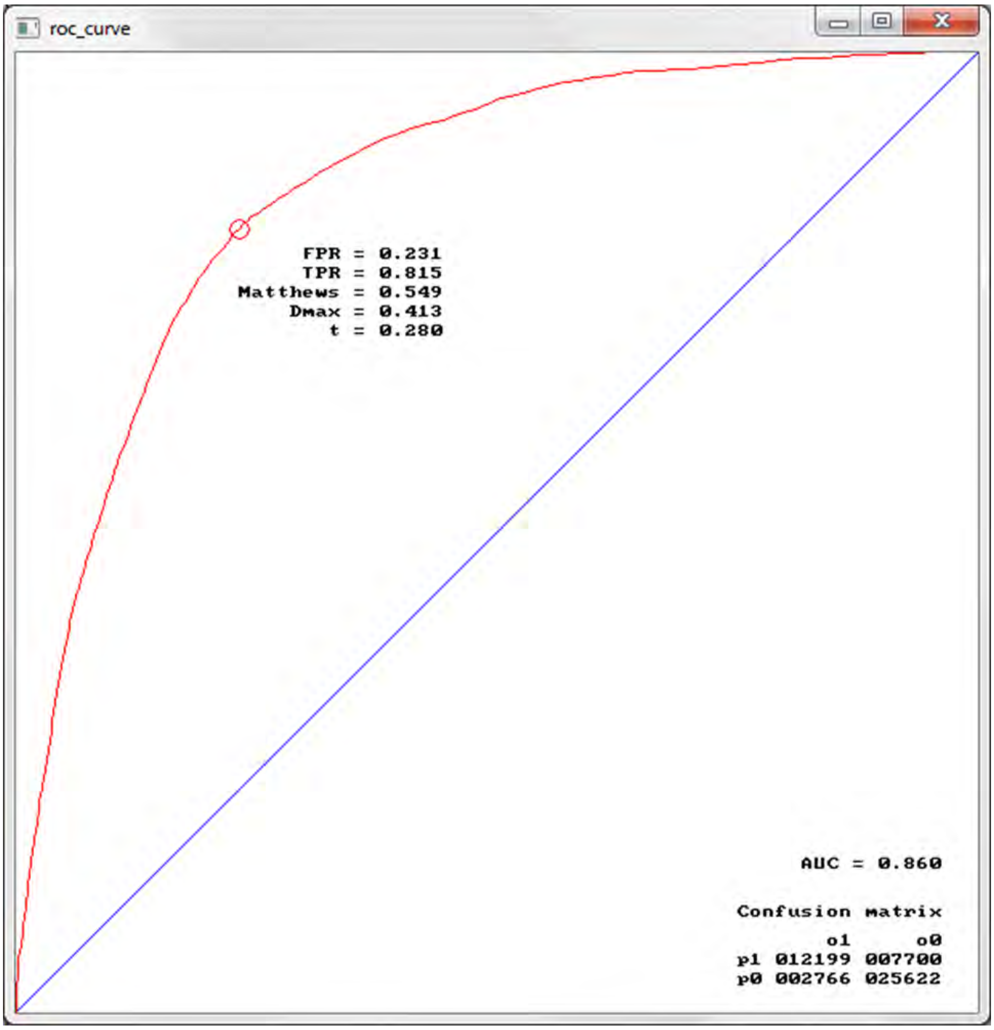
The natural threshold that discriminates between presence and absence prediction in any classifier whose output is in the [0,1] interval is 0.5, and Random Forests are no exception to this obvious rule. In fact, the results in Table 1.3.4 were obtained assuming that *P. oceanica* is predicted as present in case the majority of the trees in the Random Forest “vote” for presence.

However, in many cases the number of presence and absence records in the training data set is unbalanced, and this affects the way trees in a Random Forest vote. In practice, if absence records are more frequent, the Random Forest will learn more frequently from them and therefore it will eventually favor predictions of absence over predictions of presence.

In our data set, 87.5% of records in the training set were for absence, and therefore the Random Forest predictions were clearly biased towards absence. This problem obviously only affects the predictions for data that were not used in the training phase, and therefore it has an impact only on test set results. In fact, in Table 1.3.4 is clearly shown that the majority of the test set records in which *P. oceanica* was observed as present was associated to Random Forest predictions of absence (8,491 records out of 6,474 + 8,491 = 14,965, i.e. 56.7%). A large false negative rate was obviously not acceptable and therefore the default 0.5 presence/absence threshold could not be adopted.

In order to optimize the Random Forest output in case presence and absence records are unbalanced, its predictions have to be analyzed by means of the Receiver Operating Characteristic (ROC) curve (Liaw and Wiener, 2002). The ROC curve is defined by the relationship between true positive cases (y axis) and false positive cases (x axis). For each threshold value in the [0,1] interval, a point can be drawn and all the points define the ROC curve. The optimal threshold is the one that corresponds to the point whose distance from the diagonal (true positives = false positives, i.e. random guess) is the largest. Moreover, the area under the ROC curve can be regarded as a measure of the overall quality of a model. The ROC curve for a perfect model would exactly follow the left and the upper side of the plot, and the area under it would be 1. Real models usually do not fit perfectly the data, and therefore good values for the Area Under the ROC Curve (AUC) are usually larger than 0.8, but not as large as 1.

As our model was certainly affected by an asymmetrical distribution of presence and absence records, and it tended to favour the latter. Therefore, some post-processing based on the ROC curve analysis was strictly needed, and it was carried out using the nine test areas (not used for Random Forest training) as a benchmark. The resulting ROC curve is shown in Fig. 1.3.5.



```
 FPR = 0.231
      TPR = 0.815
 Matthews = 0.549
     Dmax = 0.413
        t = 0.280
```

```
AUC = 0.860

Confusion matrix

        o1     o0
p1 012199 007700
p0 002766 025622
```

Fig. 1.3.5. ROC curve for the *P. oceanica* Random Forest. The optimal threshold is 0.280 and the Area Under the Curve (AUC) is 0.860.

Adopting the optimal threshold suggested by the ROC curve analysis (p = 0.280), the quality of the Random Forest predictions relative to the test set was quite good and the AUC was as large as 0.86. The confusion matrices obtained using the optimal threshold, are shown in Table 1.3.5. While the results for the training set were nearly unchanged, those for the test set showed a clear improvement, with much less false negatives (2,766 out of 2,766 + 12,199 = 14,965, i.e. 18.5%). As the optimization mainly involves the off-diagonal elements of the confusion matrices, the improvement in false negatives obviously came at the cost of an increase in false positives. However, the overall quality of the Random Forest predictions was clearly better with the optimized threshold, as testified by a much larger value for the Kappa statistics (0.535).

Table 1.3.5. Confusion matrices for the P. oceanica Random Forest after ROC curve optimization (p threshold = 0.280).

		Training set				**Test set**	
		Observed				**Observed**	
		Present	*Absent*			*Present*	*Absent*
Predicted	*Present*	77662	11233	**Predicted**	*Present*	12199	7700
	Absent	4031	565187		*Absent*	2766	25622
		CCI = 97.7%				CCI = 78.3%	
		Kappa=0.897				Kappa=0.535	

In order to show the effects of the optimization based on ROC curves analysis the visual comparison between non-optimized and optimized *P. oceanica* presence predictions in Figure 1.3.6 is probably more effective than the confusion matrices, especially for non-technical readers.

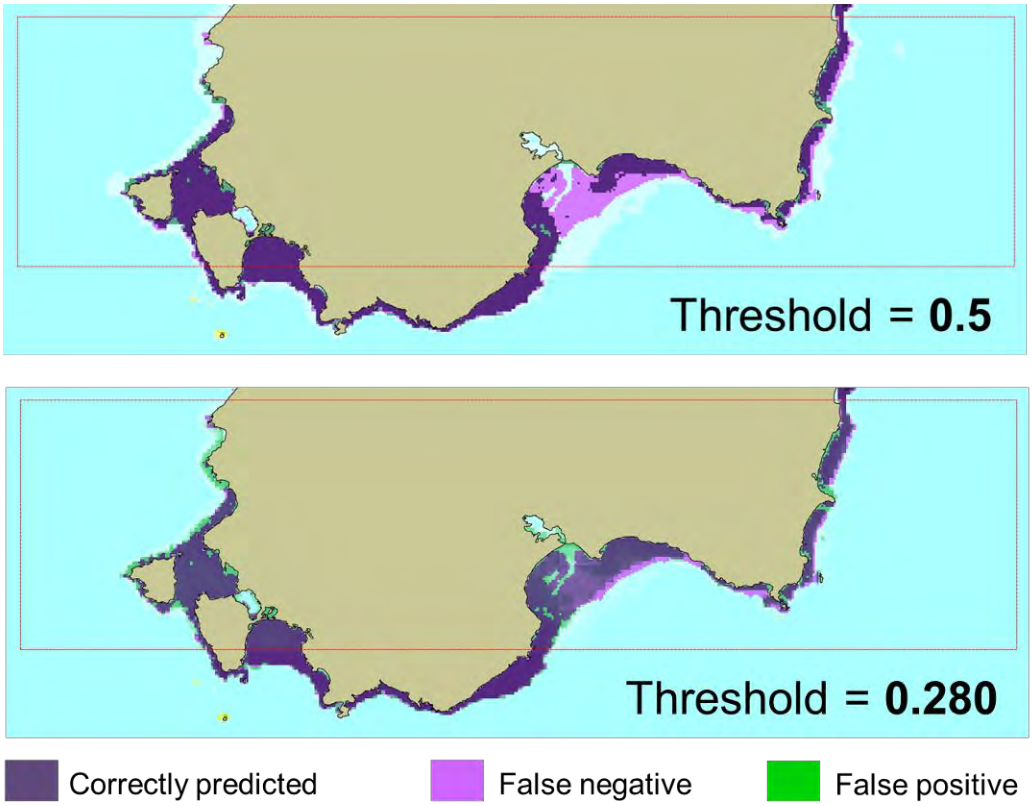


Fig. 1.3.6. Random Forest validation in the southern Sardinia test area: unoptimized results (binarization threshold = 0.5) are shown in the upper panel, while optimized ones (binarization threshold = 0.280) are shown in the lower panel.

One of the nine test areas is shown in Figure 1.3.6, namely the one located in southern Sardinia, bounded by the red rectangle. The upper panel shows the result obtained using the “natural” 0.5 threshold for the binarization of the Random Forest output. Purple pixels correspond to correct predictions of *P. oceanica* presence (i.e. to case in which more than 50% of the trees in the Random Forest voted for presence and presence was actually recorded). A few false positives pixels (in green) are found close to some sections of the shoreline (i.e. the Random Forest votes were for presence, although *P. oceanica* is known to be absent), but a rather large false negative patch (in magenta) is located in the central section of the test area (i.e. where the Random Forest votes for presence were not the majority, although *P. oceanica* is actually known to be present).

Basically, green and magenta pixels show wrong predictions, and it is very clear that especially magenta ones are much less abundant in the lower panel, where the predicted *P. oceanica* distribution was obtained using the optimized 0.280 threshold. In the inner part of the Cagliari bay (central part of the test area), some more false positives (green pixels) could be found after threshold optimization, but the decrease in the number of false negatives (magenta pixels that turned purple) was much larger and therefore the overall quality of the predictions was much improved.

Random Forest predictions were obtained for all the pixels where no information about *P. oceanica* presence was available and whose average depth was compatible with its presence. Predictions were then merged with known presence/absence records were available and the final result is shown in Figure 1.3.7 and — in finer details — in Figures 1.3.8 to 1.3.11.

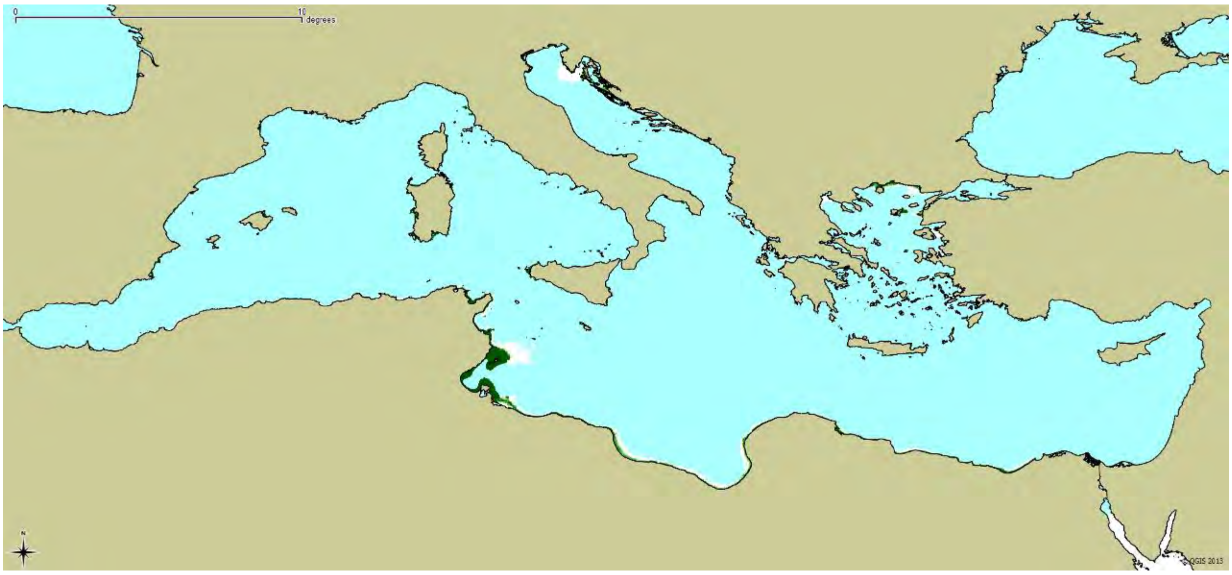


Fig. 1.3.7. *P. oceanica* distribution in Mediterraen Sea (green = present, white = absent, light blue = unsuitable habitat). (See the details in Figs 1.3.8 to 1.3.11).

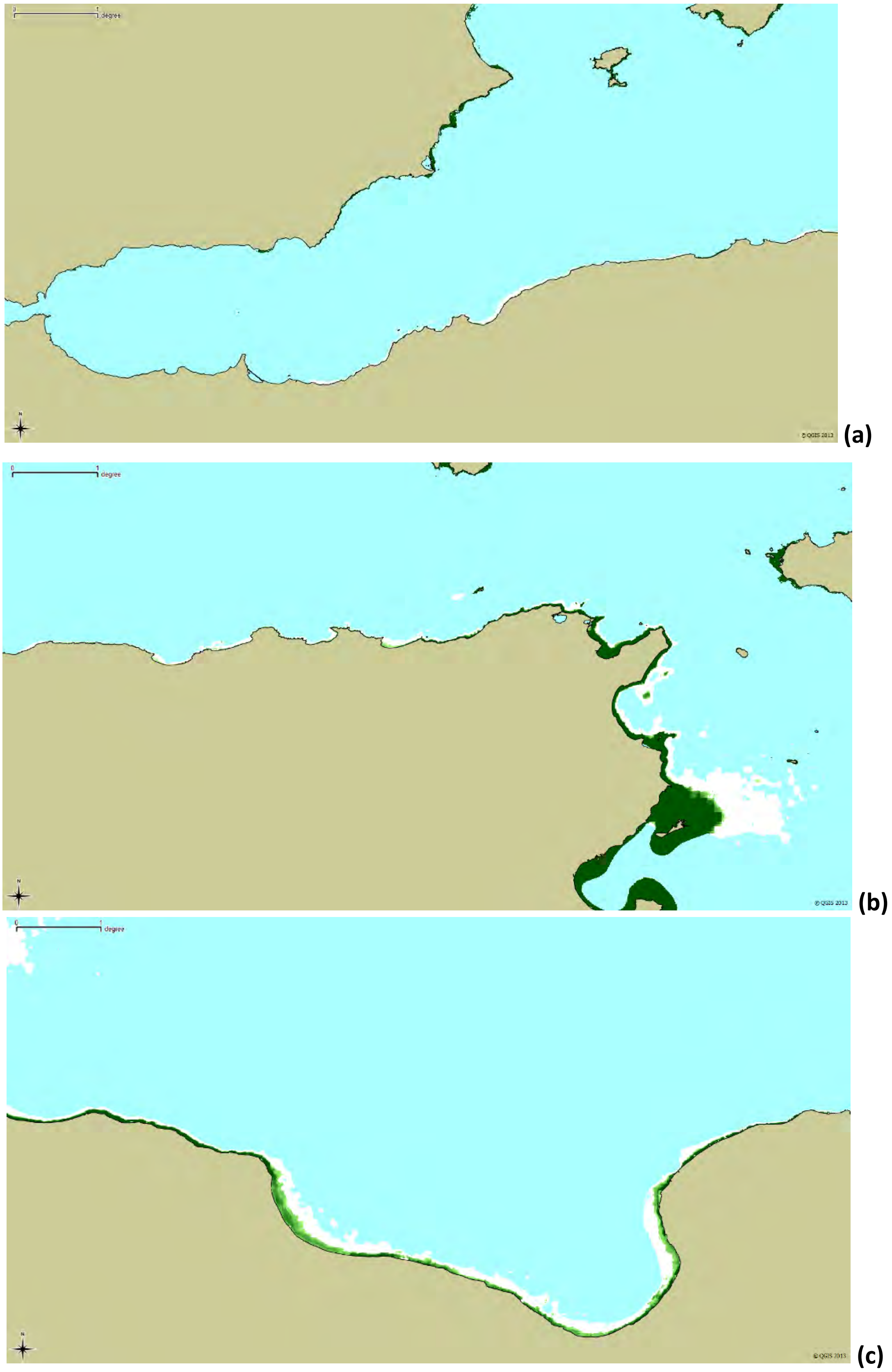


Fig. 1.3.8 (a-c). *P. oceanica* distribution in southern Mediterraen Sea (green = present, white = absent, light blue = unsuitable habitat).

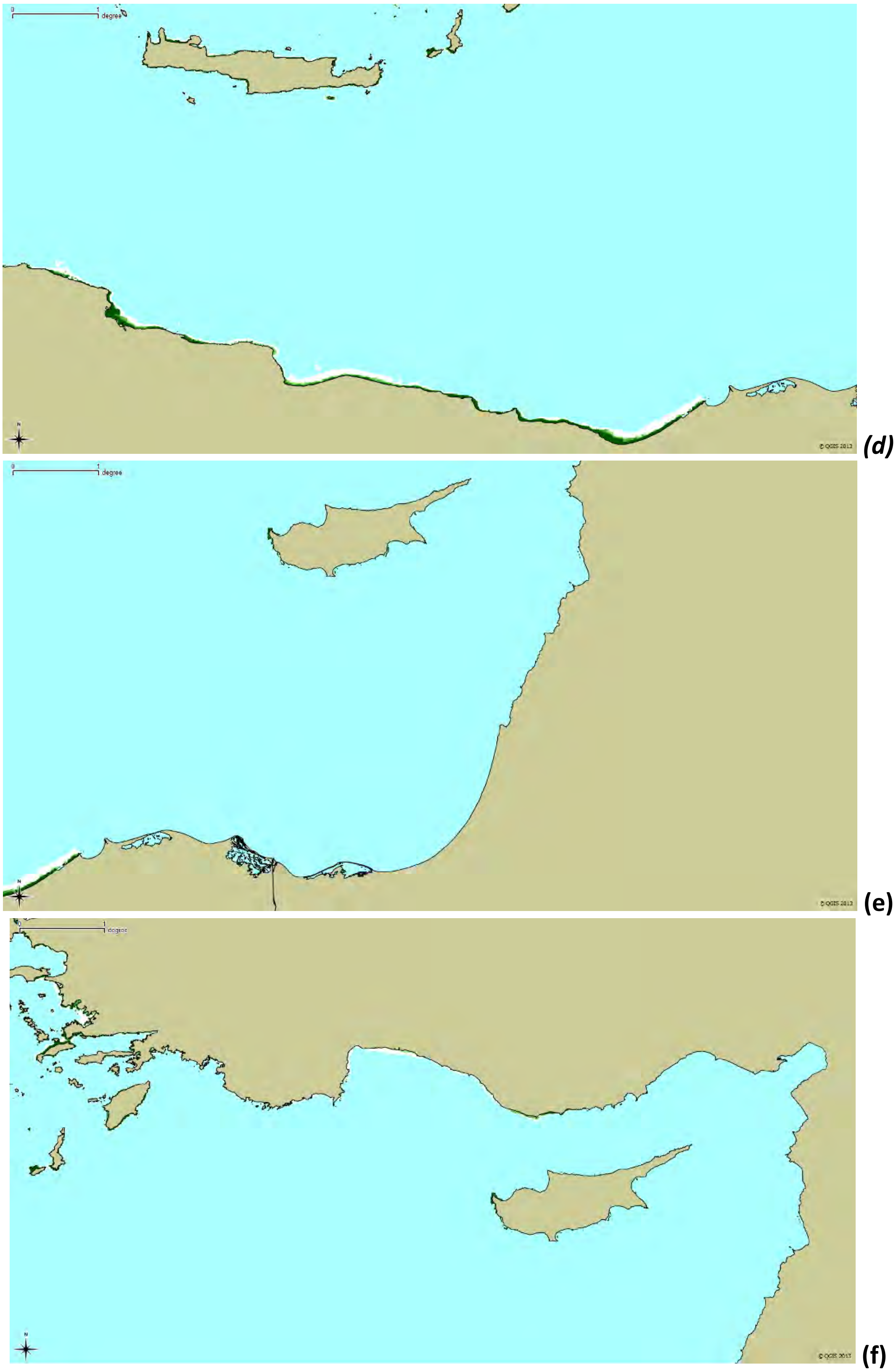


Fig. 1.3.9 (d-f). *P. oceanica* distribution in southeastern Mediterraen Sea (green = present, white = absent, light blue = unsuitable habitat).

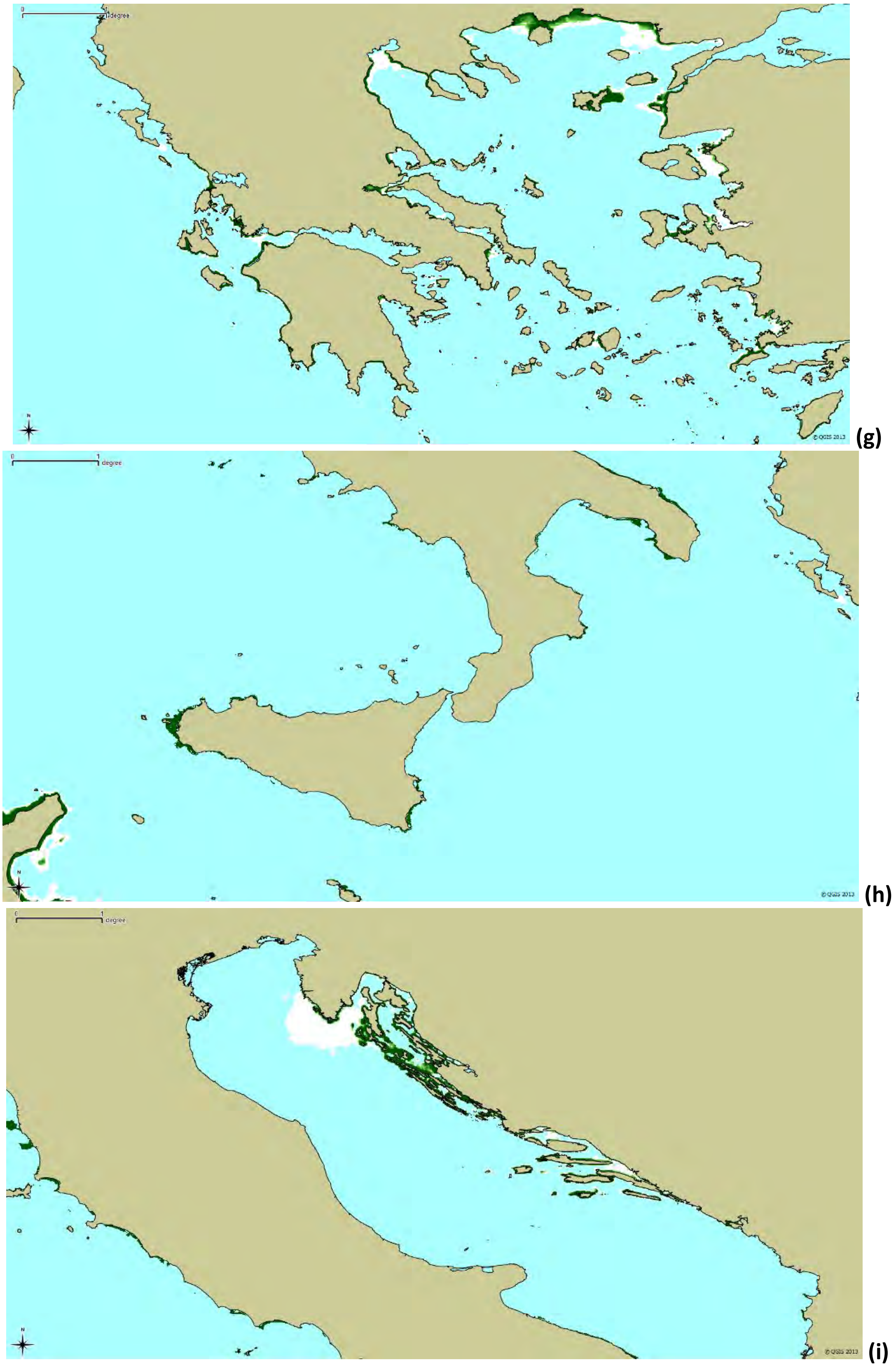


Fig. 1.3.10 (g-i). *P. oceanica* distribution in Aegean, Adriatic, Ionian and Tyrrhenian Seas (green = present, white = absent, light blue = unsuitable habitat).

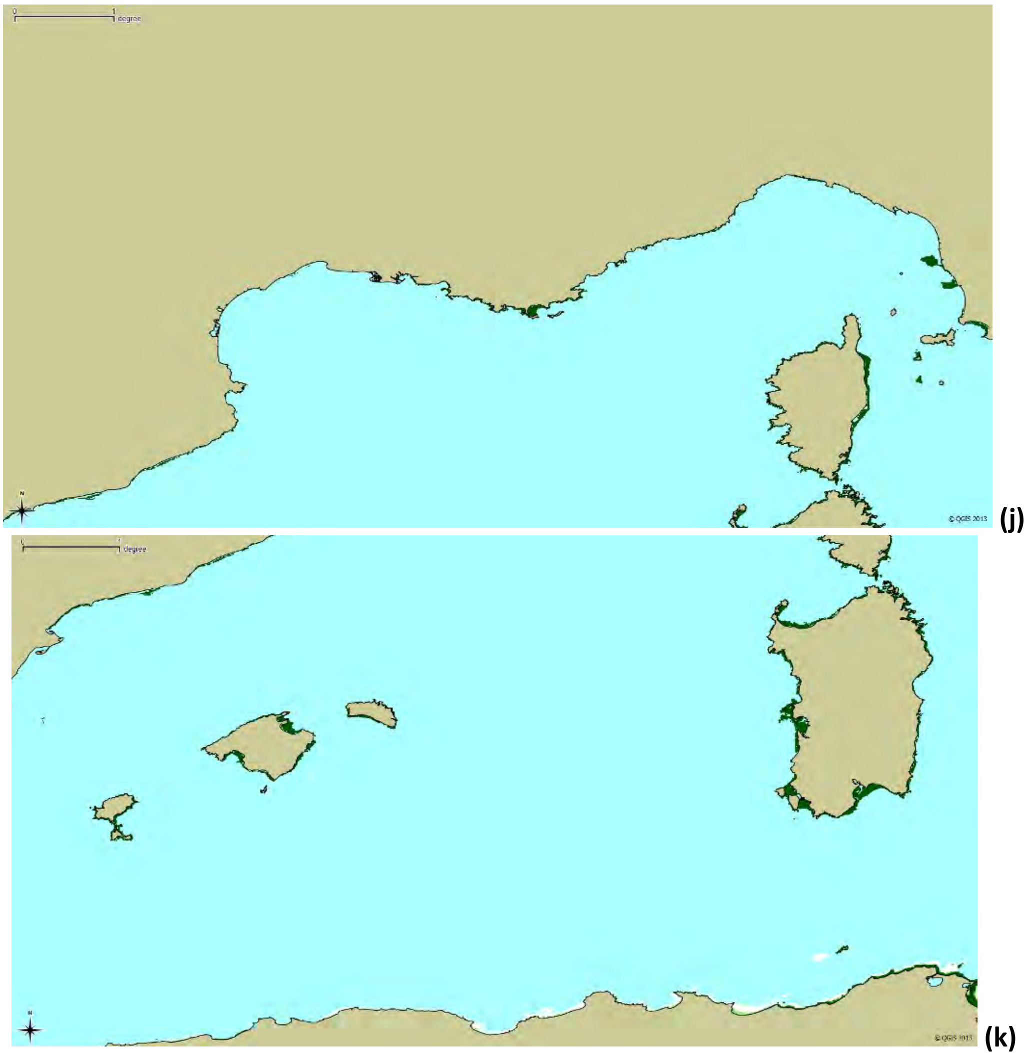


Fig. 1.3.11 (j-k). *P. oceanica* distribution in western Mediterranean Sea (green = present, white = absent, light blue = unsuitable habitat).

Needless to say, the only way to examine Random Forest predictions at an appropriate scale is to visualize the *P. oceanica* layer in a GIS software or in any other software package that is able to open and process raster data. In *P. oceanica* maps (Figs 1.3.7 to 1.3.11), all the regions of the Mediterranean Sea that are not suitable for *P. oceanica* (in 99% cases because of depth) are in light blue, while those that are suitable are either in white (*P. oceanica* is known to be absent or is predicted as absent) or in green (*P. oceanica* is known to be present or is predicted as present). Darker shades of green show pixels where *P. oceanica* presence is known or where the majority of the trees in the Random Forest voted for its presence, whereas lighter shades of green show pixels where *P. oceanica* is assumed as present after the binarization threshold optimization.

While other modeling techniques require dedicated procedures for performing sensitivity analyses aimed at understanding the relative importance of the predictive variables, Random Forests provide this information, obtained from the misclassification rate for the out-of-bag records, as one of the outcomes of a normal training procedure.

Table 1.3.6 Relative importance to the predictive variables to the *P. oceanica* Random Forest model. Variables in red were not used by the Random Forest.

Predictive variable	Relative importance (max=1)
Nitrate concentration	1.00
Silicate concentration	0.93
Bathymetry	0.77
Sea Surface Temperature (mean)	0.76
Salinity	0.75
Distance to river mouths	0.75
Phosphate concentration	0.69
pH	0.65
Bottom salinity	0.56
Photosynthetically Available Radiation	0.52
Calcite concentration	0.50
Euphotic depth	0.50
Sea Surface Temperature (annual range)	0.50
Population pressure	0.44
Bottom temperature	0.43
Ocean acidification	0.33
Nutrient input (fertilizers)	0.26
Pollutants (inorganic)	0.24
Human impact to marine ecosystems	0.20
Pollutants (organic)	0.19
Artisanal fishing	0.15
Pollution (ocean-based)	0.08
Bottom type	0.04
Shipping intensity	0.04
Aspect of the seafloor	0.02
Chlorophyll a concentration (mean)	Not used
Chlorophyll a concentration (annual range)	Not used
Climate change (SST)	Not used
Climate change (UV)	Not used
Diffuse attenuation coefficient (at 490 nm)	Not used
Dissolved oxygen [O2] concentration	Not used
Distance to 200 m isobath	Not used
Distance to coast	Not used
Distance to main ports	Not used
Sea surface current (mean)	Not used
Slope of the seafloor	Not used

In Table 1.3.6, the relative importance of the predictive variables is shown. The most important variable (nitrate concentration) is set to 1, and all the others are scaled relative to it. Out of the 36 available predictive variables, only 25 were used by the final Random Forest, while 11 were excluded (see the lines in red in Table 1.3.6). The same information is shown as a bar plot in Figure 1.3.12.

The predictive variables that played the most relevant roles are nitrate and silicate concentrations, followed by the average depth, sea surface temperature and salinity. Among the 10 most relevant variables are also found distance from river mouths, phosphate concentration, pH, bottom salinity and PAR. Other predictive variables play less relevant roles.

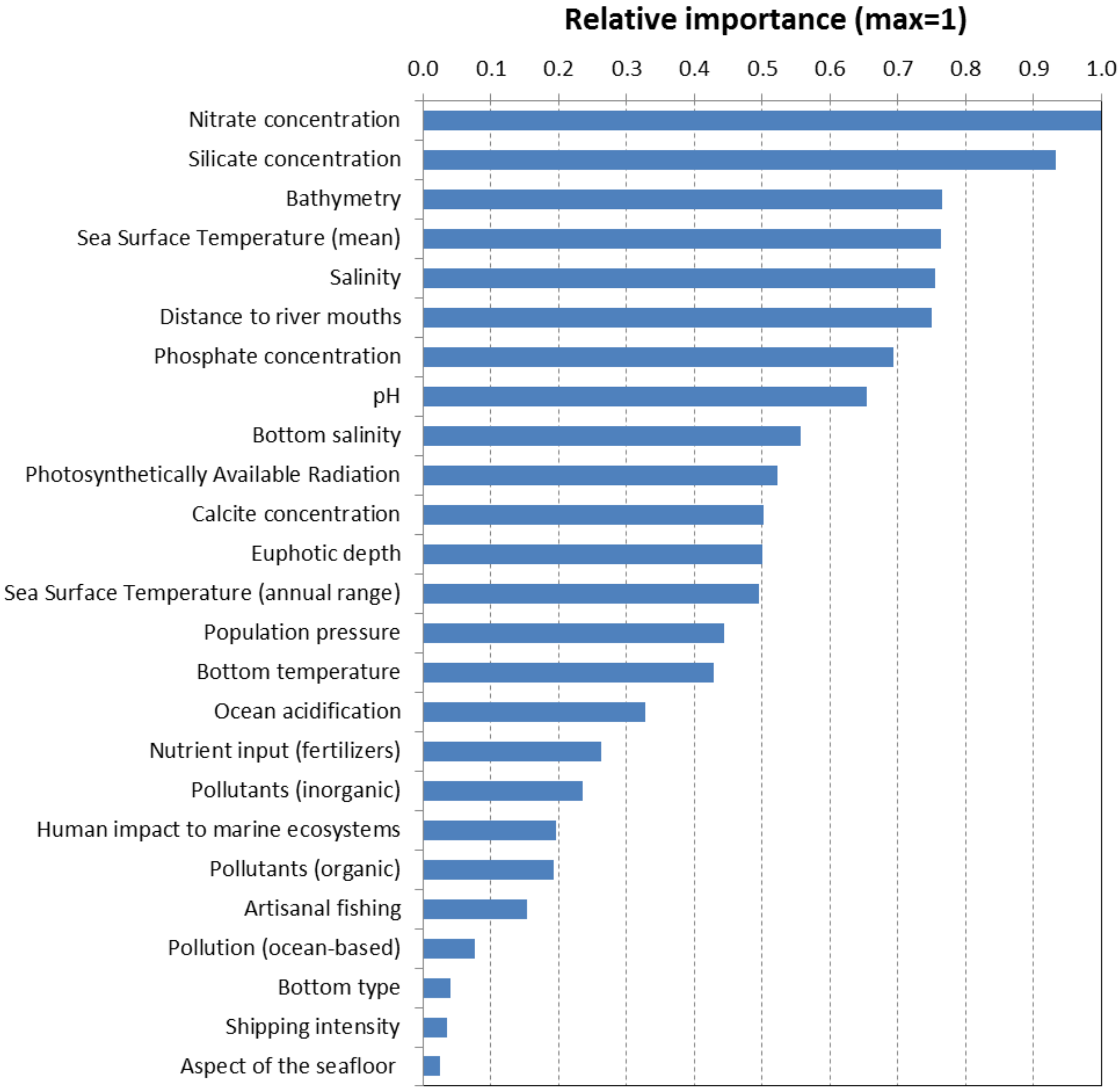


Fig. 1.3.12. Relative importance of the predictive variables that were used in the *P. oceanica* Random Forest model.

Coralligenous formations

The final model's AUC (Fig. 1.3.13) was 0.87 for both the training and test sets.

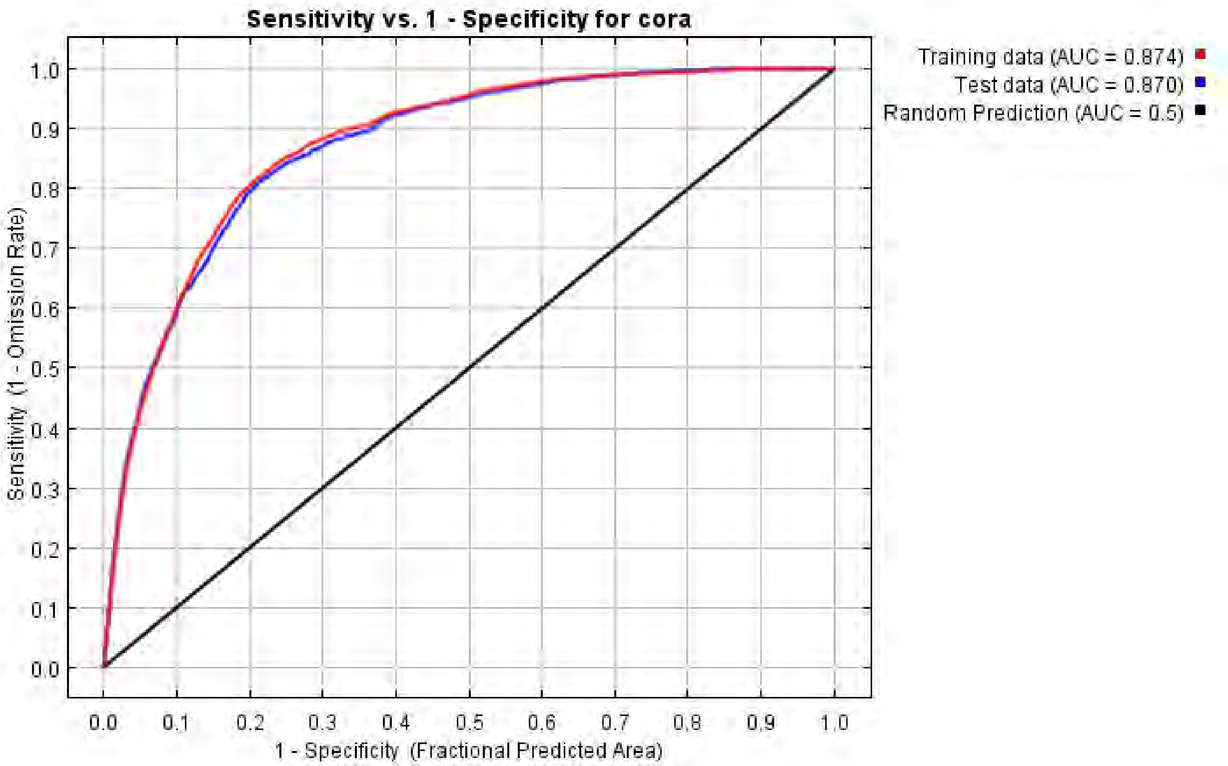


Fig. 1.3.13. ROC curves for the training (red) and test (blue) sets of coralligenous occurrence.

Table 1.3.7. Relative contributions of each predictor to the coralligenous model.

Predictor variable[2]	Contribution (%) to the model
Nutrient input (21)	31.3
Bathymetry (3)	20.5
Slope of the seafloor (36)	12.4
Distance to river mouths (17)	7.1
Sea surface current (31)	6.7
Silicate concentration (35)	6.7
Euphotic depth (18)	6.1
Distance to ports (16)	4.9
Phosphate concentration (25)	4.4

Nutrient input, bathymetry and slope of the seafloor were the three main contributors to the model (combined contribution of 64%, Table 1.3.7), whilst the remaining six predictors had a combined contribution of 36%.

The predictor variable with highest gain when used in isolation was nutrient input, which therefore appears to have the most useful information by itself (Figure 1.3.14a). The predictor variable that decreased the gain the most when it was omitted was bathymetry, which therefore had the most information that was not present in the other predictor variables. The same test carried out on test AUC (Figure 1.3.14b) confirmed that bathymetry and nutrient input were the main contributors of the model, and highlighted the possible role of silicate concentration.

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[2] The numbers in bracket after the predictor variable names are those in Table 1.3.3.

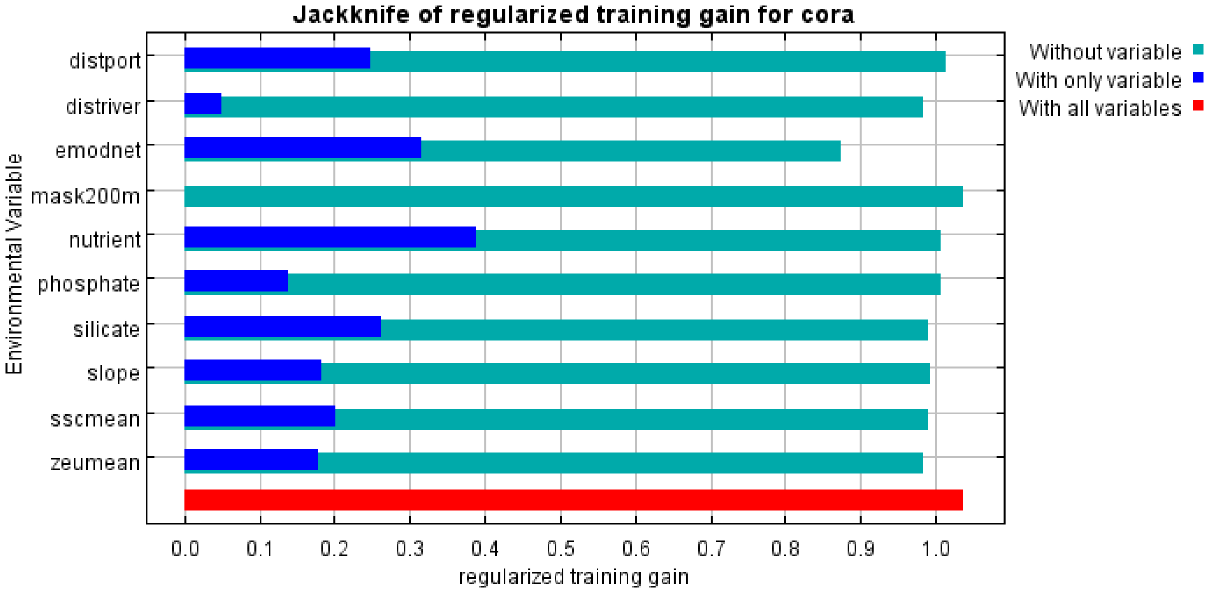

Fig 1.3.14a. Jackknife test of variable importance for the coralligenous model (training gain).

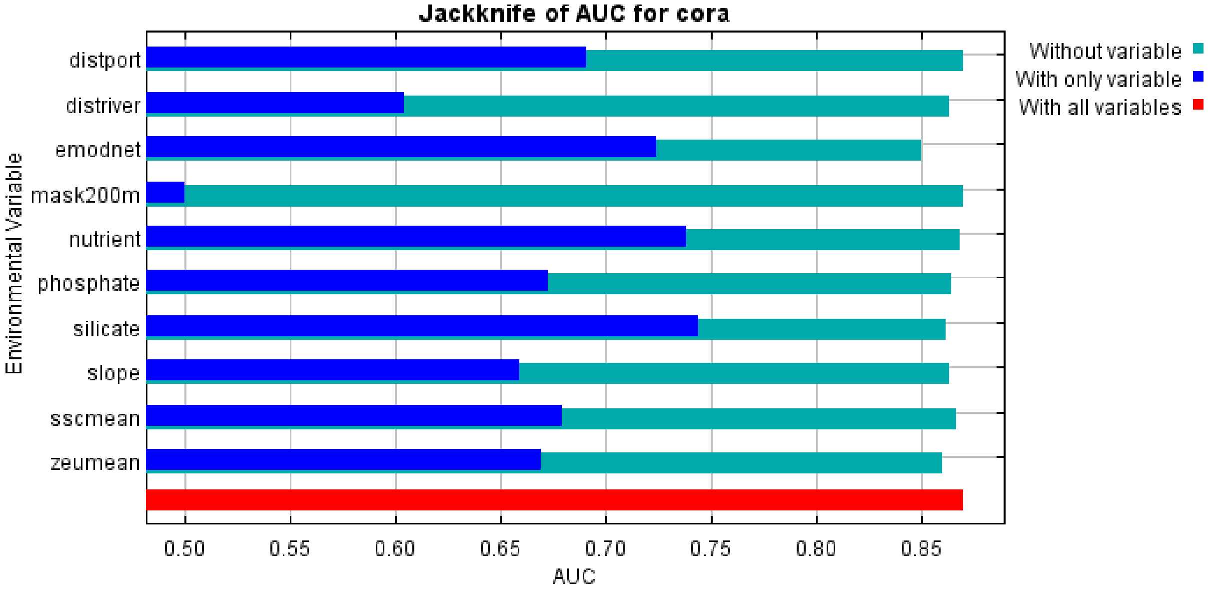

Fig. 1.3.14b. Jackknife test of variable importance for the coralligenous model (test AUC).

Predicted occurrence for coralligenous formations (Figs. 1.3.15a-d) was found to be consistent with the known distribution of this group of species across the Mediterranean Sea (Figure 1.3.2a), especially in relatively well-sampled areas such as the Italian coastline. The model had the tendency to overpredict occurrence, though this could be corrected in places where information on absence was available (e.g. Nile delta, parts of the Libyan coast, part of the eastern Spanish coast, north-eastern coast of Italy). Except from the area surrounding the border between Algeria and Tunisia, which was the most sampled of the North African coast, predicted occurrences for the rest of the North African coast were comparatively low, most probably due to too few occurrence points to train the model.

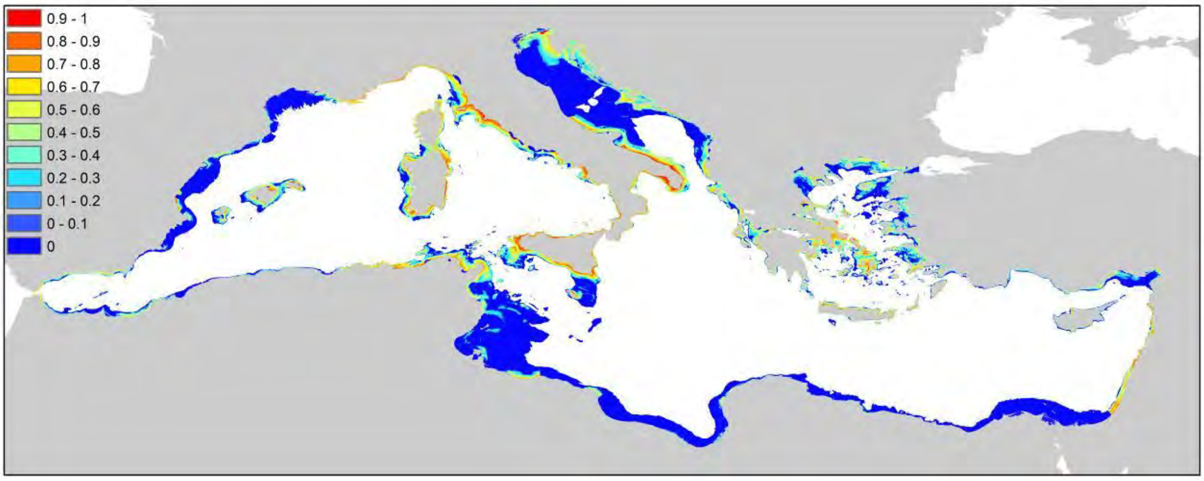

Fig. 1.3.15a. Predicted occurrence probability for coralligenous formations.

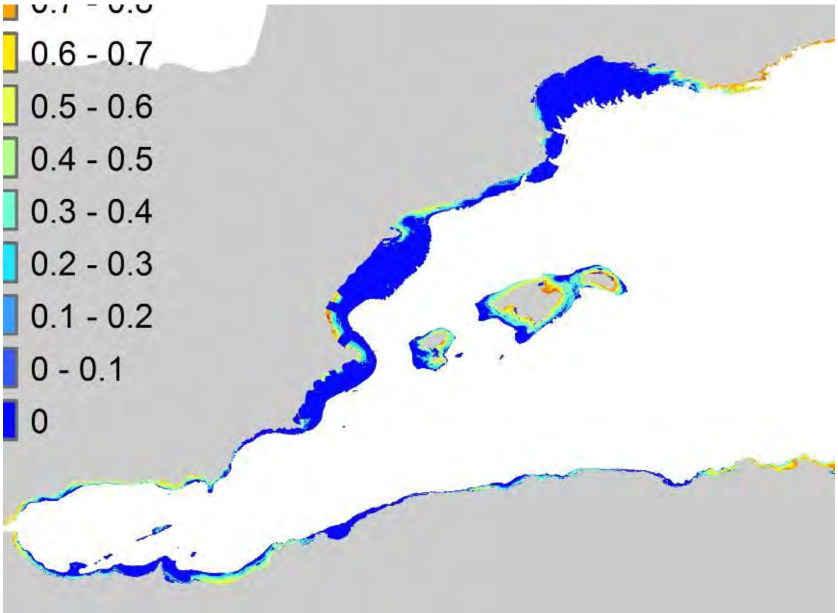

Fig. 1.3.15b. Predicted occurrence probability for coralligenous formations (western Mediterranean).

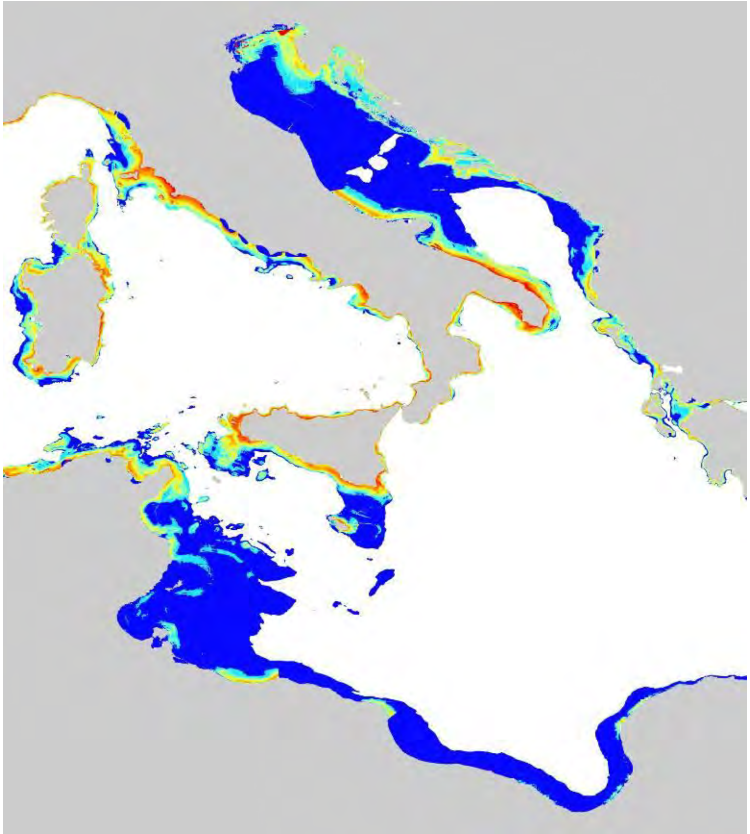

Fig. 1.3.15c. Predicted occurrence probability for coralligenous formations (central Mediterranean).

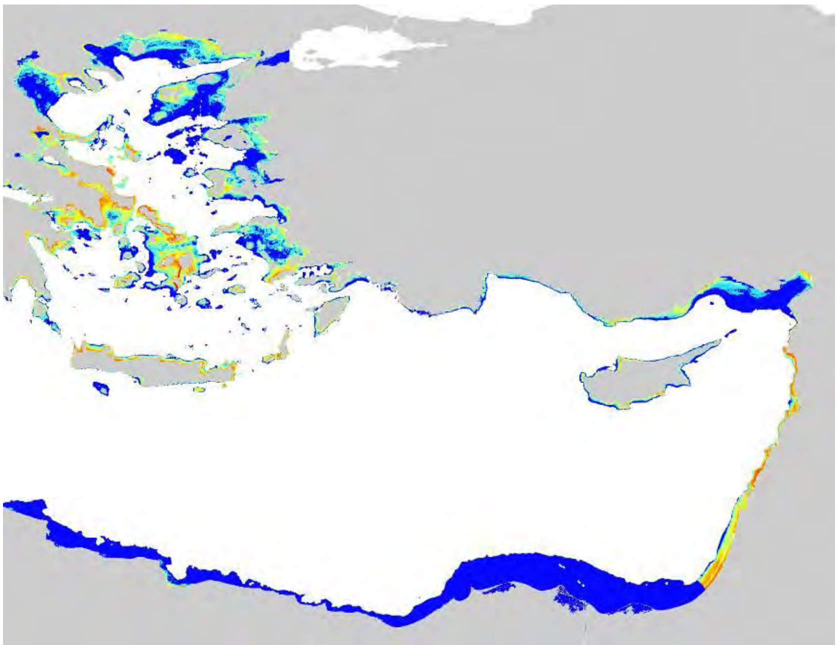

Fig. 1.3.15d. Predicted occurrence probability for coralligenous formations (eastern Mediterranean).

Mäerl beds

The final model's AUC (Fig. 1.3.16) was 0.95 for the training set and 0.94 for the test set.

Fig. 1.3.16. ROC curves for the training (red) and test (blue) sets of mäerl occurrence.

Phosphate concentration, distance to ports, bottom salinity and bathymetry were the four main contributors to the model (combined contribution of 61%, Table 1.3.8), whilst the remaining five predictors had a combined contribution of 39%.

Table 1.3.8. Relative contributions of each predictor to the mäerl model.

Predictor variable[3]	Contribution (%) to the model
Phosphate concentration (25)	18.6
Distance to ports (16)	17.9
Bottom salinity (4)	12.3
Bathymetry (3)	12.1
Distance to river mouths (17)	10.7
Silicate concentration (34)	10.1
Euphotic depth (18)	9.2
Sea surface current (30)	6.6
Bottom temperature (5)	2.5

The predictor variable with highest gain when used in isolation was phosphate concentration, which therefore appears to have the most useful information by itself (Fig. 1.3.17a). The predictor variable that decreased the gain the most when it was omitted was bathymetry, which therefore had the most

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[3] The numbers in bracket after the predictor variable names are those in Table 1.3.3.

information that was not present in the other predictor variables. The same test carried out on test AUC (Fig. 1.3.17b) confirmed that bathymetry was the main contributor of the model, and highlighted the possible role of silicate concentration.

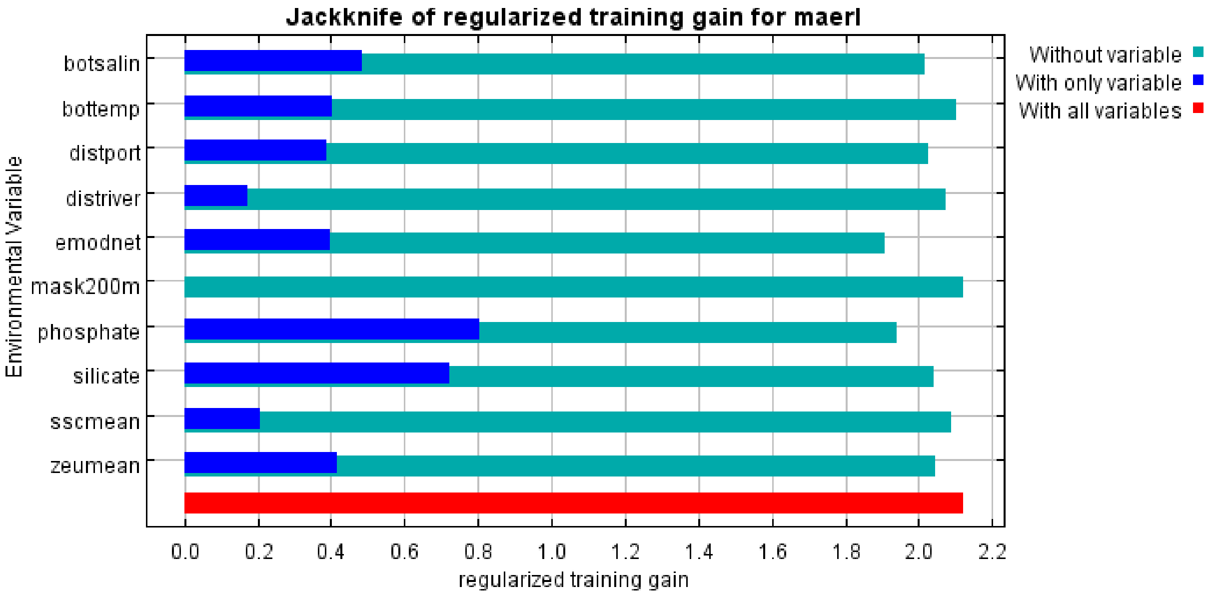

Fig. 1.3.17a. Jackknife test of variable importance for the mäerl model (training gain).

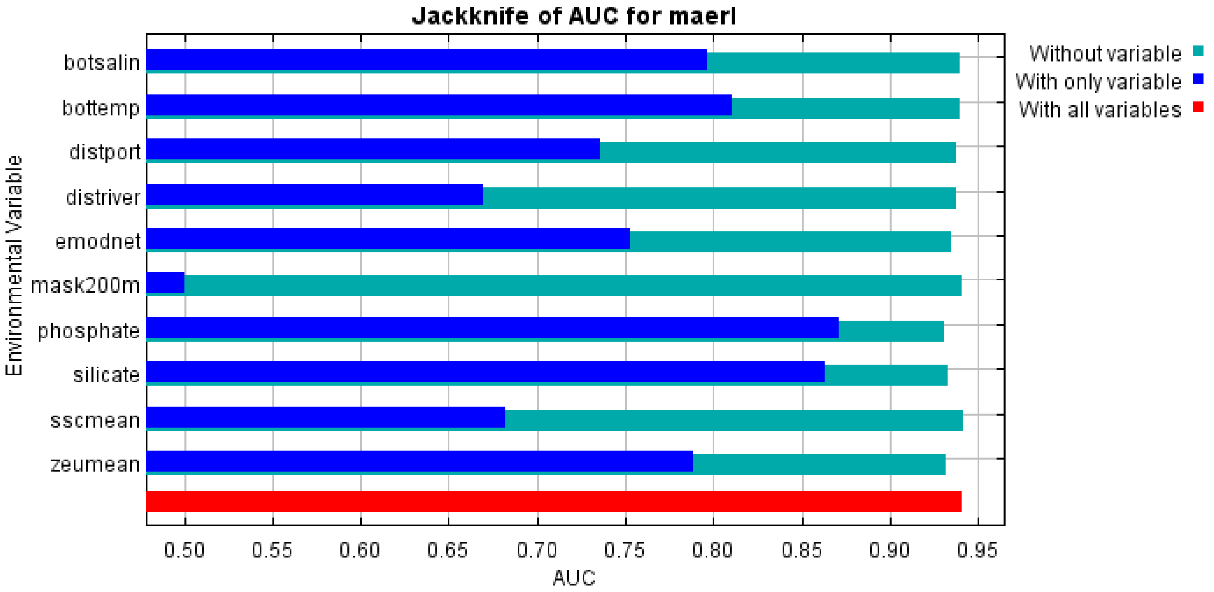

Fig. 1.3.17b. Jackknife test of variable importance for the mäerl model (test AUC).

Predicted occurrence for mäerl beds (Figs 1.3.18a-d) was found to be consistent with the known distribution of this group of species across the Mediterranean Sea (Figure 1.3.2b). Areas with known occurrences were relatively well predicted by the model. Again, the absence of occurrence record for the North African coast (excepted at two locations in Tunisian waters) meant that the model could not be trained efficiently in this area, and predicted occurrences remained very low as a result, two exceptions being on the Lybian (off Misrata) and Egyptian (West of Alexandria) coasts. Interestingly, the model predicted as very suitable (> 0.8) one area having no known record of mäerl bed: the southern Evoikos gulf (Greece). This area happens to have relatively high phosphate concentration, and groundtruthing would be necessary to confirm the actual presence of mäerl beds, beyond the predicted suitability of the area.

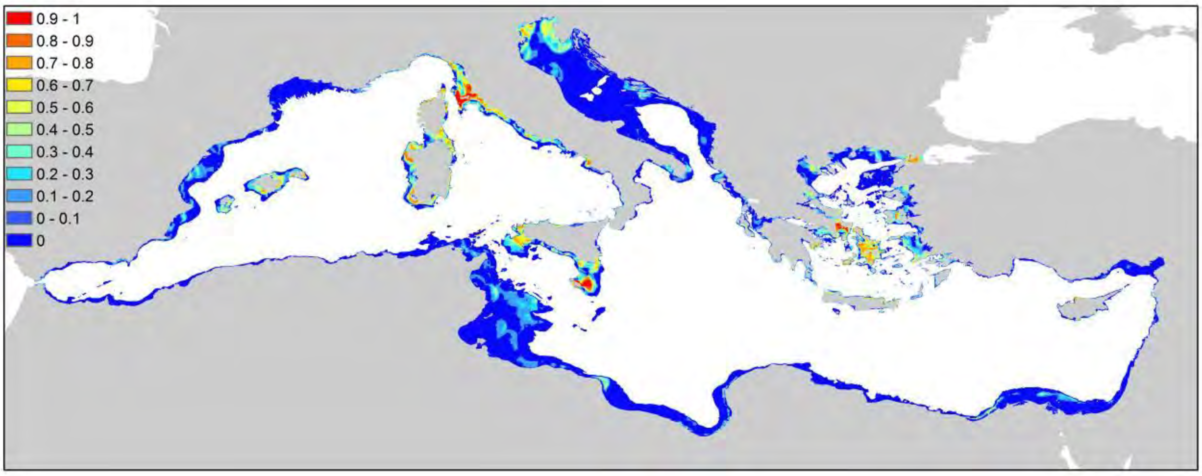

Fig. 1.3.18a. Predicted occurrence probability for mäerl beds.

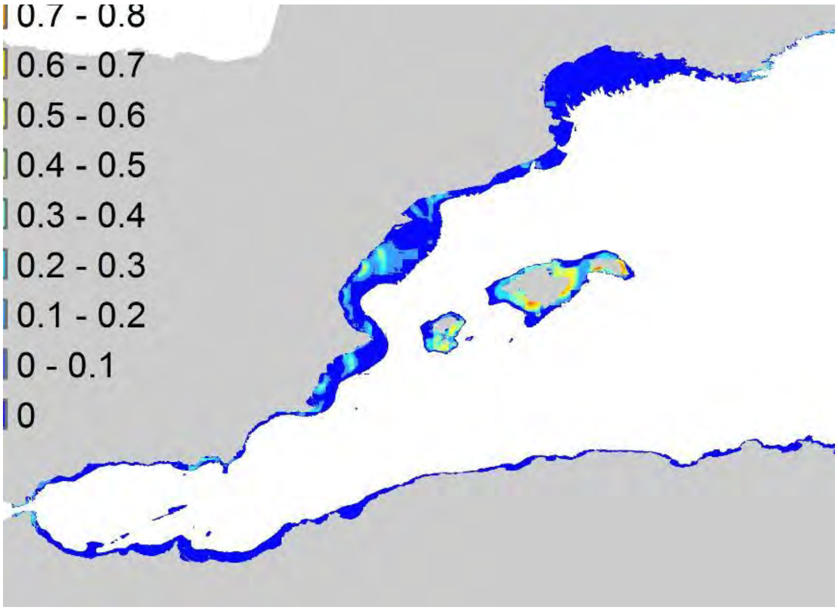

Fig. 1.3.18b. Predicted occurrence probability for mäerl beds (western Mediterranean).

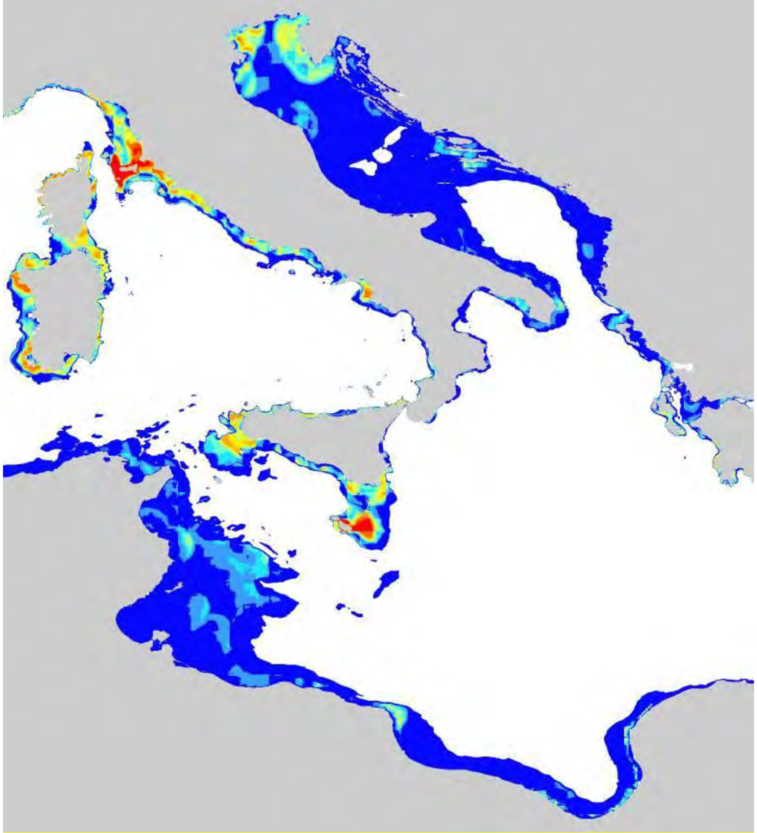

Fig. 1.3.18c. Predicted occurrence probability for mäerl beds (central Mediterranean).

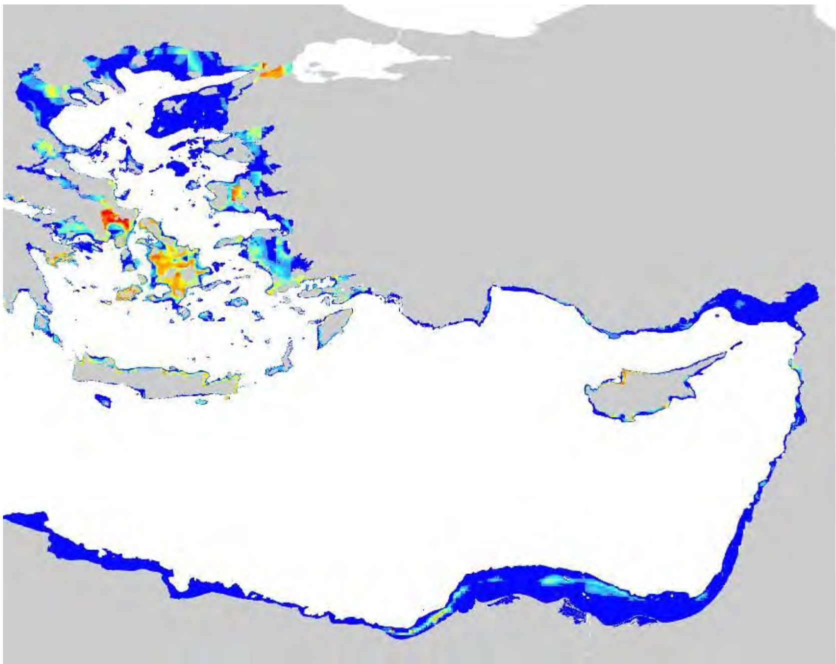

Fig. 1.3.18d. Predicted occurrence probability for mäerl beds (eastern Mediterranean).

Discussion

While modeling strategies based on presence data only may prove useful in data poor situations, and therefore in developing models for habitats whose spatial distribution is not entirely known at least in some subregions, they cannot provide reliable predictions about absence of species or habitats. This particular feature may be not relevant in some cases (e.g. prediction of a bird species distribution, i.e. prediction of the places where a bird species is more likely to be spotted), but it can be a serious drawback in others (e.g. when prediction about absence of a habitat is a necessary condition to allow a given type of fishing activity).

Our models were aimed at exploiting the existing information as effectively as possible, and therefore the modeling approach was adapted to the available data characteristics. We opted for Random Forests to model *P. oceanica* distribution because both presence and absence records were available over large regions. In fact, the better accuracy of this method comes at the cost of (1) the need for both types of records and (2) a very complex inner structure of the model (250 trees comprised of 6,000-7,000 nodes and leaves each, i.e. about 200 Mb of ASCII data).

As for coralligenous and mäerl, presence records were less abundant than those for *P. oceanica* and they were the only source of information that could support modeling. Therefore, the only viable option was to use maximum entropy models that allowed getting the very best results from the available data.

P. oceanica

The overall results of the Random Forest model were validated on the basis of the comparisons between model predictions and known records in nine test areas that accounted for about 7% of the available data (i.e. about 50,000 pixels).

While the agreement between known records and Random Forest predictions was not as good in these test regions as it was in regions from which training data were obtained, it was still very good, with almost 80% CCIs (Correctly Classified Instances) and good Kappa statistics (0.535) and area under the ROC curve (0.860). Moreover, the predicted *P. oceanica* distribution has been carefully examined by experts who found it consistent with their personal knowledge, with grey literature and with the available anecdotic information.

Due to the unbalanced frequency of presence and absence records, the Random Forest output needed to be optimized by selecting an optimal binarization threshold, i.e. the minimum percentage of trees that had to vote for *P. oceanica* presence in order to issue an overall prediction of presence.

In fact, while false positives, which in most cases are very close to the shoreline, may partly depend on the imperfect juxtaposition of the rasterized *P. oceanica* layer relative to the rasterized land mask, false negatives correspond to the inability of the Random Forest to correctly reproduce *P. oceanica* distribution. Therefore minimizing false negatives as far as possible was a very important goal, and it was achieved thanks to binarization threshold optimization performed through ROC curve analysis.

While the relative importance of predictive variables was assessed by means of a procedure that is part of the normal Random Forest training, the result is relevant only to this particular Random Forest model, and it cannot be fully generalized. The reason is that the assessed relative importance is not strictly related to the role those variables actually play in the underlying biological processes that determine the *P. oceanica* distribution. In fact, the roles of the predictive variables are strongly dependent on their spatial (and temporal) scales, as variables that are of paramount importance at small scale (meters) may be absolutely not relevant at larger scale (hundreds of metres).

For instance, depth is probably the most relevant variable in defining the distribution of *P. oceanica*, because it is strongly related to light availability and to many other factors (e.g. water movement). However, in our model the linear pixel size is about 400 m, and therefore each pixel may contain very shallow stands as well as stands that are too deep for *P. oceanica*. This means that average depth at the scale of our model is less relevant to good predictions than average depth with 40 x 40 m pixels and much less relevant than average depth with 4 x 4 m pixels. Obviously, using smaller pixels in our Random Forest Model was not a viable option, due to the coarse spatial resolution of the predictive variables.

As a consequence of the unresolved spatial heterogeneity within the smallest pixels we could afford to manage, predictive variables in our model do not affect the prediction of presence or absence through causal relationships. In fact, in most cases what Random Forests rely upon is the resemblance between some spatial features in the spatial distribution of predictive variables and the spatial distribution of *P. oceanica*. Regular shapes in groups of pixels in which *P. oceanica* is predicted as present can be found in some regions (e.g. between Tunisia and Lybia) and they clearly testify that the underlying structure of the predictive variables played a significant role in some small scale regions.

Our modeling approach not only exploited correlations more than causal relationships, but it also exploited those relationships in many different ways. As a result, trees in our Random Forest model are quite large and complex (on the average, each tree had more than 6,000 nodes and leaves), even though the minimum number of that each leaf must contain was set to 50. If a single classification tree was as large and complex as those in our Random Forest, it would probably suffer from serious overfitting problems, i.e. it would not be able to generalize what it learned. However, Random Forests are ensemble techniques, and the concurrent predictions issued from a large number of trees compensate for the lack of generalization that affects single trees.

Finally, the overall area covered by *P. oceanica* can be easily computed from the distribution obtained by merging observed data and random Forest predictions. Each pixel where *P. oceanica* is known or predicted as present can be regarded as a pixel that is (potentially) fully covered by *P. oceanica* meadows if the same is found in its Von Neumann neighborhood (i.e. the four pixels that share a whole side with it). This condition does not imply that *P. oceanica* coverage has no gaps at all, because no meadow covers 100% of the substratum over large areas, but it can be assumed as a reasonable estimate of the extension of the meadow, including small gaps, channels, etc. On the contrary, pixels on the outer boundary of the *P. oceanica* distribution may contain a very variable amount of *P. oceanica* meadow, ranging from tiny spots to a full coverage: therefore, we can assume that on the average the meadow coverage is 50%. Therefore, the best estimate for the extent of the *P. oceanica* meadows at Mediterranean basin scale can be obtained by summing up the full area of the “core” pixels and one half of the area of the outer pixels.

According to this procedure, and taking into account the latitude-related variability in pixel area (southern pixels are wider than northern ones), the overall extension of *P. oceanica* meadows in Mediterranean Sea is 44,084 km^2. As previously stated, this is an estimate of the extension of the *P. oceanica* meadows, i.e. including all the different types of gaps that are commonly found in them, which obviously cannot be modelled at the scale of our pixels.

Part of the overall extension is associated to predicted presence of *P. oceanica* obtained with less than the majority of the votes of the Random Forest, i.e. by applying the optimized 0.280 threshold instead of the “natural” 0.5 threshold. This regions account for 13,654 km^2 of meadow, i.e. for about 30% of the overall extension. As the lower threshold was validated only for the western Mediterranean, where both presence and absence data were available over large regions, we cannot be fully confident that it is optimized for the eastern and southern Mediterranean too, i.e. for those regions where pixels to be predicted were more abundant.

The role of prediction uncertainty due to the selection of the best threshold value is summarized in Figure 1.3.19. The upper and middle bars show the proportions of the three possible predictions in regions where *P. oceanica* is known to be present (upper bar) or absent (middle bar). The dark green section shows the percentage of pixels associated to a Random Forest majority vote for presence, whereas the light green sections show the percentage of pixels where the Random Forest votes for presence ranged from 0.280 to 0.5 (i.e. where more than 28% of the trees, but less than 50% of them, voted for presence).

According to the previously described threshold optimization, these cases can be regarded as valid predictions of presence in western Mediterranean, while their reliability could not be validated for the eastern basin as well as for part of the southern shore of the Mediterranean. The lower bar in Figure 1.3.19 shows how the three types of predictions are distributed in unknown pixels, and the uncertainty due to the lack of validation corresponds its light green section, that accounts for about 20% of the pixels.

In conclusion, our results showed that about 80% of the predictions were correct when validated in western Mediterranean test areas. In other Mediterranean regions, however, there is still an undefined level of uncertainty in case the trees of the Random Forest that vote for presence range from 28% to 50%, and this problem affects about 20% of the pixels.

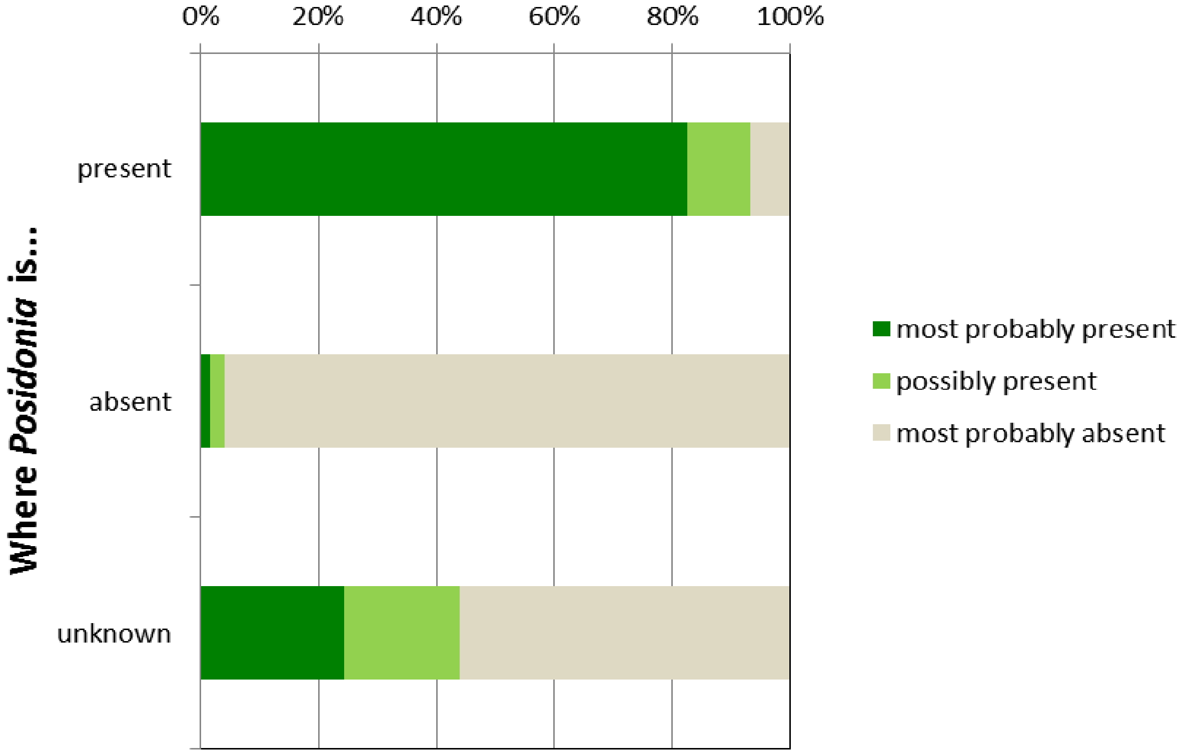

Fig. 1.3.19. Distribution of the three possible types of Random Forest output in regions where *P. oceanica* is present, absent or unknown. Dark green shows the number of cases in which more than 50% of the Random Forest trees voted for presence, while light green corresponds to votes for presence obtained from more than 28%, but less than 50% of the trees. As the optimized 28% threshold was only validated in western Mediterranean, it can be regarded elsewhere as a potential source of uncertainty.

Coralligenous formations and mäerl beds

Modeling strategies based on presence-only data help delineating the potential habitat of the species, or groups of species, studied, which can be valuable as part of a precautionary approach to conservation. As metioned above however, they cannot provide reliable predictions on absence, meaning that the predicted occurrence probability maps presented here for coralligenous formations and mäerl beds should not be used for management purposes, e.g. for the establishment of fisheries restricted zones. The maps should only be used to inform about geographical areas that are more likely to have these sensitive habitats, and possibly for directing future groundtruthing efforts. Future work could be directed towards collecting sufficient information on absence of coralligenous or mäerl, and then use the more powerful presence-absence modeling approaches, such as Random Forest.

Besides the inherent limitation of presence-ony modeling, one other major limitation of the work undertaken here was that the modeling was carried out on groups of species, as opposed to individual species. Indeed, both coralligenous formations and mäerl beds group numerous species under these two umbrella terms (UNEP-MAP-RAC/SPA, 2008). The compositions of these *species communities* vary geographically, and so do their habitat preferences. One way to deal with this issue is to use multivariate techniques to first classify communities into different groups, and then model the different groups' habitats separately. This, however, could not be done here as only part of the occurrence datasets were detailed enough to provide species compositions at the various locations. One option for future work could be to extract location information for dominant species, and develop models for each separately.

Another aspect of this study that clearly limited the power of the models was due to coralligenous occurrence records being unevenly distributed across the Mediterranean, as a result of varying levels of sampling efforts. The problem was even more acute for mäerl. This resulted in smaller probability of occurrence in poorly-sampled and un-sampled areas. Please refer to this report's section on Task 1.2 for more details.

Yet another factor limiting the models' predictive power related to the variables used as predictors. Apart from all having relatively coarse spatial resolutions (and some more than others), they often were indirect proxies of variables that would much better predict the occurrence of coralligenous or mäerl. For instance, an extremely good predictor of coralligenous formation occurrence is the presence of steep underwater cliffs, combined with strong currents, hard bottoms and mesotrophic waters. In contrast, coralligenous formations would be unlikely to occur in sedimentary zones without hard substrate, enclosed estuarine systems, and sandy areas with low salinities, although some exceptions exist. For mäerl beds, flat and sandy/muddy areas would tend to be suitable habitats, as well as straights with bottom currents. For both coralligenous and mäerl, river mouths would tend to be unsuitable habitats due to siltation, i.e. turbidity due to river output. High resolution spatial data on, for instance, bottom types or salinity, do exist, but not at the scale of the Mediterranean basin.

The broad-scale seabed habitat mapping undertaken by Cameron and Askew (2011) in the western Mediterranean (Figure 1.3.20a) followed a multicriteria evaluation approach, whereby variable layers such as bottom substrate, current and bathymetry, were combined within a GIS using various thresholds. Comparing this with maximum entropy predictions (present study, Figure 1.3.20b), there are areas where the two approaches agree well (e.g. North Algerian coast, parts of the southeastern French coastline, western Corsican and Sardinian coasts, Balearic islands, etc), and other areas where discrepancies are significant (e.g. most of the western Italian coast is missed by the multicriteria approach, and also the eastern Corsican and Sardinian coasts, etc). This initial comparison would need to be deepened so as to understand such major discrepancies between the two approaches.

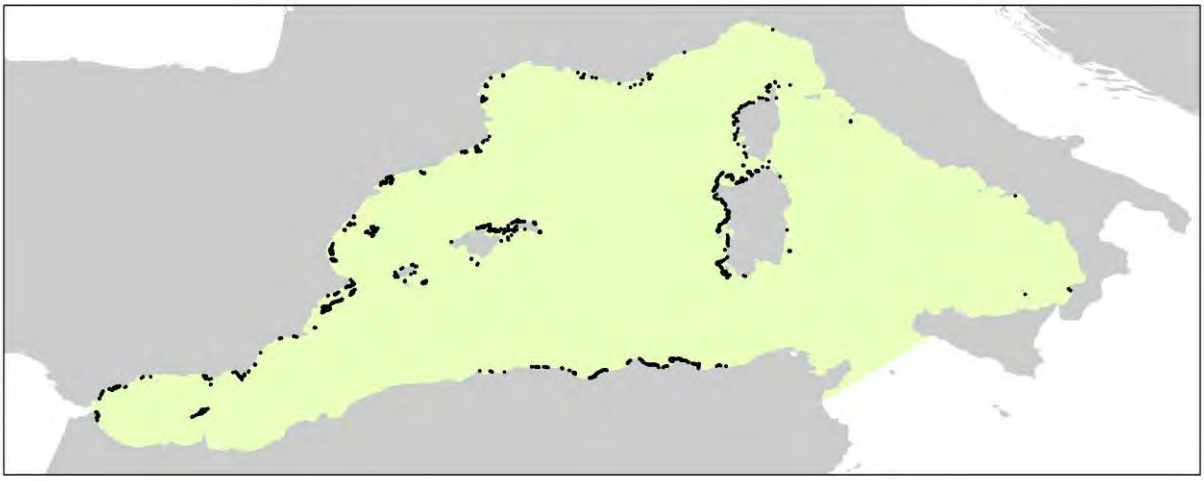

Fig. 1.3.20a. Predicted locations (points, black colour) of coralligenous formation in the western Mediterranean basin (Cameron and Askew, 2011). The study area is highlighted in light green.

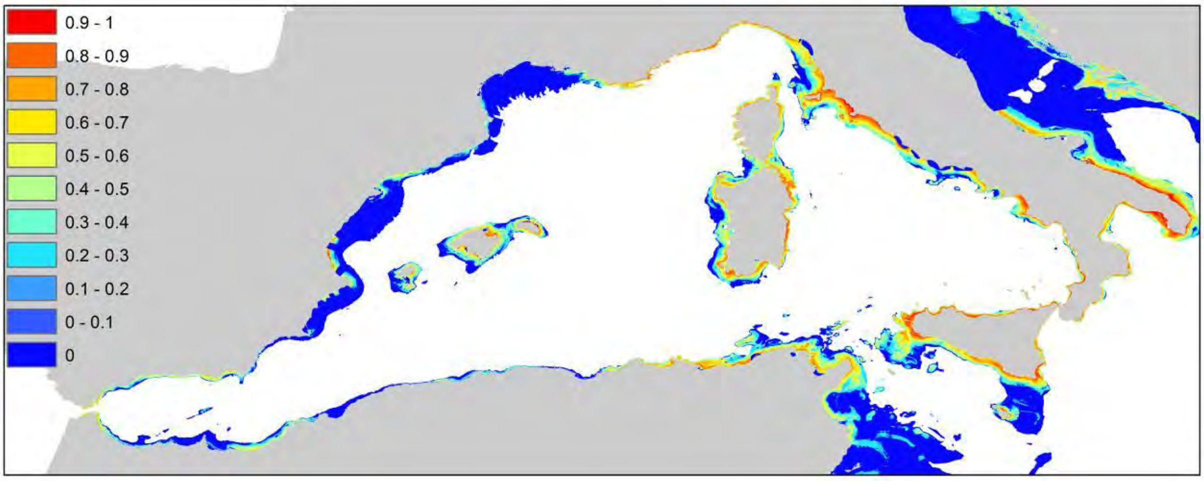

Fig. 1.3.20b. Predicted occurrence probability for coralligenous formations (for comparison with Figure 1.3.20a).

For both coralligenous and mäerl, model performance was tested using a test set that had been excluded from model development. One drawback from this approach is that the test set is spatially autocorrelated with the training set. Future modeling work should address this by using a geographically distinct, and representative, test set, though this will be difficult to achieve with the presently relatively small coralligenous and mäerl datasets used as input into the models.

Difficulties encountered and remedial actions

The distribution maps for *P. oceanica* meadows, coralligenous formations and mäerl beds that were obtained from the combination of thorough collection and modeling are probably the most accurate presently available at their spatial scale.

By all means models are not perfect. Habitat modeling techniques are very effective in filling the gaps in available data, but it cannot be taken for granted that their predictions are correct over huge unknown areas. Needless to say, the best way to improve habitat distribution models is to collect new, additional data, both for validating existing models and for developing new ones.

Although no model can fully overcome problems in the available resolution of predictor variables and that some uncertainty must be accepted, the models we developed are state-of-the-art and as accurate as possible. Therefore, we are confident that their results will be useful to support environmental management policies at Mediterranean basin scale.

To conclude, despite its limitation, our modeling approach has shown great potential. As additional occurrence, and possibly absence, data become available, along with higher resolution or more relevant predictor variables, models performance will be improved, resulting in better predicted occurrence maps.

To date, however, this modeling exercise is unique in the Mediterranean basin, having provided continuous predicted occurrence maps for three of its most important habitats, both at sampled and un-sampled locations.

Gaps in knowledge and suggestions for future actions

While more occurrence data on sensitive habitats distribution are certainly needed to improve models, models also need suitable spatial information about predictor variables. The latter must be available over the whole domain to be modelled, correlated to the habitat distribution, and possibly linked to it by causal relationships at an appropriate spatial scale. Unfortunately, very few, if any, predictor variables have all these properties.

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Task 1.4 Reviewing and mapping of all types of existing marine protected areas in different GSAs in the Mediterranean basin

(Scientific Responsible: C. Smith (HCMR), Partners involved: HCMR, CoNISMa, CNR-IAMC, CNR-ISMAR, COISPA, IEO, CIBM, FCD- MSDEC)

Cited as: *N. Papadopoulou, Smith C., M. Gristina, A. Belluscio, S. Fraschetti, A. Santelli, M. L. Pace, V. Markantonatou, M. Nikolopoulou, V. Valavanis, M. Giannoulaki, E. Palikara, C. Martin, M. Scardi, L. Telesco, Fabi G., Barro J., Grati F., Scarcella G., Punzo E., Knittweis L., Guarnieri G., D'Anna G., Pipitone C.,Spedicato M. T.* Reviewing and mapping of all types of existing marine protected areas in different GSAs in the Mediterranean basin. *Mediterranean Sensitive Habitats (MEDISEH) Final Report, DG MARE Specific Contract SI2.600741*

Background

It is acknowledged that the level of information available and the designation of MPAs between EU and non-EU states is largely unbalanced (Abdulla et al. 2008) although, under the recent UNEP/MAP/GEF Strategic Partnership for the Mediterranean Large Marine Ecosystem backed up by the EU, environmental protection is high on the regional agenda. For the EU Member States obligations arising from the Habitats Directive (eg protection of priority habitats and appropriate conservation targets) and the recent Marine Strategy framework Directive are significant drivers for mapping state and pressures and achieving/maintaining good environmental status. Spatial information will be provided on the existing MPAs along with known initiatives/proposals for new MPAs.

Objectives

The general objectives of Task 1.4 is to provide an up-to-date integrated information system concerning the occurrence of already existing marine protected areas (MPAs), where different types of measures of fishing control are adopted as well as mature proposals for near-future MPAs and Fisheries Restricted Areas (FRAs) with relevant conservation targets. Much of this information is available (although significantly less so for FRAs) but is dispersed in space and time and not yet in a digitilized format in the form of geospatial data and organised in a common database to be used for management purposes.

Thus the specific objectives of this task are to:

- identify and categorize all existing marine protected areas (MPAs) in the Mediterranean area
- identify proposed MPAs at late stage planning
- identify other areas or applied fishery measures with a spatial dimension that currently allow some levels of protection to marine species and habitats.
- review and map all types of existing marine protected areas and areas that have some degree of spatial/temporal protection from fishing activities within the Mediterranean basin.

In order to meet these objectives within the framework of MEDISEH an expert team was composed within the MAREA Consortium from scientists with long term expertise on Marine Protected Areas and fishery protected areas working at different areas in the Mediterranean basin. Details on the list of experts and external collaborators one can see below at Table 1.4.1. For CV details check MAREA expert web-site http://www.mareaproject.net/.

Table 1.4.1. Expert list involved in WP1, Task 1.4.

Participant	Participant affiliation
C. Smith	HCMR
N. Papadopoulou	HCMR
S. Fraschetti	CoNISMa (& input from 1.2)
A. Belluscio	CIBM (& input from 1.1)
L. Telesco	CIBM (input from 1.1)
M. Gristina	CNR-IAMC
G. Fabi	CNR-ISMAR
A. Santelli	CNR-ISMAR
F. Grati	CNR-ISMAR
G. Scarcella	CNR-ISMAR
E. Punzo	CNR-ISMAR
V. Markantonatou	HCMR
M. Nikolopoulou	HCMR
M. Giannoulaki	HCMR
E. Palikara	HCMR
V. Valavanis	HCMR (input from WP 3.)
L. Knittweis	FCD (MSDEC)
M. L. Pace	FCD (MSDEC)
M. Scardi	CoNISMA (input from Task 1.3.)
G. Guarnieri	CoNISMA
M. T. Spedicato	COISPA
C. Martin	HCMR/ Current affiliation: UNEP-WCMC (Cambridge, UK) (input from Task 1.3.)
G. D’Anna	CNR-IAMC
C. Pipitone	CNR-IAMC
J. Barro	IEO

Table 1.4.2. Non partners and additional experts list that contributed to WP1, Task 1.4.

Participant	Participant affiliation
Bruno Meola	MedPan
Charis Charilaou	DFMR MOA GOV Cyprus
Marie Romani	MedPan
Menachem Goren	Dept Zoology, Tel Aviv University
Alessandro Lucchetti	CNR-ISMAR
Raquel Goni	IEO
Antonello Sala	CNR-ISMAR
Med Dhia Guezguez	RAC/SPA

Deliverables and Milestones foreseen

The following table describes the Task Deliverables & Milestones as foreseen by the proposal.

Deliverable	Description	Timeframe
M1.4.1.	Identification of Mediterranean MPAs	Month 6
M1.4.2	Identification of areas with certain applied fishery measures that currently allow some levels of protection to marine species and habitats	Month 12
M1.4.3	Synthesis map of existing and proposed MPAs based also on the output of Task 1.1, Task 1.2 and Task 1.3	Month 14
M1.4.4	Report of gaps in knowledge and future research needs	Month 16
D1.4.1	Database with GIS information on existing MPAs	Month 6
D1.4.2	Database with GIS information on habitat areas subjected to particular protective fishing measures in the Mediterranean mainly enforced by national legislation	Month 12
D1.4.3	Report with a synthesis map reviewing the existing information on Mediterranean MPAs, results of WP1 and proposed areas	Month 16

Progress achieved

Within the framework of Task 1.4 and according to MEDISEH proposal four meetings were held within the framework of the project. Specifically:

A one day workshop took place following the kick-off meeting of the project that was held in Heraklion (Crete) in October 2011, in order to exchange information between partners involved in Marine Protected and Fishery Restricted Areas and GIS experts. This aimed to standardise the work among the partners involved especially concerning the input data format. Participants were: Nadia Papadopoulou, Vessa Markantonatou, Vassilis Valavanis (Greece), Leyla Knittweis (Malta), Gianna Fabi, Fabio Grati, Michele Gristina, Simonetta Fraschetti (Italy), Andrea Belluscio (Italy), Maria Teresa Spedicato, Giuseppe Lembo (Italy) and the task coordinator Chris Smith (HCMR).

Half a day workshop was held within the second meeting of MEDISEH at Palermo (Sicily) in February 2012. WP1.4. lead partner and project participants have presented aims and progress towards these meetings, and having assessed the situation, they also agreed to further actions to achieve the task objectives.

At the third MEDISEH meeting held in Orto Botanico, Rome WP1.4 a presentation was given on 26.09.12 and discussions held in parallel sessions on 27-28.09.12 with focus on the completion of the Fishing Restriced Areas work. WP1.4. lead partner presented “Task 1.4 Review and mapping of all types of existing marine protected areas in different GSAs in the Mediterranean basin: Overview of the work done. Smith C.J., Papadopoulou K.N. & V. Markantonatou (HCMR) with multi-partner contributions.” Significant progress was noted at this stage in comparison with Palermo, February 2012) and the Interim Report (March 2012). One Excel database file with all the protected area entries (MPAs, SPAMIs, proposed MPAs, FRAs) was constructed along with the respective shapefiles that have been created separately. The progress noted in numbers on each of the four thematic areas was:

- MPAs: this was noted to be 97% complete with only 5 shapefiles missing (out of 31 missing in the Interim report). As part of the MPA information, the SPAMI list includes an updated list of 32 entities, 100% complete
- Proposed MPAs: all the major mature Med MPA proposals (16 proposals for 337 listed areas) have been recorded in the database, but missing shapefiles were anticipated (unavailable information or detail in certain proposals).
- FRAs: this was noted to be about 90% complete with 25% missing shapefiles. This is part of Deliverable 1.4.2.

In addition, discussions were held to identify WP1 relevant Gaps in the knowledge.

At the fourth and final MEDISEH meeting held in Heraklion, Crete, in January 2013, a status report was made and presented during a plenary session of the meeting participants. The presentation ”Task 1.4: Review and mapping of all types of existing marine protected areas in different GSAs in the Mediterranean basin – The Final Deliverable: C.J. Smith, N. Papadopoulou, V. Markantonatou & M. Nikolopoulou, HCMR” was uploaded and made available on the MAREA ftp site.

The presentation and the related discussion covered the following points:

- Update of Deliverable 1.4.1. (delivered by month 6): following the recent update of the MEDPAN resource the project team undertook extensive checks and wherever necessary updated the MPA database records supplementing these with additional shapefiles.
- Progress of work on FRAs and Proposed MPAs (Deliverable 1.4.2). Significant progress was made on FRAs since 3rd MEDISEH meeting in Rome and its potential was shown through the MEDISEH online GIS viewer (eg gear closures across the Mediterranean. Ongoing work on proposed MPAs as parts of major proposals (eg OCEANA or Greenpeace) for Mediterranean Marine reserves or SPAMIs was presented.
- Focus and form of Deliverable D.1.4.3 “Report with a synthesis map reviewing the existing information on Mediterranean MPAs, results of WP1 and proposed areas”: This was agreed to be made available through the MEDISEH online GIS viewer as a series of spatial queries allowing for the estimation of the overlap between existing and proposed MPAs and *Posidonia/* and mäerl and coralligenous habitats based on the information collected within Tasks 1.1 and Task 1.2 of MEDISEH.

Project partners present at the meeting were asked for the availability of any further data sources that might have been missed, final checks and to comment on the data presented through the online GIS viewer. It was noted that the data for FRAs in France and Spain were probably under-reported due to the lack of contacts or willingness to provide data. Meetings agendas are given in Annex III of this report.

Details on the progress of the work achieved after January 2013 towards the Task deliverables and milestones prior to the submission of the Final Report are given below:

- Existing MPAs & SPAMIs: the fully updated version of Deliverable 1.4.1., includes 2 datasheets within a common Excel database that involves 146 and 32 entries respectively (including information on 37 and 25 data fields, respectively) accompanied with spatial information. This is now re-submitted with the Final Report and can be found as D.1.4.1. at http://mareaproject.net/FTPMareaProject/#22/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/task1.4/Annex

1.4.1/ Deliverable 141_142.xlsx and the geoserver at http://geoserver.org/). The visual inspection of these entries can be done at the online GIS viewerhttp://mareaproject.net/mediseh/viewer/med.html

- Proposed MPAs: the majority of entries were accompanied with shapefiles, bringing this task to 100% completion, although a large number of these are depicted as single points on the MEDISEH online GIS viewer. This was anticipated and is mostly the result of the lack of detail in the original proposals (e.g. area descriptions, no name concerning seamounts and the lack of geographic coordinates/spatial data). In some cases shapefiles were created by digitizing maps. Entries in many cases do not represent unique areas as proposed to be protected. For example, a number of areas are consistently proposed by several proposals e.g. Alboran Sea and/or seamounts and Balearic Islands and/or seamounts feature in 5 proposals while Eratosthenes seamount appears in 7 proposals. Every effort was made to check and include all recent updates and proposals (eg replacing less detailed shapefiles with newer as area definitions were firmed up or spatial data were freely available). The final datasheet (within a common database) now includes 333 entries with information given in 31 fields including legal proposed status (i.e. MPA, SPAMI, marine reserve etc) and special protection targets (species and/or habitats). Proposed MPAs is part of Deliverable 1.4.2 and is available in the http://mareaproject.net/FTPMareaProject/#22/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/task1.4/Annex 1.4.1/ Deliverable 141_142.xlsx and the geoserver at http://geoserver.org/). The visual inspection of these entries can be done at the online GIS viewerhttp://mareaproject.net/mediseh/viewer/med.html
- Fisheries Restricted Areas (FRAs): following extensive quality control, as well as the removal of various technical non spatial measures and small scale short duration temporal restrictions, this datasheet (within the common Excel database) now includes 422 entries with information given in 22 fields including gear group, closure type, shapefile name and viewer identifier, bringing this task to 100% completion. This was a major undertaking and one considered very worthwhile to be continued updated and enriched in the future. The plethora of national legislations in the Mediterranean countries along with the plethora of gears used and the varying degrees of implementation and/or adoption of EU legislation in non-EU MS made this task a challenging necessity. Fisheries Restricted Areas is part of Deliverable 1.4.2. and is available in the http://mareaproject.net/FTPMareaProject/#22/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/task1.4/Annex 1.4.1/ Deliverable 141_142.xlsx and the geoserver at http://geoserver.org/). The visual inspection of these entries can be done at the online GIS viewerhttp://mareaproject.net/mediseh/viewer/med.html
- Synthesis map: following the completion of all the WP1 tasks quantative queries of spatial overlap of existing and proposed MPAs with priority and sensitive Mediterranean habitats were calculated and selected ones depicted with maps/grabs from the MEDISEH online GIS viewer. This work concerns Deliverable 1.4.3. This deliverable can be visualized and realized through the online GIS viewerhttp://mareaproject.net/mediseh/viewer/med.html
- Detailed descriptions of Deliverables 1.4.1 – 1.4.3 and major findings of D1.4.3. are given in the section below.

Sources of data

Within the framework of this Task information was reviewed from multiple sources and it was collated in a common Excel database with geospatial data. This database is part of Deliverables 1.4.1. & 1.4.2 and are included in the Excel file *MEDISEH_WP14 MPA v20March2013 Deliverable 141142.xlsx*, detailing the existing MPAs, SPAMIs and FRAs as well as the proposed MPAs.

Specifically, a lot for information was derived from 3 critical sources:

- The Network of Managers of Marine Protected Areas in the Mediterranean (MedPAN.org),
- the updated (in accordance to WDPA standards for reporting) and newly available resource Mapamed.org (a MEDPAN and UNEP RAC-SPA collaboration) and
- the World Database on Protected Areas (WDPA-marine.org), whereas additional information obtained through OCEANA, IUCN, CIESM, GFCM, ACCOBAMS, and the EEA (Natura2000 sites).

Additional geospatial information was kindly made available by the MEDISEH participants who have further added, checked data sources and provided additional GIS shapefiles, maps, and sources of published information. GIS shapefiles (or at the very least some geographic coordinates or maps as jpeg files) are present for almost all of MPAs and hot clickable to the original source if available on the web. Effort was made to provide shapefiles for all the proposed MPAs although as expected a large part of the available shapefiles were only single point/circles shapefiles. This is related to the original lack of detail in the proposals as in some cases whole bays/seas are proposed with no local spatial detail. As witnessed in the repeated names of certain areas in the database entries and seen by others (e.g. UNEP MAP RAC-SPA 2010 de Juan & Lleonart, Coll et al 2011, Portman et al 2012, Micheli et al 2013) there is protection consensus for a large number of areas.
Although almost all FRA (i.e. Fishery Closure Area or Fisheries Restricted Area is defined as a fishery closed or restricted by a government entity or a regional authority. A Fisheries Restricted Area is an area closed to fishing permanently, temporary or seasonally and this closure may apply to one or more gears. (http://www.protectplanetocean.org/introduction/introbox/glossary/glossary/introduction-item.html#mpa) entries in the database include some form of spatial information there are still numerous cases where it was not possible to create a shapefile (in 117 out of the 422 entries, i.e. 28%). Most notable reasons included restrictions referring to unknown locations or unknown capes despite thorough check even at navigation maps, relating to distances from undefined locations for example aquaculture farms (the only recent published map with google earth single pointers is by Trujillo et al 2012), harbours, river mouths and deltas, and some referring to un-available bathymetric contours. Another major drawback is the lack of shallow bathymetric contours (less than 50 m depth) in the Mediterranean as well as the lack of mapping data for key habitats, predominant habitats and bottom substrate. It seems that although the pelagic and satellite domain has done relatively well the benthic habitats descriptors data collection and mapping have fallen behind and seem sub-standard and in need of further focussed research efforts.

The status on the work done on this Task in relation to the associated deliverables is summarized in Table 1.4.3.

Table 1.4.3. Table indicating the state of art for each deliverable: the percentage of foreseen results and the possibility to reach the 100% of the foreseen results.

Deliverable	Description	% of foreseen results	Timeframe to reach 100% of results
M1.4.1.	Identification of Mediterranean MPAs	100%	By Month 6
M1.4.2	Identification of areas with certain applied fishery measures that currently allow some levels of protection to marine species and habitats	70%	By Month 12
M1.4.3	Synthesis map of existing and proposed MPAs based also on the output of Task 1.1, Task 1.2 and Task 1.3	20%	By Month 14
D1.4.1	Database with GIS information on existing MPAs	95% 100%	By Month 6 By Month 17
D1.4.2	Database with GIS information on habitat areas subjected to particular protective fishing measures in the Mediterranean mainly enforced by national legislation	50% 100%	By Month 12 By Month 17
D1.4.3	Report with a synthesis map reviewing the existing information on Mediterranean MPAs, results of WP1 and proposed areas	20% 100%	By Month 16 By Month 17

Detailed description of Milestones 1.4.1-1.4.3 and Deliverables 1.4.1-1.4.3.

Detailed description of the final form of the Excel database of the Mediterranean MPAs & FRAs (D. 1.4.1-1.4.2.)

The following section described the combined Excel file database with individual Sheet Descriptions. The sheets are as follows:

- ***Credits/About***: self-explanatory introduction about the data file and credits, while acknowledging contributions by MEDISEH partners and external contributors.
- ***Index***: index includes definitions of terms (and source/reference) and acronyms used in the different Excel sheets, including List of GSAs, Legal Status, International Recognition, IUCN Management Category, MPA Zoning, Gears Forbidden, Activities Forbidden or regulated and Special Protection Targets. This datasheet contains 144 entries (Tables 1.4.4-1.4.7).

Table 1.4.4. Table showing the GSA **(Geographical Sub-Area)** Number and name.

GSA Number	Geographical Area Name
1	northern Alboran Sea
2	Alboran Island
3	Southern Alboran Sea
4	Algeria
5	Balearic Island
6	northern Spain
7	Gulf of Lions
8	Corsica Island
9	Ligurian and North Tyrrhenian Sea
10	south Tyrrhenian Sea
11.1	Sardinia (west)
11.2	Sardinia (east)
12	northern Tunisia
13	Gulf of Hammamet
14	Gulf of Gabes
15	Maltese Islands
16	south of Sicily
17	northern Adriatic
18	southern Adriatic Sea
19	western Ionian Sea
20	eastern Ionian Sea
21	southern Ionian Sea
22	Aegean Sea
23	Crete Island
24	north Levant
25	Cyprus Island
26	south Levant
27	Levant
28	Marmara Sea
29	Black Sea
30	Azov Sea

Table 1.4.5. Table showing the types of legal status designated to marine protected areas at the national level.

Legal status
Archaeological Protection Area (APA)
Marine Protected Area
Protected area
Marine and Coastal Protected Area
Specially Protected Area
Marine Nature Reserve
Marine Park
Marine Reserve
Natural Monument
Hunting Reserve
National Park
Nature Park
Nature Reserve
Fishery Closure Area = Fisheries Restricted Area (FRA)
Natural Reserve
Biotope Protection Ordered Zone
Special Environmental Protected Areas (SEPAs)
ZTB: biological protection areas
Essential Fish Habitat (EFH)
National Forest Park

Table 1.4.6. Table showing the types of legal status designated to marine protected areas at the international level (at EU, Regional Sea Convention and other levels)

International Recognition
Natura 2000
RAMSAR site (Wetlands of International Importance)
Important Bird Area (IBA)
Biosphere Reserve
SPAMI
World heritage site

Table 1.4.7. Table showing types of activities prohibited or regulated or allowed in the MPAs (or core and other zones of MPAs)

Activities	Acronym

Recreational fishing	RF
Professional fishing	PF
Spear fishing	SF
Mooring, anchoring	M/A
Navigation, sailing	N/S
Scuba diving	SD
Scientific research	SR
Swimming	SW

- ***Existing MPAs***: This datasheet contains 37 data fields and 146 records; the type of data entered in each data field is shown in the Table below (Category vs Explanation).

Table 1.4.8. Information within the Data Set of Existing MPAs (categories and definitions).

Category	**Explanation**
Sub- region	sub part of the Mediterranean where the MPA is located
GSA	GFCM sub-areas within the Mediterranean
Country	The main country where the MPA is located
ID MEDISEH	The Identification code of the MEDISEH project for each MPA
WDPA IDs related to the selected area	Identification Numbers for World Database of Protected Areas (WDPA: http://protectedplanet.net)
Names of the related areas	
Protected area	Area name within countries
Geographical coordinates	Latitude Longitude for the centre of the area
Legal status (Nature Protection Area, Marine Protected Area MPA, Specially Protected Area, Marine Reserve etc)	Legal definition of the MPA
Year Establishment National Recognition	Year that the MPA was officially created
Additional International Recognition (Natura 2000, SPAMI, IBA etc)	Any other recognition information
Year Establishment International Recognition (Natura 2000, SPAMI, IBA etc)	Year that the MPA acquired international recognition
Legal aggreg category	*Legal aggregation category. Records are assigned to 15 aggregation categories given in the index (and include for example MR-MPA Marine Reserve MPA, NP MPA National Park MPA, S-MPA Sanctuary-MPA, FRA, SPAMI etc).*
IUCN Mgmt. category	International Union for Conservation of Nature management category: Ia Strict Nature Reserve, Ib Wilderness Area, II National Park, III Natural Monument, IV Habitat/Species Management

Category	Explanation
	Area, V Protected Landscape/seascape, VI Managed Resource Protected Area
Mgmt. body	Management body overseeing the MPA
Marine area (km2)	Size of the total MPA in the marine environment
Multizone	If there are different protection zones
Zoning	e.g. Core, integral, buffer, etc.
No- take zone	If there is a no-take zone
I surface (km2)	Size of integral zone
Prof_fishing I, gears forbidden in I	*professional gears forbidden in I*
Prof_fishing B, gears forbidden in B	*professional gears forbidden in B*
Prof_fishing P, gears forbidden in P	*professional gears forbidden in P*
I prohibited activities	Prohibited activities in I
I regulated activities	Regulated activities in I
I allowed activities	Allowed activities in I
Special Protection Targets	Targeted protection for species, ecosystems, habitats
Available Polygon/Shapefiles and source	Yes/no, and source or link for an available GIS shapefile
Recommended shapefile	*recommended shapefile and source*
Map Source/Ref	Yes/no and citation or reference for an available map of the area
Additional Information/problems/inconsistencies	Any additional information or problems with the data for example inconsistencies between multiple data sources
information Provider: Partner name	Name and institution of the data provider
References for the MPA	Any additional references for the MPA
WDPA_ID or Natura_ID	WDPA or Natura ID number corresponding to the chosen and displayed in the viewer shapefile
WDPA Name of Protected Area corresponding to WDPA_ID or Natura_ID	WDPA Name of Protected Area corresponding to WDPA_ID or Natura_ID
Gear prohibited in Core/integral part of MPA	Gear prohibited in Core/integral part of MPA
Viewer ID	MEDISEH online GIS viewerID Number

- ***SPAMIs List:*** This datasheet contains the list of SPAMIs (also included in the MPAs), with 25 data fields and 32 records; the type of data entered in each data field is shown in the Table below (Category vs Explanation). These are additional data as given by WDPA as open access data.

Table 1.4.9. Information within the Data Set of Existing ***SPAMIs List*** (categories and definitions).

Category	**Explanation**
Code, Name of the SPAMI, Year of inscription	Code, name of SPAMI and year of designation
Published Sources	Source and link (e.g. UNEP MAP RAC/SPA reports and links to these)
WDPA ID	WDPA ID by http://www.protectedplanet.net/
Country	country
name	Name of SPAMI
orig_name	The original name of the protected area
desig	Designation. The type of protected area as legally/officially established or recognised (e.g. national park, world heritage site) provided in Latin characters.
desig_eng	The type of protected area as legally/officially established or recognized translated into English, where possible.
desig_type	Designation type: 'national' for nationally designated sites or 'international' for a protected area recognized under an international convention such as UNESCO World Heritage, UNESCO Biosphere Reserve or RAMSAR.
iucn_cat	IUCN Protected Area Management Category (C)
marine	Marine. Given by a “1” for True or “0” for False. Marine sites as defined for the WDPA, encompass any portion of the marine environment in whole or in part according to geographic location and management strategy.
rep_m_area	Reported Marine area. Total marine extent of the protected area (square kilometres) as reported to UNEP-WCMC by the data provider. Contingent on the Marine field being True.
rep_area	Reported Area (km2). Total protected area extent, cumulative of both marine and terrestrial are as reported to UNEP-WCMC (square kilometres).
status	Current legal or “official” status of the site (e.g. proposed, designated).
gov_type	Governance structure of a protected area if reported
mang_auth	Management authority. The organisation(s) or agency/ies responsible for management of the protected area
int_crit	International Criteria used to define the protected area designation type
mang_plan	Management plan. A reference to an official management plan for the protected area
no_take	No take area if present
no_tk_area	Size of no take area
Shape_Length	Shape length
Shape_Area	Shape area
Related Mediseh MPA ID	The related MEDISEH MPA ID is given here, since a lot of MPAs have multiple designations but their spatial borders are not always the same despite the “same” name.
SPAMI ID	This is the MEDISEH ID for the SPAMIs and the corresponding online GIS viewerID

- ***Existing FRAs:*** This datasheet contains the list of FRAs, with 22 data fields and 422 records; the type of data entered in each data field is shown in the Table below (Category vs Explanation) and is part of the future Deliverable 1.4.2.

Table 1.4.10 Information within the Data Set of Existing ***FRAs*** (categories and definitions).

Data Fields	**Explanation**
Sub- region	sub part of the Mediterranean where the FRA is located
GSA	GFCM sub-areas within the Mediterranean
Country	The main country where the FRA is located
Protected area	Geographical area within the country that is protected
Protected area details	Coordinates or delimitation features of the area (depth, distance, coordinates)
FRA type (FRA, ZTB, FMZ, EFZ, GFCM, reefs, Technical measure, gear ban)	Type: FRA-fisheries restricted area, ZTP-Biological Protection Area. FMZ-, EFZ-, GFCM, reefs-, technical measure-, gear ban
Date established	Date that the FRA was officially created
Prohibition period (no of month per year)	Time period that the prohibition covers
Measure/Gear Information	Measure or type of fishing gear prohibition
Changed/abolished restrictions	Date of major change or abolition of the measure
Shapefile availability "yes/shapefile created", "no" and "NA"	Whether a shapefile is available for the record
Map & Ref.	Reference or website with map
Additional Information/problems/inconsistencies	Any noted inconsistency in the definition for he record (position, gear etc.)
information Provider: Partner name	MEDISEH participant data source
FRA References	Original FRA information source
Shapes, names	Name of shapefile
Viewer_id	Identification number for the MEDISEH online GIS viewer
Gear group	Major fishing gear concerned
Closure type	Closure type (spatial or temporal)
MEDISEH ID	MEDISEH project identification code
Reasons for No and NA shapefiles	Reasons why shapefiles are not available (eg lack of bathymetry contours, unknown location of aquaculture farms or unknown harbours and capes)
Reasons for not shown in the viewer	Reasons why certain shapefiles are not shown in the viewer (mostly due to spatial overlap with other measures/records and in cases of annual temporal restrictions shown in the “general restrictions” part of the viewer as detailed in the viewer help file)

- ***Proposed MPAs & FRAs:*** This datasheet contains the list of Proposed MPAs, with 31 data fields and 333 records; the type of data entered in each data field is shown in the Table below (Category vs Explanation) and is part of the future Deliverable 1.4.2.

Table 1.4.11. Information within the Data Set of Existing ***Proposed MPAs & FRAs*** (categories and definitions).

Category	**Explanation**
Searching by proposal	Searching by proposal name
Sub- region	sub part of the Mediterranean where the MPA is located
GSA	GFCM sub-areas within the Mediterranean
Country	The main country where the MPA is located
ID MEDISEH	The Identification code of the MEDISEH project for each MPA
Protected area	Area name within countries
Geographical coordinates	Latitude Longitude for the centre of the area
Legal existing status	As/if existing
Legal proposed status	As proposed (eg as marine reserves, SPAMIs, Priority areas for Conservation, Marine Peace Parks, EBSAs, etc)
IUCN Mgmt. category	International Union for Conservation of Nature management category: Ia Strict Nature Reserve, Ib Wilderness Area, II National Park, III Natural Monument, IV Habitat/Species Management Area, V Protected Landscape/seascape, VI Managed Resource Protected Area
Marine area (km2)	Size of the total MPA in the marine environment
Multizone?	If the MPA has different protection zones
Zoning	What are the zones (Core, integral, buffer, etc.)
No- take zone	If there is a no-take zone
I surface (km2)	Size of integral zone
Prof_fishing I, gears forbidden in I	*professional gears forbidden in I*
Prof_fishing B, gears forbidden in B	*professional gears forbidden in B*
Prof_fishing P, gears forbidden in P	*professional gears forbidden in P*
I prohibited activities	Prohibited activities in I
I regulated activities	Regulated activities in I
I allowed activities	Allowed activities in I

Category	**Explanation**
Special Protection Targets	Targeted protection for species, ecosystems, habitats.
Available Polygon/Shape files and source	Yes/no, and source or link for an available GIS shapefile
Map Source/Ref	Yes/no and citation or reference for an available map of the area
Additional Information/problems/inconsistencies	Any additional information or problems with the data for example inconsistencies between multiple data sources
information Provider: Partner name	Name and institution of the data provider
References for the MPA	Any additional references for the MPA
Shapefile name	Shapefile name
Shapefile provider	Shapefile provider
Comments about shp	Comments about the shapefile (if for example shapefiles are shown as single points based on proposal maps)
Viewer ID	MEDISEH viewer ID Number

- ***References:*** This datasheet contains the References used (263 records and 44 websites) and is part of Deliverable 1.4.1. and Deliverable 1.4.2.

Detailed description of the final form and content of Deliverable 1.4.3.

The deliverable involves various *"Syntheses Maps and Tables"* that effectively integrate information from Tasks 1.1., 1.2 and 1.3 with the different types of spatial restrictions information collected *and* is presented in detail below:

The current status of MPAs, SPAMIs and NATURA in the Mediterranean Sea is shown in Figs 1.4.1 to 1.4.3. The number and the spatial extent of MPAs although higher in the Western Mediterranean they seem rather balanced between eastern and western Mediterranean (Fig 1.4.1, 1.4.4). The picture further differentiates when seen at a country level (Fig. 1.4.5). When Pelagos sanctuary is excluded, Spain seems to have the largest percentage of MPAs compared to the total MPAs area in the Mediterranean (i.e. 33%). Greece, Italy and Turkey are next with a percentage of MPAs up to 16%. Percentages can largely vary upon the inclusion of Pelagos sanctuary and zones such as the Italian ZTB and the Maltese fisheries management zone. Similarly, the percentage of NATURA sites largely differentiates between countries. NATURA sites in Greece correspond to almost 35% of the total area whereas 28% in France and 24% in Italy, respectively (Fig. 1.4.6).

Fig. 1.4.1. The current status (2013) of MPAs (including SPAMIs) distribution across the Mediterranean Sea as seen in the MEDISEH online GIS viewer.

Fig. 1.4.2. The current status (2013) of SPAMIs distribution across the Mediterranean Sea as seen in the MEDISEH online GIS viewer.

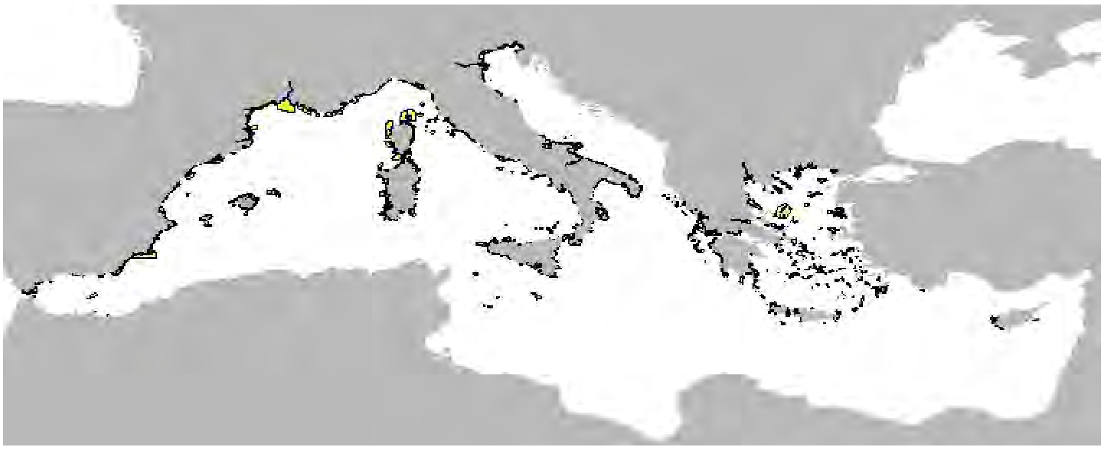

Fig. 1.4.3. The current status (2013) of NATURAs distribution across the Mediterranean Sea as seen in the MEDISEH online GIS viewer.

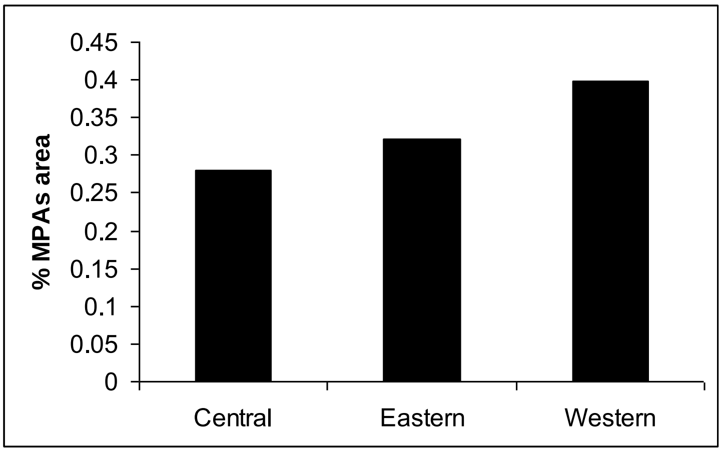

Fig. 1.4.4. The percentage of MPAs in the Eastern, Central and Western part of the Mediterranean in relation to the total MPAs area. (East Med: Aegean Sea & Levantine; Central Med: Adriatic Sea, Sicily, Tunisia; Western Med: Spanish Med Waters, Gulf of Lions, Tyrrhenian, Liguria, Algeria, Morocco). Pelagos Sanctuary is excluded.

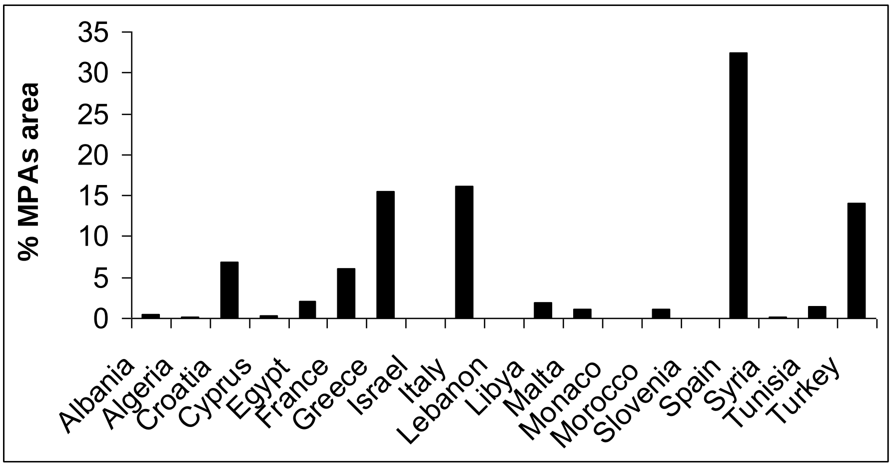

Fig. 1.4.5. The percentage of MPAs as allocated in the different countries across the Mediterranean Sea in relation to the total MPAs area. Pelagos Sanctuary is excluded.

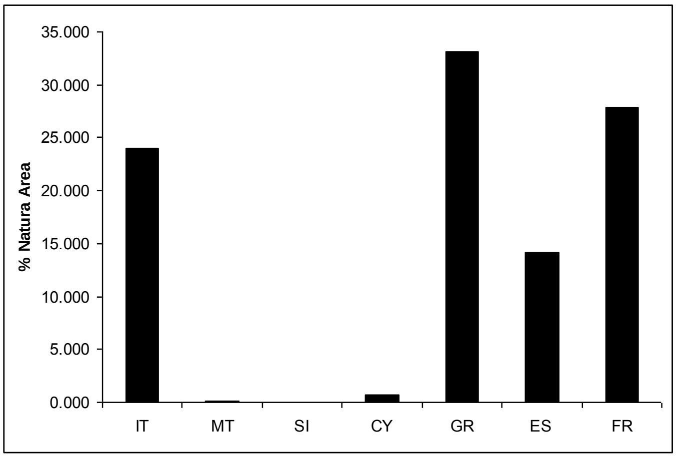

Fig. 1.4.6. The percentage of NATURA areas as allocated in the different countries across the Mediterranean Sea in relation to the total NATURA area.

There is only a limited number of EU/GFCM FRAs, all with international recognition status although more proposals are widely discussed. These EU GFCM FRAs are well known and cover substantial areas however, the work done within MEDISEH is the first attempt to retrieve and collate the often ignored, nationally defined FRAs along with existing well known international FRAs (see for example Figs 1.4.7 and 1.4.8). This was a major undertaking and a task that needs to be continued with more dedicated research efforts. Fisheries restrictions, as revealed by national laws, often refer to different categories of small scale gears, gears-species-times combinations, technical measures, spatial (from the country level to the very local level) and various temporal restrictions (i.e. from 2 months up to 12 months on a yearly basis) and their evolution in time. Current FRAs as depicted and calculated through geospatial information cover a far larger area of the Mediterranean Sea compared to existing MPAs and NATURA 2000 sites (see Figs 1.4.7. and Table 1.4.12). This is especially true for the bottom trawl prohibitions (based on the Mediterranean Regulation 1967/2006) that include depths greater than 1000 m and depths shallower than 50 m or in distances less than 1.5 nm from the shore. This becomes more important considering that the Mediterranean is predominantly a deep sea with the major part deeper than 1000 m.

The number of retrieved FRAs per country is shown in Fig. 1.4.9. Apparently, Greece has the highest number of FRAs (120 for bottom trawls/ 86 for purse seines and 47 for small scale gears) followed by Turkey (48 for bottom trawls/ 31 for purse seines and 2 for small scale gears).

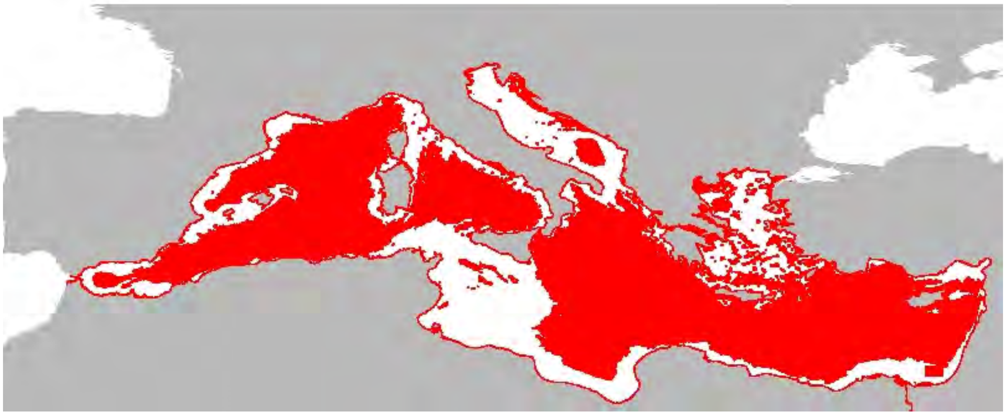

Fig. 1.4.7. Mediterranean FRAs where bottom trawl is prohibited as seen in the MEDISEH online GIS viewer. The 1000 m isobath where bottom trawl operation is prohibited across the Mediterranean is also shown.

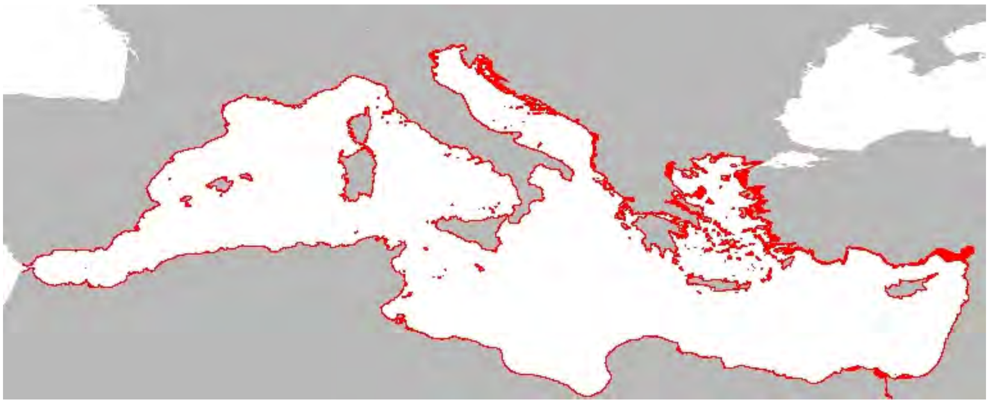

Fig. 1.4.8. Mediterranean FRAs where purse seine is prohibited as seen in the MEDISEH online GIS viewer. Please not that as per EC 1967/2006 “The use of purse seines shall be prohibited within 300 meters of the coast or within the 50 metres isobath where that depth is reached at a shorter distance from the coast”

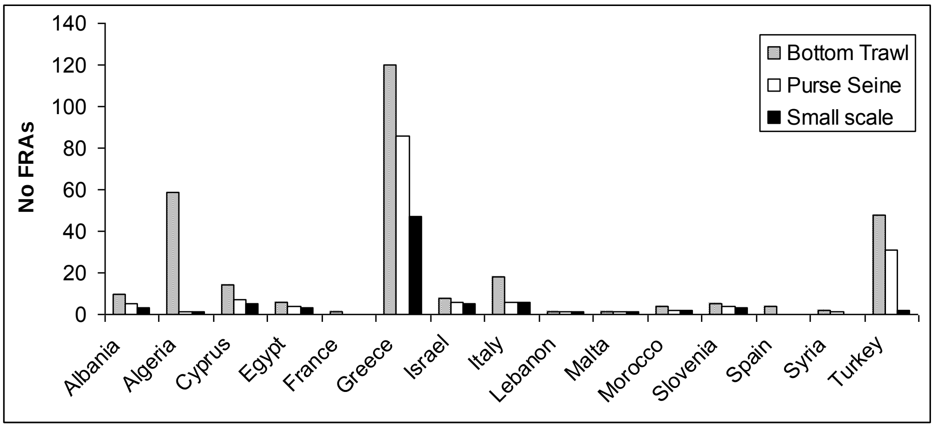

Fig. 1.4.9. Number of FRAs where bottom trawl /purse seine and small scale gears are prohibited per country in the Mediterranean.

Table 1.4.12. Spatial extent information (in km^2 and as percentage of the Mediterranean) of bottom trawl, purse seine and total FRAs in the Mediterranean. Total FRAs in this case include the GFCM bottom trawling prohibition for depths over 1000 m.

	M**editerranean, km^2**	FRA extent, **km^2**	Percentage **of Mediterranean covered by FRA**
Bottom trawl FRAs	2513713.4	1655854.4	65.9
Bottom trawl excl 1000 m FRA	2513713.4	191453.7	7.6
Purse seine FRAs	2513713.4	65837.0	2.6
> 1000 m depth, 1000 m FRA (GFCM bottom trawl prohibition)	2513713.4	1464401.0	58.3
Total FRAs incl 1000 m	2513713.4	2057926.5	71.9

Table 1.4.13. Spatial extent information (in km^2 and as percentage of the Mediterranean) of FRAs in the Mediterranean (including and excluding include the GFCM bottom trawling prohibition for depths over 1000 m) and FRAs total extent excluding spatial overlap with other designated types of protection i.e. MPAs, SPAMIs and NATURAs.

	M**editerranean, km^2**	FRA extent, **km2**	Percentage **of Mediterranean covered by FRA**
FRAs total incl 1000 m FRA	2513713.4	2057926.5	71.9
FRAs total excl 1000 m FRA	2513713.4	593525.5	23.6
FRAs+MPAs+SPAMIs+ NATURAs , excl 1000 m	2513713.4	492529.7	19.6

With the environmental protection being high on the world, EU and regional agendas show initiatives and directives favoring the creation of MPAs networks thus a lot of information is published on proposals for MPAs and SPAMIs. Despite the consensus in conservation areas (see Fig. 1.4.10 & 1.4.11) and targets (see for example DeJuan & Lleonart 2010, Portman et al 2012, Micheli et al 2013), detailed spatial information is often lacking (see Fig. 1.4.12 & 1.4.13). This largely depends on the level of the maturity of the proposal. Proposals building up support with time will also build consensus on spatial borders of their proposed MPAs. As it is, current proposals cover (aim to protect) a very significant part of the Mediterranean (around 80%), including shallow, shelf and deep habitats. Although biodiversity hotspots of different ecological components (e.g. fish, turtles, cetaceans, see Coll et al 2010 & 2012), conservation targets, representativeness of habitats and human impacts and high threat areas can be variable the spatial coverage of the proposed MPAs is still somewhat disproportionate between eastern and western Mediterranean and/or north south (Fig. 1.4.14).

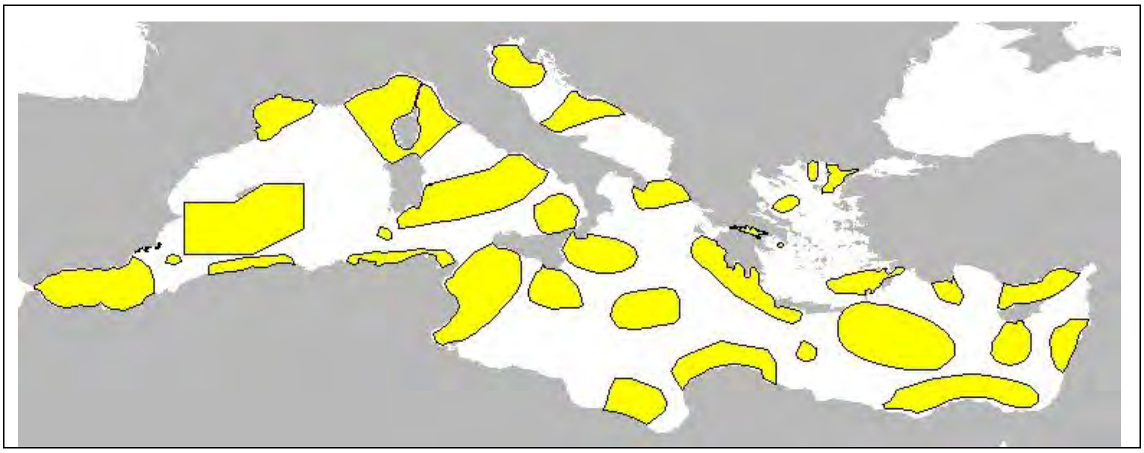

Fig. 1.4.10. Mediterranean proposed MPAs by Greenpeace 2006/2011 as seen in the MEDISEH online GIS viewer

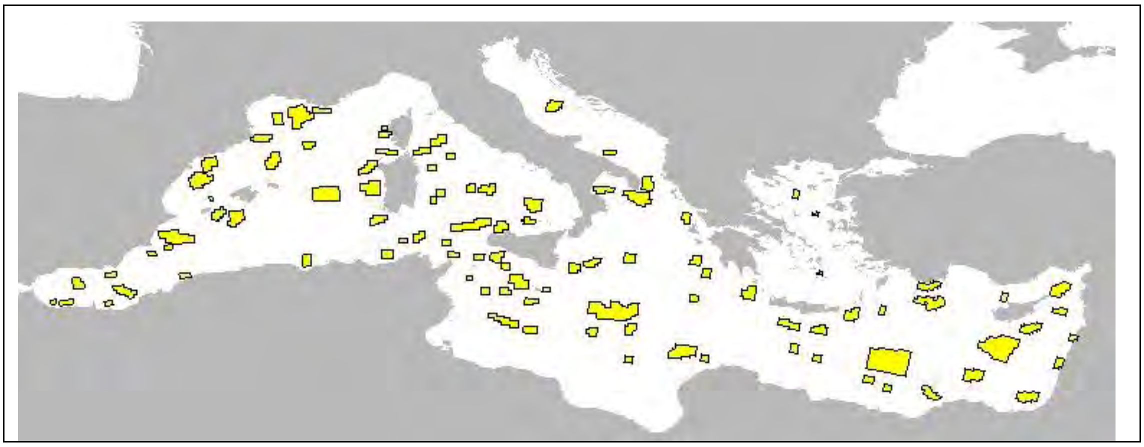

Fig. 1.4.11. Mediterranean proposed MPAs by OCEANA 2011 as seen in the MEDISEH online GIS viewer

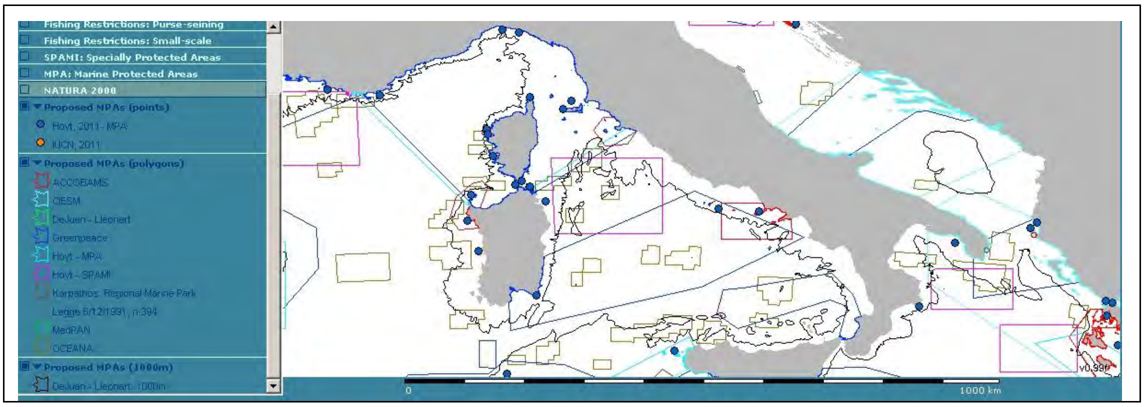

Fig. 1.4.12. Close-up on Mediterranean proposed MPAs in the north-central Mediterranean by Proposal as seen in the MEDISEH online GIS viewer (note range of spatial accuracy in delimitation of areas from detailed spatial borders to single point circles)

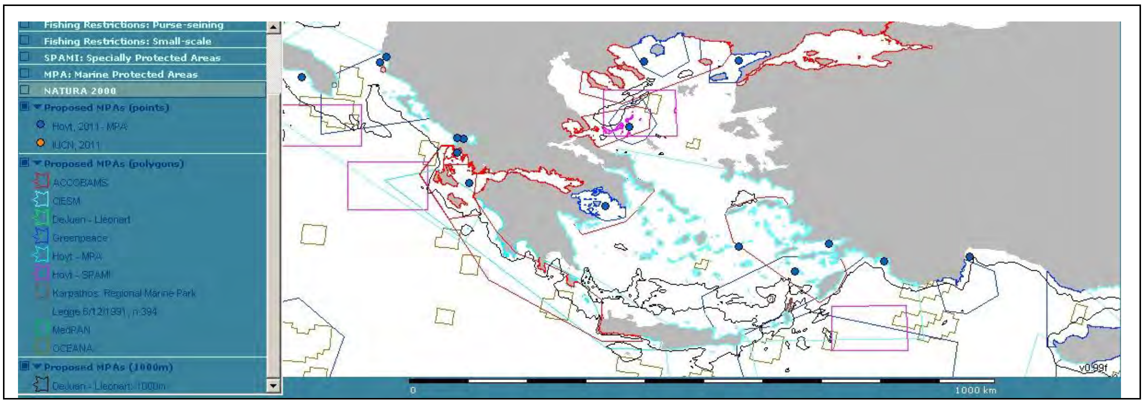

Fig. 1.4.13. Close-up on Mediterranean proposed MPAs in the north east Mediterranean by Proposal as seen in the MEDISEH online GIS viewer (note range of spatial accuracy in delimitation of areas from detailed spatial borders to single point circles)

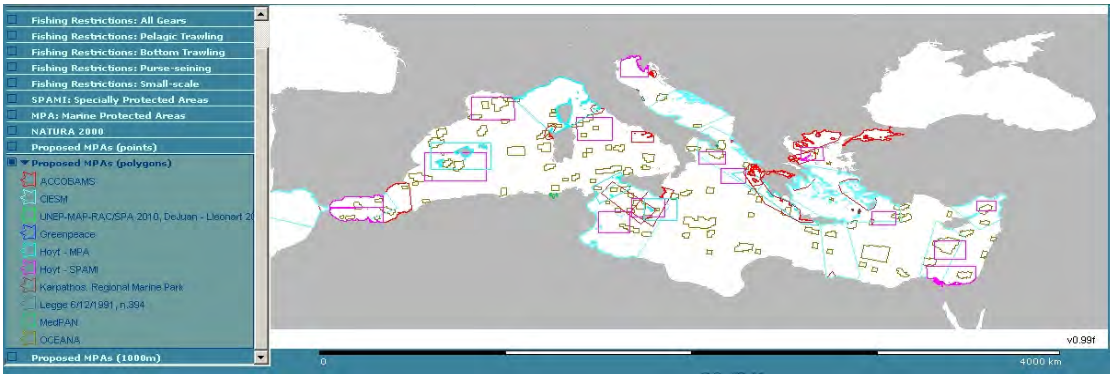

Fig. 1.4.14. Mediterranean proposed MPAs as seen in the MEDISEH online GIS viewer

The work done within MEDISEH and Deliverable 1.4.3 goes beyond recording extents and distribution of existing and proposed protection measures. This is done through a series of spatial queries that look into the spatial overlap of current and existing measures with key habitats and primarily (in relation to D.1.4.3) with *Posidonia oceanica*. Modeled estimates and actual presence distribution data acquired through WP1.1 - WP.1.3 were used to calculate several spatial overlaps.

As seen below in Tables 1.4.12 to 1.4.17, a significant part (>60%) of the Posidonia habitat is subjected to some form of fisheries restrictions (i.e. FRA or depth or distance from shore resstriction). However, the actual protection levels implemented might deviate from this. A similar part of the habitat is covered by the 1.5 nm distance from shore trawling prohibition (around 60%) and an even larger part of the habitat (around 85%) is within one of the most common depth restrictions concerning 50 m prohibition (Table 1.4.15). Restrictions in depths shallower than 50 m depth cannot be visualized in the viewer due to the inaccuracy of Mediterranean-wide shallower data (e.g. inability to map the 25 m isobath). A rough estimate of Posidonia presence at 25 m depth is given here (Table 1.4.13.) based on the bathymetry grid and selected pixels 25-0 m depth from the Posidonia model.

For Posidonia the difference in modeled habitat covered by the 1.0 and 1.5 nm bottom trawling restriction (FRA) results into an additional protection of 10%. For mäerl and corraligenous the difference is around 75 and 17% respectively, with mäerl being potentially afforded considerably more protection than corraligenous habitats (Table 1.4.16). The spatial overlap of modeled habitat with NATURA, MPAs, SPAMIs and FRAs show marked variations depending on habitat type. FRAs seemingly “cover” large parts (69-72%) of all 3 habitats while larger parts of mäerl and corraligenous are covered by MPAs rather than NATURA 2000 sites. The opposite is true for Posidonia with larger percentage cover seen in NATURA 2000 than MPAs (and probably over the shallower parts of the Posidonia distribution). The spatial overlap between Posidonia habitat with existing MPAs and Natura 2000 sites is estimated around 10%. The actual protection implemented strongly depends on how the locally imposed management measures are actually enforced. For example, large parts of the modelled Posidonia habitat falls within EU fishing restriction zones, however if these Posidonia beds are not mapped and incorporated in the VMS system then trawling prohibition is actually not in place and no protection is applied. Although quantitative summary data on VMS caught violations for fishing over the Posidonia habitat are not available, implementation should not be assumed to be 100%. Difference in extent between modelled and known as existing or mapped Posidonia beds, equally varies between countries as do the MPA designations.

Table 1.4.18 shows the extent of Posidonia per country (EEZ), MPA extent per country and the ratio Posidonia to MPA. The Posidonia habitat in this case is a combination of polygons available to WP.1.1 and single points available to WP 1.3, to improve the models. To show disparity between priority habitat extent and MPA extent per country, in WP.1.4 task, with the help of WP. 3, these single points were transformed to shapefiles each with a minimum pixel area of 90*90 m. The total Posidonia extent estimated this way (51838 km2) is very close to the model result (53541 km2, WP 1.3). A source of variation is the lower resolution of the EEZ coastline of the EEZ layer compared to the coastline layer used by the model. Tunisia, Algeria and Libya show a very high ratio of Posidonia/MPA ratio. This coincides with the fact that a large number of MPAs in the South Mediterranean are in process of being proposed and/or designated. Overall MPA extent in the Mediterranean is roughly twice that of the Posidonia habitat although the average country Posidonia/MPA ratio is around 3.

Finally, only 4.5 % of the Mediterranean and 8.9 % of the Posidonia habitat is currently protected under the MPAs scheme. Targets in both the Habitats Directive (for protection of 60% of the habitat of priority species) and CBD conservation targets are still not met. The CBD Aichi Target 11 calls for by 2020, “*at least 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures,* *and integrated into the wider landscapes and seascapes”*. (http://www.cbd.int/sp/targets/). Although still less that half-way to 10%, the Contracting Parties to the Barcelona Convention adopted the vision of a clean, healthy and productive Mediterranean with preserved ecosystems and biodiversity and set strategic goals and 11 ecological objectives to be achieved by 2020 towards the application of the Ecosystem Approach. This includes the establishment of Marine Protected Areas in open sea areas and the deep sea. Additionally, the EU Marine Strategy Framework Directive with a 2020 goal for achieving Good Environmental Status is further driving the EU Member States in the region, while the recent Antalya Declaration of the 2012 MPA Forum is driving the regional stakeholders towards an operational representative and connected MPA Network that meets the existing international objectives.

Table 1.4.14. Spatial extent information (in km2 and as percentage of the Mediterranean) is shown for MPAs, SPAMIs, NATURA2000 sites, FRAs, Posidonia, mäerl, and coralligenous. NB: MPAs, SPAMIs, NATURA2000 & FRAs estimates are based on geospatial information collated through WP.1.4. Posidonia, mäerl and corraligenous estimates extent are based on modelled data produced by WP.1.3. and displayed in the MEDISEH online GIS viewer. The threshold used for *Posidonia* is >28% probability of presence and for mäerl and corraligenous is >50% probability of presence (for details see report section W.1.3) Total Mediterranean Sea area is 2513713.4 km^2.

Name	**Protected Area or habitat Extent, km2**	**Percent**
MPA (incl SPAMIs)	113815.2	4.53
SPAMI	90352.3	3.59
NATURA 2000	34534.7	1.37
FRA	2057926.1	71.9
Posidonia (>28% prob)	53540.9	2.13
Mäerl (>50% prob)	47032.9	1.87
Coralligenous (>50% prob)	111409.0	4.43

Table 1.4.15. Spatial extent (in km2 and as percentage of habitat) of Posidonia within 3 depth zones: a shallow zone up to 25 m depth, the 50 m depth a common fisheries restriction (trawling) limit used in the Mediterranean, and an upper deeper zone up to 100 m depth. (*): Note that the less than 25 depth estimates are indicative only and are based on bathymetry grid and not on the 25m-isobath as this is lacking in the Mediterranean along with any other isobaths for <50 m depths. Posidonia estimates on extent are based on modelled data as produced by WP.1.3. and the threshold used is >28% probability of presence (for details see report section W.1.3)

Posidonia (>28% probability of presence)	**Extent (in km^2)**	**Percent**
Total (as produced by modeling by WP 1.3)	53540	
up to 100 m depth	47075	87.9
up to 50 m depth	45860	85.7
up to 25 m depth (* rough estimate)	34076	63.6

Table 1.4.16. Spatial extent (in km2 and as percentage of habitat) of Posidonia, mäerl and coralligenous within four shore zones: 100m, 500m, 1 nm and the recently implemented 1.5 nm in some of the Mediterranean states for bottom trawl fishing. Posidonia, mäerl and corraligenous estimates on extent are based on modelled data as produced by WP.1.3. and displayed in the MEDISEH GIS viewer. The threshold used for Posidonia is >28% probability of presence and for mäerl and corraligenous >50% probability of presence (for details see report section W.1.3)

Name	**Zone (distance from coast)**	**Habitat extent in zone, km^2**	**Total habitat extent, km^2**	**Percent habitat in zone**
Posidonia (>0.28 prob)	100m	1845.3	53540.9	3.4
Mäerl (>50% prob)	100m	216.0	47032.9	0.5
Coralligenous (>50% prob)	100m	882.2	111409.0	0.8
Posidonia (>0.28 prob)	500m	11208.8	53540.9	20.9
Mäerl (>50% prob)	500m	1851.3	47032.9	3.9
Coralligenous (>50% prob)	500m	7191.2	111409.0	6.5
Posidonia (>0.28 prob)	1 nm	27790.7	53540.9	51.9
Mäerl (>50% prob)	1 nm	8862.4	47032.9	18.8
Coralligenous (>50% prob)	1 nm	31772.2	111409.0	28.5
Posidonia (>0.28 prob)	1.5 nm	33075.6	53540.9	61.8
Mäerl (>50% prob)	1.5 nm	44218.7	47032.9	94.0
Coralligenous (>50% prob)	1.5 nm	12776.8	111409.0	11.5

Table 1.4.17. Spatial extent (in km2) and as percentage of spatial habitat overlap of Posidonia, mäerl and coralligenous within Natura 2000 sites, MPAs, SPAMIs and FRAs. Posidonia, mäerl and corraligenous estimates on extent are based on modelled data as produced by WP.1.3. and displayed in the GIS environment of the MEDISEH viewer. The threshold used for Posidonia is >28% probability of presence and for mäerl and corraligenous >50% probability of presence (for details see report section W.1.3). PA: Protected Area. Percent spatial overlap shows percent of each habitat under each protection scheme.

Name	**Habitat in PA, km^2**	**Habitat extent in Mediterranean, km^2**	**Percent spatial overlap**
Posidonia in Natura	6251.6	53540.9	11.7
Mäerl in Natura	3605.5	47032.9	7.7
Coralligenous in Natura	9205.6	111409.0	8.3
Posidonia in MPA	4763.7	53540.9	8.9
Mäerl in MPA	12957.9	47032.9	27.6
Coralligenous in MPA	16161.0	111409.0	14.5
Posidonia in SPAMI	2726.0	53540.9	5.1
Mäerl in SPAMI	9902.6	47032.9	21.1

Name	Habitat in PA, km^2	Habitat extent in Mediterranean, km^2	Percent spatial overlap
Coralligenous in SPAMI	13553.4	111409.0	12.2
Posidonia in FRA	36679.7	53540.9	68.5
Mäerl in FRA	36314.3	47032.9	77.2
Coralligenous in FRA	91848.9	111409.0	82.4

Table 1.4.18. Posidonia extent (in km^2) in each country (EEZ) and as percentage of total Mediterranean habitat. MPA extent in each country in km2 and as percentage of total MPA extent in Mediterranean. Ratio Posidonia/MPA. NB: Posidonia in this case is not modeled (sensu 1.3) but a combination of polygons available to WP.1.1. and single points available to WP 1.3. to improve the models. For the purpose of the WP.1.4 task, and with the help of WP.3. these single points were transformed to shapefiles each with a minimum pixel area of 90*90 m. The total Posidonia estimated extent this way (51838 km2) is very close to the model output (53541 km^2, WP1.3.).

	MPA extent, km^2	Posidonia extent in EEZ, km^2	% National Posidonia in total Med.	% National MPA in total Med.	Ratio Posidonia/MPA
Albania	73.0	85.4	0.165	0.447	1.17
Algeria	26.4	893.9	1.724	0.162	33.84
Croatia	1128.6	5132.4	9.901	6.901	4.55
Cyprus	49.6	123.8	0.239	0.303	2.50
Egypt	326.1	2100.6	4.052	1.994	6.44
France	993.6	1254.8	2.421	6.075	1.26
Greece	2527.4	10560.6	20.372	15.453	4.18
Israel	11.2			0.069	
Italy	2632.3	4963.4	9.575	16.094	1.89
Lebanon	5.1			0.031	
Libya	307.4	8722.8	16.827	1.879	28.38
Malta	187.0	71.9	0.139	1.143	0.38
Monaco	0.3	0.9	0.002	0.002	2.72
Morocco	190.2	66.6	0.128	1.163	0.35
Slovenia	6.3	0.8	0.001	0.038	0.12
Spain	5333.1	2099.8	4.051	32.608	0.39
Syria	24.3			0.149	
Tunisia	241.2	12812.8	24.717	1.475	53.11
Turkey	2292.1	2947.8	5.686	14.014	1.29
Total extent	16355.5	51838.2	100.000	100.000	3.17

Overall comments

- Analysis of the MPA information and visualization/display within the MEDISEH online GIS viewer is in full agreement with the most recent assessment of "Status of

Marine Protected Areas in the Mediterranean 2012" (http://www.medpan.org/en/mediterranean-mpa-status)

- The information on Mediterranean MPAs is now more accurate, with many more MPAs now having up-to-date validated geo-referenced data available, freely available through the MAPAMED database and the WDPA site
- Within MEDISEH and the current Task, emphasis was given to cover the lack of knowledge concerning the fishing restrictions and measures applied in the various types of protected areas (e.g. MPAs, SPAMIs, FRAs).
- Efforts were also made to document and display (into a GIS environment) the increasing number of proposed MPA and Marine Reserves in the Mediterranean, to allow calculations of spatial queries and future protection scenarios.
- Despite the progress since the last assessment of "Status of Marine Protected Areas in the Mediterranean 2008" (Abdulla et al., 2008) the target of 10% protection is still far from being achieved with current levels of protection closer to 4%.
- Spatial overlap analysis of protection measures and key Mediterranean habitats shows marked variations in coverage and protection levels between different measures (also depending on specificity and implementation e.g. gears forbidden and actual compliance).

Difficulties encountered and remedial actions

Generally, major difficulties included impediments in accessing and assessing sources in many uncommon languages, lack of local knowledge on locations and gears and modes of operation, lack of knowledge of some regionally adopted measures. Even derogations to EU measures were hard to find in sufficient detail. Many national measures are described in laws without accompanied maps, proper geographical or geospatial information. Although there were questions at the beginning of the MEDISEH project concerning the usefulness and the subsequent effort to undertake the MPA and FRAs databases, the final presentations of the deliverable through the online GIS viewerhighlighted its potential power as a management tool and gained the support of the project partnership. The combined MPA/FRA task is a worthwhile candidate for future research, for the task outputs to be continued to be updated and enriched in the future.

For the existing MPAs, certain issues/difficulties were identified concerning the information available on different internet sites: including:

- large amount of conflicting information and inconsistencies between and within data sources,
- variations in geographical names,
- marine protected areas are not always strictly marine (i.e. wetlands, lagoons and occasionally terrestrial/false marine),
- not all the sources are available in a common language,
- project participants were not able to cover all the Mediterranean countries to the same detail,
- not all data sources refer to a unique identification number (for MEDISEH we used the WDPA number).

This has made matching records and comparisons often a very difficult task. Project participants have undertaken extensive screening and digitization tasks. The very recent update (end of 2012) by MEDPAN and RAC-SPA and the release of the *mapamed.org* free open-access resource to information and spatial data is a very significant step towards documenting, assessing the status and following the growth in Mediterranean MPAs.

Moreover,

- Limitations on reporting were largely imposed by the amount and the quality of data available. Some of the available shapefiles have been found, or are known to be “faulty” (e.g. MPAs shown on land, correct coastline issues, or problems with the display of some spatial data and borders of some Natura2000 sites, etc.) and some of the “available” shapefiles were only circles around a mid-point and not clearly border-defined areas.
- Disparity of data availability across the Mediterranean mirroring the differing research efforts and the publications in local languages in regional media.
- There were limitations on access and true availability of even published geospatial data e.g. a large amount of time and effort was spent in redigitizing maps or recreating shapefiles.
- The resolution of the Mediterranean Sea predictors is very coarse with the highest resolution for some at the 20 km pixels level. The bathymetry grid is resolved at 800 m pixels derived from a 400 m grid. This resolution is too low to effectively express the variability found in the distribution of seagrass, coralligenous and mäerl. Bathymetric contours less than 50 m depth e.g. 10 or 20 or 35 m depths relevant to numerous fisheries restrictions in Mediterranean states are not resolvable in GIS and therefore these spatial gear restrictions cannot be depicted/shown in GIS form or in the MEDISEH viewer. Therefore, complete high-resolution spatial overlap of fisheries measures and habitats cannot be assessed.
- One of the difficulties identified through the collation of information was related to the actual extent of the Mediterranean Sea (in total or in different regions and zones). There are several “standard” estimates available through different projects and organisations all of which are different. For the purposes of the Task the value of 2513713.4 km2 was used, based on high resolution coastline (GSHSS link). Care must be taken with different area estimates as each will give different values when related to individual habitats or protected areas.
- Finally, acquiring habitat estimates for Posidonia (to update and contrast with those reported by each EU MS under Article 17 for Habitats Directive every 6 years, http://rod.eionet.europa.eu/obligations/269) and to compare with MPA extent per country was far less straightforward than originally anticipated. However Task 1.4. explored the outputs of both Task 1.3 (model output) and Task 1.1. & 1.2 (presence and distribution data) in a standardized way by employing certain assumptions to transform single data points to minimum size polygons.

Gaps in Knowledge and future actions

- There is a lack of accurate shallow bathymetry data for the Mediterranean, which prevents the creation of shallow bathymetric contours that decrease accuracy in the calculation of areas and overlaps. The lack of high resolution bathymetry data combined with the lack of accurate coastline data and limited habitat mapping data compromise research, marine spatial planning exercises and conservation efforts.
- There is no central archiving of Mediterranean habitats data. The EU/DG Mare European Marine Observation and Data Network (EMODNET) should be promoted as an essential tool for data banking with easily “clickable” downloading for datasets.
- In addition, the lack of knowledge on the extent of artisanal and recreational fishing impacts our knowledge on the restrictions applied in many MPAs where it is largely

not specifically area/effort managed. A large number of fisheries measures have a local nature, involving different areas, gears, species and seasons and are still largely unrecorded.

- Generally, the major impediments concern the difficulty in accessing and assessing sources in many different (and uncommon) languages, lack of local knowledge on locations and gears and modes of operation, lack of knowledge of some regionally adopted but nationalized measures. In certain cases even derogations to EU measures were hard to find in sufficient detail.

The Synthesis map (Deliverable 1.4.3) visualized through the online GIS viewerand the spatial queries highlighted its potential power as a management tool and gained the full support of the project partnership. The combined MPA/FRA and Proposed MPAs/FRAs task is a worthwhile candidate to continue research, with information to be added, updated and enriched in the future. Continued availability of these on the viewer and the ability to allow the use and exploration of existing and additional spatial queries will be beneficial to both marine scientific community and marine policy makers.

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WP2. Mapping of nursery and spawning grounds of small pelagic and demersal fish

2.1 Background

Based on the following Terms of Reference of the content of the European Commission DG MARE request Ares(2011)665688:

"Compile information supporting the identification and location of nursery areas (juveniles in their first and, if appropriate, second year of life) and spawning aggregations. This information, which is to be collated and archived in formats adequate for GIS rendering, shall refer to all the demersal and small pelagic species in the Mediterranean included in Appendix VU of Council Regulation (EC) No 199/2008 as well as for the species subject to minimum size (Council Regulation (EC) No 1967/2006-Annex III). In addition, ecological characterisation of these areas, both in terms of biological community (assemblage) and habitats therein, must be provided."

the technical tender form of the Specific Contract 2 (MEDISEH) defined the following objectives for WP2:

- Review and map all existing information on historical and current data of nurseries and spawning grounds of certain small pelagic **(**i.e., ***Engraulis encrasicolus, Sardina pilchardus*, *Scomber spp., Trachurus spp)*** and demersal species (i.e., ***Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris*****,** ***Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa)*** that are included in the Data Collection Framework for the Mediterranean and subjected to minimum landing size based on Council Regulation No 1967/2006-Annex II
- To analyze existing survey data and apply spatial analysis techniques in order to identify locations that are more likely to be density hot spot areas or are being more suitable for fish nurseries and spawning grounds for ***Engraulis encrasicolus, Sardina pilchardus*, *Scomber spp., Trachurus trachurus, Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris*, *Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa*** These areas will also be characterized from an environmental and ecological perspective upon data availability.
- Integrate and present the aforementioned information through a web based GIS viewerwith an associated geo-referenced database that will operate as a consulting tool for spatial management and conservation planning.
- Following the revision of the knowledge base, to identify gaps and suggest future research priorities.

In order to meet these objectives within the framework of MEDISEH an expert team was composed within the MAREA Consortium from fisheries biologists with long term expertise on small pelagic and demersal fisheries, working at different areas in the Mediterranean basin (see Tables 2.1 and 2.2, see CV details in MAREA expert web-site).

Table 2.1. Expert list involved in WP2, Task 2.1.

Participant	Participant affiliation
M. Giannoulaki	HCMR
M.M. Pirounaki	HCMR
K. Tsagarakis	HCMR
A. Machias	HCMR
A. Siapatis	HCMR
S. Somarakis	HCMR
M. Iglesias	IEO
P. Tugores	IEO
B. Patti	CNR-IAMC
I. Leonori	CNR-ISMAR
A. De Felice	CNR-ISMAR
F. Campanella	CNR-ISMAR
C. Vasapollo	CNR-ISMAR
G. Basilone	CNR-IAMC
A. Bonanno	CNR-IAMC
M. D'Elia	CNR-IAMC
N. Papadopoulou	HCMR (Collaboration with Task 1.4)
M. Nikolopoulou	HCMR (Collaboration with Task 1.4)
V. Valavanis	HCMR (Collaboration with WP3)

Table 2.2. Expert list involved in WP2, Task 2.2.

Participant	Participant affiliation
F. Colloca	CNR-IAMC
F. Ordines	IEO
E. Massuti	IEO
M. Iglesias	IEO
P. Tugores	IEO
L. Gil de Sola	IEO
P. Sartor	CIBM
L. Knittweis	FCD (MSDEC)
M.L. Pace	FCD (MSDEC)
G. Garofalo	CNR-IAMC
P. Lembo	COISPA
I. Bitteto	COISPA
M.T. Spedicato	COISPA
M.T. Facchini	COISPA
N. Nikolioudakis	HCMR
W. Zupa	COISPA
P. Carbonara	COISPA
A. Martiradonna	COISPA
G. Jona Lasinio	CONISMA
R. Carlucci	CONISMA
G. Tserpes	HCMR
A. Anastasopoulou	HCMR
K. Kapiris	HCMR
E. Lefkaditou	HCMR
F. Grati	CNR-ISMAR
G. Scarcella	CNR-ISMAR
A. Mannini	CIBM
G. Mastrantonio	CIBM
G. Ardizzone	CIBM
V. Valavanis	HCMR (Collaboration with WP3)

Task 2.1 Mapping of nursery and spawning grounds of small pelagic fish

(Scientific Responsible: Dr M. Giannoulaki (HCMR), Partners involved: HCMR, CNR-IAMC, CNR-ISMAR, IEO)

Cited as: *Giannoulaki M., Iglesias M., Leonori I., Patti B., M.M. Pirounaki, P. Tugores, F. Campanella, A. Siapatis, G. Basilone, M. D'Elia, A. Machias, A. De Felice, S. Somarakis, V. Valavanis, N. Papadopoulou, M. Nikolopoulou, A. Bonanno, C. Vasapollo, K. Tsagarakis 2013 Mapping of nursery and spawning grounds of small pelagic fish. Mediterranean Sensitive Habitats (MEDISEH) Final Report, DG MARE Specific Contract SI2.600741, Heraklion (Greece).*

2.1.1 Objectives

Small pelagic fish are known to play a key ecological role in coastal ecosystems, transferring energy from plankton to upper trophic levels (Cury *et al.,* 2000). Their relatively low position in the marine food web, together with their short life-span and their reproductive strategy of producing large quantities of pelagic eggs over an extended spawning season, makes their population strongly dependent on the environment (Bakun, 1996). Juveniles are much more vulnerable to environmental changes compared to adults and are a better index of stock status when it comes to short-lived, small pelagic fish species. Large-scale conservation planning requires the identification of priority areas or areas of particular concern such as fish nursery grounds. Most Mediterranean fish stocks are being reported as fully exploited or overexploited (Cardinale *et al.,* 2010), which impairs the need for large scale fisheries management.

The main objective of this task is the identification of the juvenile and spawning grounds of certain small pelagic fish species within the Mediterranean basin. For this purpose habitat suitability modeling will be applied, that relates abundance information from surveys with environmental variables. The aim is to provide essential information for the identification of priority areas for the management of small pelagic stocks in the Mediterranean. Spawning and nursery grounds could be selected as priority areas for protection because protecting juveniles and spawning grounds can maintain good population status and highly increase the effectiveness of large scale fisheries management.

Specifically within this Task the following objectives will meet:

- Review and map all existing information on historical and current data of nurseries and spawning grounds of certain small pelagic **(**i.e., ***Engraulis encrasicolus, Sardina pilchardus*****,** ***Scomber spp., Trachurus spp)*** that are included in the Data Collection Framework for the Mediterranean and subjected to minimum landing size based on Council Regulation No 1967/2006-Annex II
- Analyze existing survey data and apply spatial analysis techniques in order to identify locations that are more likely to be density hot spot areas or are being more suitable for fish nurseries and spawning grounds for ***Engraulis encrasicolus, Sardina pilchardus*****,** ***Scomber spp., Trachurus trachurus, Trachurus mediterraneus.*** These areas will also be characterized from an environmental and ecological perspective upon data availability.
- Integrate and present the aforementioned information through a web based GIS viewerwith an associated geo-referenced database that will operate as a consulting tool for spatial management and conservation planning.

- Identify gaps and suggest future research priorities.

2.1.2 Deliverables and Milestones foreseen

The following Milestones and Deliverables were foreseen according to the proposal for Task 2.1

M 2.1.1 Revision on existing information on spawning and juvenile grounds of the target small pelagic species (i.e., ***Engraulis encrasicolus, Sardina pilchardus*, *Scomber spp., Trachurus trachurus***) all over the Mediterranean basin (Months 1-6)

M 2.1.2 Analysis of survey data concerning the target small pelagic species in order to identify juveniles and spawners in a standardized way. Collection of environmental data. Standardization of environmental data layers. Data transformation for modeling (Months 1-8)

M 2.1.3 Species distribution modeling of juvenile and spawning grounds for target small pelagic species. Model fitting and validation (work will be implemented at a regional level or at a larger scale depending on data availability, Months 8-14)

M 2.1.4 Production of annual maps (i.e., probability maps for nurseries and spawning grounds at a regional and Mediterranean level), estimation of mean probability and persistence maps for target small pelagic species. Production of GIS compatible files with the predicted habitat layers (Month 12-16)

D2.1.1 Mean probability maps for nurseries and spawning grounds at a regional and wider spatial scale e.g. the Mediterranean level (Month 16)

D2.1.2 Persistence maps of the potential spawning and juvenile habitat of the Mediterranean basin (Month 16)

D2.1.3 Environmental features of nursery and spawning grounds of the target species (Month 16)

D2.1.4 Maps presenting the persistent spawning and nursery grounds of the target small pelagic species along with the locations of protected habitats (Month 16)

2.1.3 Progress achieved

Towards the Task 2.1 objectives four meetings plus one additional workshop were held within the framework of this Task.

- One and a half day workshop during the kick-off meeting of the MEDISEH project during 10-13 October 2011 in Heraklion (Greece) that aimed at the standardization of the work, the definition of the timeframe for milestones and deliverables.
- A second meeting was held during 6-9 February 2012 at Palermo (Sicily) in accordance with the MEDISEH proposal (Month 6). During this second meeting the WP activities have been revised and scheduled. The progresses achieved in the activities foreseen for Milestones 2.1.1 and 2.1.2 have been reviewed and participants have briefly showed the main information collected and the work done to prepare the datasets required carrying out the spatial analyses.
- Moreover, one day joined workshop with Task 2.2 was devoted to the presentation of common scripts for data analysis and spatial modeling.

- A third meeting took place in Orto Botanico (Rome-Italy) 26-28 September 2012 in accordance to MEDISEH proposal (month 12). The meeting focused on the evaluation of the modeling techniques applied, the initial modeling results obtained and the difficulties encountered. The timeframe for future work, the development of common tools for data analysis and common template for reporting were discussed and agreed.

- A fourth meeting took place in Astoria Capsis Hotel (Heraklion-Greece) 8-10 January 2013 in accordance to MEDISEH proposal (month 16). Final modeling results on the target small pelagic species were presented. Specifically, modeling results were presented concerning annual maps for nursery and spawning grounds, mean probability maps as well as persistent maps for the period 2000-2010 for the target species. A discussion took place on the evaluation of these results.

The work achieved in the activities foreseen for Milestones 2.1.1, 2.1.2, and 2.1.3 is presented in the following chapter.

Within the framework of Task 2.1 the following scripts were presented and discussed along with practical examples to ensure standardization of data analysis (see meeting report). Scripts are available at http://mareaproject.net/FTPMareaProject/#2:

- RoME which is an R routine devoted to perform multiple checks on MEDITS Survey data (TA, TB and TC files)
- R-RSI which is an R routine for the estimation of mean length of Recruits and Spawners and for the calculation of Indices from scientific survey data
- Presence/Absence GAMs which is an R scipt to apply spatial analysis GAM to presence/absence data relating fish spatial distribution with environmental data
- Machine learning techniques were also presented and suggested for application in data poor situations.

All deliverables concerning the revised information for WP2, Task 2.1 is also available as GIS shapefiles incorporated into the MEDISEH server according to the following table:

Speciffically, a list of the available shapefiles has been uploaded to the FTP server of MAREA (http://www.mareaproject.net/FTPMareaProject/) and accompanied by metadata excel files (FTPMareaProject/specific projects/specific project 2 MEDISEH/interim report/wp2.1/shp). The shapefiles include polygons that depict the distribution areas of *E. encrasicolus, S. pilchardus, S. scombrus, S. colias, T. mediterraneus* and *T. trachurus* in Mediterranean Sea derived from revised information. The shapefiles with the metadata excel files have also been provided to the task leader of WP3 to be included in the web-based GIS viewer(http://mareaproject.net/mediseh/viewer/med.html).

In order to identify the appropriateness of each available survey per target species and life stage the following summary tables indicating the temporal overlap between the available surveys per area and the spawning / recruitment period for the target species in question, were constructed. It is apparent that no appropriate data are available to define spawning grounds for *Scomber scombrus* and *Trachurus trachurus*.

Table 2.1.2. Aegean Sea: Overlap between surveys (*) and the spawning period (highlights) of each target species.

Species	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
E. encrasicolus	2003-2008				🟨	🟨 *	🟨 *	🟨 *	🟨				

S.pilchardus	1999, 2000	▨ *		▨								▨ *	▨ *
S. scombrus				▨	▨								
S. colias	2006, 2008, 2010				▨	▨	▨ *	▨ *	*				
T. trachurus		▨	▨	▨	▨	▨							▨
T. mediterraneus	2006, 2008, 2010				▨	▨ *	▨ *	▨ *	▨	▨			

Table 2.1.3. Aegean Sea: Overlap between surveys (*) and the recruitment period (highlights) of each target species.

Species	**Year**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
E. encrasicolus	1999, 2000, 2007, 2009	▨ *	▨ *								▨	▨ *	▨ *
S.pilchardus	1998, 1999, 2003-2008				▨	▨	▨ *	▨ *					
S. scombrus	1998, 1999, 2003-2006, 2008, 2010				▨	▨	▨ *	▨ *	▨				
S. colias	1999, 2000	▨	▨ *									▨	▨ *
T. trachurus	1998, 1999, 2003-2006, 2008, 2010					▨ *	▨ *	▨ *	▨				
T. mediterraneus	1999, 2000, 2009	▨ *	▨ *								▨	▨	▨ *

Table 2.1.4. Spanish Mediterranean waters: Overlap between surveys (*) and the spawning period (highlights) of each target species.

Species	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
E. encrasicolus	2009-2011			🟨	🟨	🟨	🟨 *	🟨 *	🟨	🟨	🟨		
S.pilchardus		🟨	🟨	🟨	🟨	🟨				🟨	🟨	🟨 *	🟨 *
T. mediterraneus								🟨	🟨	🟨	🟨		
T. trachurus				🟨	🟨	🟨	🟨	🟨	🟨				
S. scombrus							**Unknown**						
S. colias							**Unknown**						

Table 2.1.5. Spanish Mediterranean waters: Overlap between surveys (*) and the recruitment period (highlights) of each target species.

Species	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
E. encrasicolus	1997-2009	🟨	🟨									🟨 *	🟨 *
S.pilchardus	2000-2010, 2009-2011						🟨 *	🟨 *					
T. mediterraneus	1997-2009	🟨	🟨								🟨	🟨 *	🟨 *
T. trachurus	2000-2010, 2009-2011					🟨	🟨 *	🟨 *	🟨				
S. scombrus	2009-2011				🟨	🟨	🟨 *	🟨 *	🟨				
S. colias	1997-2009	🟨	🟨									🟨 *	🟨 *

Table 2.1.6. Adriatic Sea, GSA 18: Overlap between surveys (*) and the spawning period (highlights) of each target species.

Species	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
E. encrasicolus	2008-2010-2011				🟨	🟨	🟨	🟨 *	🟨 *	🟨	🟨		
S.pilchardus	2008-2010-2011	🟨	🟨									🟨	🟨
S. scombrus	2008-2010-2011			🟨	🟨								
S. colias	2008-2010-2011				🟨	🟨	🟨	🟨					
T. trachurus	2008-2010-2011	🟨	🟨	🟨	🟨	🟨							🟨
T. mediterraneus	2008-2010-2011				🟨	🟨	🟨	🟨	🟨	🟨			

Table 2.1.7. Adriatic Sea, GSAs 17-18: Overlap between surveys (*) and the recruitment period (highlights) of each target species.

Species	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
E. encrasicolus	1998-2011, 2007, 2008-2009	🟨	🟨 *				*	*	*	🟨 *	🟨 *	🟨 *	🟨
S.pilchardus	1998-2011, 2007, 2008-2009		🟨 *	🟨	🟨	🟨	🟨 *	🟨 *	🟨 *	🟨 *	*	*	
S. scombrus	1998-2011			🟨	🟨	🟨	🟨 *	🟨 *	🟨 *	🟨 *	*	*	
S. colias.	1998-2011	🟨	🟨	🟨			*	*	*	🟨 *	🟨 *	🟨 *	🟨
T. trachurus	1998-2011						🟨 *	🟨 *	🟨 *	🟨 *	🟨 *	🟨 *	🟨
T. mediterraneus	1998-2011	🟨	🟨	🟨			*	*	*	*	🟨 *	🟨 *	🟨

Table 2.1.8. Strait of Sicily: Overlap between surveys (*) and the spawning period (highlights) of each target species.

Species	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
E. encrasicolus	2000-2011				🟨	🟨	🟨 *	🟨 *	🟨 *	🟨			
S.pilchardus	2000-2011	🟨	🟨	🟨	🟨							🟨	🟨
T. trachurus	2000-2011			🟨	🟨	🟨 *	🟨 *	*					
T. mediterraneus	2000-2011					🟨 *	🟨 *	🟨 *	🟨				
S. scombrus	2000-2011						**Unknown**						
S. colias	2000-2011						**Unknown**						

Table 2.1.9. Strait of Sicily: Overlap between surveys (*) and the recruitment period (highlights) of each target species.

Species	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
E. encrasicolus	2000, 2001, 2004, 2005	🟨	🟨							*	🟨 *	🟨	🟨
S.pilchardus	2000-2011					🟨	🟨 *	🟨 *	🟨 *	🟨			
T. trachurus	2000-2011			🟨	🟨	🟨 *	🟨 *	🟨 *	🟨	🟨			
T. mediterraneus	2000-2011					*	*	*		🟨	🟨	🟨	🟨
S. scombrus	2000-2011						**Unknown**						
S. colias	2000-2011						**Unknown**						

2.1.3.1 Methodological Framework

A summary on the revised information concerning M 1.2.1 and M 1.2.2 for each of the target species is cited below. Detailed information can be found in Annex 2.1.1.

2.1.3.1.1 Engraulis encrasicolus

2.1.3.1.1.1 Spawning areas

Revised information

The main spawning areas for anchovy in the Eastern part of the Mediterranean basin are indicated in the North Aegean Sea both by the observed distribution patterns of eggs based on ichthyoplankton surveys (Somarakis et al., 2004; Somarakis, 2005; Somarakis et al., 2006a) as well as modeling approaches using environmental variables (Schismenou et al., 2008). Other smaller spawning grounds for anchovy are indicated in the central Ionian and Aegean Seas based on survey results of July 1998 and June 1999 in this area (Somarakis et al., 2002; Somarakis et al., 2006a). Schismenou et al., 2008 have also indicated spawning spots in the coastal areas of Asia Minor, along the Turkish coasts (e.g., Izmir Bay), which have been reported as anchovy fishing areas (Turan et al., 2004).

Concerning the Central Mediterranean, in the Adriatic Sea the presence of anchovy eggs has been reported for the entire area within the 200 m depth zone during the spawning season. However it seems that eggs are absent from the deeper Jabuka pit and the southern Adriatic trench (Gamulin and Hure, 1983; Regner, 1985; Casavola *et al.,* 1987). The main spawning activity takes place in the coastal waters of the western Adriatic between the Gulf of Trieste and the Gargano Peninsula (Casavola *et al.,* 1985; Regner, 1996) and the largest number of eggs occurs in the Gulf of Trieste and off the Po river mouth. (Piccinetti *et al.,* 1980; Coombs *et al.,* 1997; Piccinetti ,2001). Some other spawning areas have been found in the eastern part of the basin (open waters between Jabuka pit and Susak Island and around Palagruza) but the spawning activity seems to be lower (Gamulin and Hure, 1983; Regner, 1996; Sinovcic, 1978; 2000).

At the Strait of Sicily anchovy spawning and nursery areas were mapped for several years in the northern part (off southern Sicily coast), starting from 1997. Three main spawning grounds have been identified:

(1) northern, over the Adventure Bank;
(2) central, in coastal areas from Sciacca to Licata;
(3) southern, over the Gela Gulf and the Maltese shelf.

However, these main spawning grounds experienced significant year-by-year changes in relation to surface circulation (Patti et al., 2004; Cuttitta et al., 2006; Patti, 2010). Recently observed larval distribution confirms the previous findings (García Lafuente et al., 2002) indicating a concentration process on the Maltese shelf area, due to current transport and retention mechanisms characterizing the area. At the Gulf of Tunis, during spring, the main anchovy spawning area is located in the north of the Gulf, to the west and southwest of Zembra Island (Zarrad *et al.* 2006). During summer, high egg and larvae abundances were also observed to the southwest of Zembra Island, but secondary spawning grounds were detected in the vicinity of the mouths of the Rivers Majreda and Meliane (Zarrad *et al.* 2006).

Finally in the western part of the basin, within the northern Spanish Mediterranean waters and mainly in the Catalan coast, the spatial distribution of anchovy eggs and larvae was extensively studied in the 80s and 90s. Their spatial distribution was widespread from the coast untill offshore waters. The distribution of anchovy spawning is fairly continuous in the NW Mediterranean (Garcıa and Palomera, 1996; Palomera et al., 2007), but higher egg densities off the Ebro river mouth and at the shelf break in the Gulf of Lions region. Cross-shelf distribution of anchovy eggs and larvae show relatively low densities of eggs in shallow areas close to the coast (<50 m depth) and maximum densities near the edge of the shelf (ca. 200 m isobath) (Palomera and Sabates, 1990; Palomera, 1992; Palomera and Olivar, 1996; Olivar et al., 2001). At the Alboran Sea eggs were mainly found in the western part although not confined to the continental platform (Rubín 1996).

Below there is a summary Table for all areas on the revised information for anchovy spawning grounds:

Eastern Mediterranean

Area	**Species**	**Stage (Spawners or Juveniles)**	**Periods (year, months, season)**	**Format (e.g shapefile)**	**Type of survey (trawls/acoustic/ichthyoplankton survey)**	**Source**
C. Aegean Sea and Ionian Sea	*E. encrasicolus*	larvae	1998-1999, June, July	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2011a
N. Aegean Sea	*E. encrasicolus*	eggs, larvae	1995-1996, June	shapefile	Ichthyoplankton survey	Somarakis and Nikolioudakis 2007
N. Aegean Sea	*E. encrasicolus*	larvae	1993-1996, June	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2011b
N.E. Aegean Sea	*E. encrasicolus*	larvae	2003-2006, June	shapefile	Ichthyoplankton survey	Isari *et al.* 2008

Central Mediterranean

Area	**Species**	**Stage**	**Periods**	**Format**	**Type of survey**	**Source**
Strait of Sicily	*E. encrasicolus*	Spawners	Summer 1997-98-99, 2002	GIS file	Ichthyoplankton	Patti et al., 2004
Strait of Sicily	*E. encrasicolus*	Spawners	Summer 2000-2001	GIS file	Ichthyoplankton	Patti et al., 2004; Cuttitta et al., 2003;
Strait of Sicily	*E. encrasicolus*	Spawners	Summer 2005	GIS file	Ichthyoplankton	Final Report MIPAF-August 2007
Strait of Sicily	*E. encrasicolus*	Spawners	Summer 2006	GIS file	Ichthyoplankton	Final Report MIPAF-August 2007
Strait of Sicily	*E. encrasicolus*	eggs, larvae	June-July 1998	shapefile	Ichthyoplankton survey	Lafuente *et al.* 2000
Adriatic Sea	*E. encrasicolus*	eggs	July 1984	shapefile	Ichthyoplankton survey	Casavola *et al.*1985
Adriatic Sea	*E. encrasicolus*	eggs	August 1995	shapefile	Ichthyoplankton survey	Coombs *et al.* 1997
Adriatic Sea	*E. encrasicolus*	eggs	Seasonal survey from 1973 to 1976	shapefile	Ichthyoplankton survey	Gamulin and Hure 1983
Adriatic Sea	*E. encrasicolus*	eggs	August 2000	shapefile	Ichthyoplankton survey	Piccinetti 2001

Area	**Species**	**Stage**	**Periods**	**Format**	**Type of survey**	**Source**
Adriatic Sea	*E. encrasicolus*	eggs	July-September 1976-1979	shapefile	Ichthyoplankton survey	Piccinetti *et al.* 1980
Adriatic Sea	*E. encrasicolus*	eggs	July-September 1976-1984	shapefile	Ichthyoplankton survey	Regner 1985
Gulf of Tunis	*E. encrasicolus*	eggs, larvae	August, October, February, April 2002-2003	shapefile	Ichthyoplankton survey	Zarrad *et al.* 2006

Western Mediterranean

Area	**Species**	**Life stage**	**Periods**	**Format**	**Type of survey**	**Source**
Catalan coast	*E.encrasicolus*	eggs	July 1993	shapefile	ichthyoplankton	García and Palomera 1996
Catalan coast	*E.encrasicolus*	eggs	June 1996	shapefile	ichthyoplankton	Olivar et al 2001
Catalan coast	*E.encrasicolus*	eggs	May 1990	shapefile	ichthyoplankton	Palomera and Pertierra 1993
Catalan coast	*E.encrasicolus*	larvae	June 1996	shapefile	ichthyoplankton	Olivar et al 2001
Catalan coast	*E. encrasicolus*	eggs, larvae	1983-1985, April-October, June	shapefile	Ichthyoplankton survey	Palomera and Sabates 1990
Catalan coast, Gulf of Lions and Ligurian	*E.encrasicolus*	larvae	July 1992	shapefile	ichthyoplankton	García and Palomera 1996
Ligurian and Thyrrenan	*E.encrasicolus*	eggs	September 1993	shapefile	ichthyoplankton	García and Palomera 1996
Málaga and Almería	*E.encrasicolus*	eggs	May-Sept 1982-1993	shapefile	ichthyoplankton	Rubín 1996
Málaga and Almería	*E.encrasicolus*	larvae	May-Sept 1982-1993	shapefile	ichthyoplankton	Rubín 1996
Bay of Málaga	*E. encrasicolus*	larvae	2000-2001, July	shapefile	Ichthyoplankton survey	Garcia *et al.* 2003
NW Alborean Sea	*E. encrasicolus*	eggs, larvae	2008, July	shapefile	Ichthyoplankton survey	Macias *et al.* 2011
Alboran and Balearic Sea	*E. encrasicolus*	eggs	May 1982	shapefile	ichthyoplankton	Lago de Lanzos and Solá 1986
Alboran and Balearic Sea	*E. encrasicolus*	larvae	May 1982	shapefile	ichthyoplankton	Lago de Lanzos and Solá 1986

Data analysis

Surveys and periods used for modeling

Ichthyoplankton surveys data were used for the identification and the modeling of spawning grounds of anchovy. A summary Table with the surveys used is summarized below. Details on these surveys characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)
C. Aegean Sea	Ichthyoplankton	1990,1991	June, September, December	50 WP2 stations per survey	Ichthyoplankton survey
C. Aegean Sea and Ionian Sea	Anchovy	1998, 1999	July (1998), May-June (1999)	168 WP2 stations per survey	Ichthyoplankton survey
North Aegean Sea	Greek National Fisheries Data Collection Program	2003-2006, 2008	June-July	200 WP2 stations per survey	Ichthyoplankton survey

Adriatic Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ichthyoplankton surveys)
GSA 18 (Montenegro in 2005, Montenegro and Albania(1) in 2008, SW and SE(1) Adriatic in 2010)	GSA 18 Eggs and Larvae survey	2005, 2008, 2010	July-August	Total number of DEPM stations: 185	Ichthyoplankton survey

(1) in the framework of FAO AdriaMed project

Strait of Sicily

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ Ichthyo-plankton surveys)
GSA 16 +GSA 15(1)	Bansic 2000	2000	24 June-8 July 2000	131	Ichthyoplankton survey
GSA 16 +GSA 15(1)	Ansic 2001	2001	7 July-25 July 2001	143	Ichthyoplankton survey
GSA 16 +GSA 15(1)	Ansic 2002	2002	11 July -31 July 2002	218	Ichthyoplankton survey
GSA 16 +GSA 15(1)	Ansic 2003	2003	11 July-2 August 2003	166	Ichthyoplankton survey
GSA 16 +GSA 15(2)	Ansic 2004	2004	18 June-7 July 2004	180	Ichthyoplankton survey
GSA 16 +GSA 15(2)	Ansic 2005	2005	7 July-9 August 2005	170	Ichthyoplankton survey
GSA 16 +GSA 15(2)	Ansic 2006	2006	30 July-24 August 2006	119	Ichthyoplankton survey
GSA 16	Bansic 2007	2007	28 June-17 July	161	Ichthyoplankton

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ Ichthyo-plankton surveys)
+GSA 15$^{(2)}$			2007		survey
GSA 16 +GSA 15$^{(2)}$	Bansic 2008	2008	25 June-14 July 2008	182	Ichthyoplankton survey
GSA 16 +GSA 15$^{(2)}$	Bansic 2009	2009	3 July– 22 July 2009	149	Ichthyoplankton survey
GSA 16 +GSA 15$^{(2)}$	Bansic 2010	2010	25 June –14 July 2010	187	Ichthyoplankton survey
GSA 16 +GSA 15$^{(2)}$	Bansic 2011	2011	8 July – 26 July 2011	134	Ichthyoplankton survey

(1) partial coverage of shelf areas. (2) full coverage of shelf areas in the framework of MedSudMed project.

Egg data were collected from Daily Egg Production Method (DEPM) surveys carried out in the North Aegean Sea in June 2003–2006 and 2008 (Somarakis *et al*., 2011a). A 10×5 nmi grid of stations was sampled by vertical plankton hauls (Table 1) using a WP2 sampler (mouth opening, 0.255 m^2; mesh size, 0.200 mm). More details are provided in Schismenou *et al.* (2008). Similarly, egg data were also collected in the Strait of Sicily during ichthyoplankton surveys carried out on board the R/V Urania in the Strait of Sicily in July 2003–2008. Plankton was sampled on the continental shelf of the southern Sicilian coast over a station grid of 4×4 nmi close to the coasts and 12×12 nmi in off-shore areas (Table 1). Bongo-net oblique hauls were carried out at each station using nets of 0.200 mm mesh size. Nets were towed from the bottom to the surface or from 100 m to the surface where depth was more than 100m, with a speed of 2 nmi h^{-1} (Cuttitta *et al.,* 2003). Samples were preserved in 4% buffered formaldehyde solution for later analysis and enumeration of anchovy eggs in the laboratory.

Environmental data

Satellite environmental data as well as bottom depth were used as explanatory variables to model the habitat of anchovy in the Mediterranean basin. Specifically, sea surface temperature (SST in ^{o}C), sea surface chlorophyll concentration (CHLA in mg m^{-3}), photosynthetically active radiation [PAR in Einstein m^{-2} day^{-1}, 1 Einstein (Ein) = 1 mole of photons], and sea level anomaly (SLA in cm) were used for this purpose. These environmental variables are considered important either as a direct influence on the distribution of anchovy (e.g. SST, CHLA) or as proxies for causal factors. For example, SLA varies with ocean processes such as gyres, meanders and eddies (Pujol and Larnicol, 2005) which enhance productivity and often function as physical barriers affecting the distribution of species or their life stages. Similarly, satellite-measured SeaWiFS PAR is the photosynthetically active radiation (integrated over the spectral range 400–700 nm) reaching the sea surface over a 24 hour period (Frouin *et al.,* 2003). It is indicative of the solar energy available for photosynthesis, controlling the growth of phytoplankton thus critical also for fisheries and carbon dynamics. Bathymetry, as an indirect factor, was derived from a blending of depth soundings collected from ships with detailed gravity anomaly information obtained from the Geosat and ERS-1 satellite altimetry missions (Smith and Sandwell, 1997). Satellite variables were mostly used at their best available resolution provided by the online satellite data distribution archives (Table 2) in order to obtain environmental characteristics for each sampling point. This results in an average spatial resolution of 1.5 km (Valavanis *et al.,* 2008), adequately defining environmental spatial heterogeneity in relation to both the applied sampling unit (5 km) of icthyoplankton data and the best available resolution of the explanatory environmental variables.

Modeling approach

Since available survey data were located in certain areas i.e. the northern Aegean Sea and the Strait of Sicily we decided to apply habitat suitability modeling techniques and use environmental data in order to obtain an idea of anchovy potential spawning grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent spawning areas based on annual distribution maps.

For this purpose, Generalized Additive Models (GAMs, Hastie and Tibshirani, 1990) were applied to define the set of environmental factors that describe anchovy's distribution in the study areas. The selection of the GAMs smoothing predictors was done using the 'MGCV' library in the R statistical software (R Development Core Team, 2012). In each model fit a double penalty was applied to the penalised regression solved by MGCV, which allows variables to be solved out of the model entirely (Marra and Wood 2011), being more robust to identify important features. The degree of smoothing was chosen based on the observed data and the restricted maximum likelihood (REML) estimation that outperforms the Generalized Cross Validation (GCV) smoothing parameter selection, as suggested by Marra and Wood (2011).

The final model was built by testing all variables that were considered biologically meaningful, starting from a simple initial model with one explanatory variable. The best model was selected based on the minimization of the the Akaike's Information Criterion (AIC) and the level of deviance explained (0–100%; the higher the percentage, the more deviance explained) taking also into account the model's predictive ability. Specifically, as response variable (y), we used the presence/absence of anchovy eggs. Only datasets presenting at least a percentage of 20% of anchovy eggs presence were used for modeling in order to ensure the credibility of the selected model. As independent variables (x covariates), we used the cube root of the bottom depth (to achieve a uniform distribution of bottom depth), the natural logarithm of CHLA (to achieve a uniform distribution of CHLA), SST, SLA and PAR.

The binomial error distribution with the logit link function was used and the natural cubic spline smoother (Hastie and Tibshirani, 1990) was applied for smoothing the independent variables and GAM fitting. Following the selection of the main effects of the model, all first order interactions of the main effects were tested. In order to avoid over-fitting and simplify the interpretation of the results, the REML method was applied and the maximum degrees of freedom (measured as number of knots k) allowed to the smoothing functions were limited to the main effects at k=4 and for the first-order interaction effects at k=20.

Validation graphs (e.g. residuals versus fitted values, QQ-plots and residuals versus the original explanatory variables) were plotted in order to detect the existence of any pattern and possible model misspecification. Residuals were also checked for autocorrelation. The output of the final selected GAMs is presented as plots of the best-fitting smooths. Interaction effects are shown as a perspective plot without error bounds. In each case the following models were constructed.

Model validation. In a subsequent step, the selected model was tested and evaluated for its predictive performance for areas and periods not included in model selection. For this purpose, we estimated the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000). AUC is a threshold-independent metric, widely used in the species' distribution modeling literature. Moreover, sensitivity (i.e. the proportion of observed positives that are correctly predicted) and specificity values (i.e. the proportion of observed negatives that are correctly predicted) were used for model evaluation (Lobo *et al.,* 2008). They were measured in relation to two threshold criteria: (i) the maximization of the specificity-sensitivity sum (MDT) and (ii)) the prevalence values (Jiménez-Valverde *et al.,* 2008; Lobo *et al.,* 2008).

The GAMs for the potential spawning habitat were validated using data from a) the North Aegean Sea in 2008 (not included in the model), b) the Strait of Sicily in July 2006 and c) the Montenegro coastal waters in 2008 and 2010. Mean monthly satellite values, estimated for each sampled coordinate, were used for this purpose. A specific probability of habitat adequacy for anchovy spawners was estimated for each sampled coordinate. All metrics estimation was performed using the "Presence/Absence" library of R statistical language.

Mapping. Based on validation results, the selected models were applied in a predictive mode to provide probability estimates and habitat adequacy over a grid of mean monthly satellite values at a GIS resolution of 4 km, covering the entire Mediterranean basin (i.e., practically indicating areas where a specific set of values concerning satellite variables occur). Although the model was fitted and validated at a finer resolution (1.5 km) it was re-predicted and mapped at a coarser grid (about 2.5 times coarser). The error was considered minimum since the available satellite data were derived from a single optimum resolution (see Table 2) that minimizes the interpolation error and provides similar values for the variables at any point in space for the two grids. This was considered a reasonable trade-off between the patterns identified by the model and the required computer power to map the resulted probabilities at the scale of the Mediterranean Sea.

Subsequently, annual habitat suitability maps were constructed. GIS techniques were used to estimate the mean of these annual maps, summarising the mean average probability estimates at each grid point. Similarly, the variability map, representing the inter-annual variability in potential adult and juvenile habitats and spawning grounds, was also produced by estimating the standard deviation of the annual maps.

Finally, persistent (or otherwise preferential) and occasional spawning grounds were defined based on average probability and variability maps (Bellier *et al.* 2007). Based on Bellier *et al.* (2007) a habitat allocation map was created indicating: (a) recurrent spawning sites as areas with high mean probability and low standard deviation values, (b) occasional spawning sites: areas with high mean probability and high standard deviation values (i.e., where anchovy eggs are present indicating high probability in some years but not in others) and (c) rare spawning sites - areas with low mean and low standard deviation values. The ArcMap v. 9 was used for mapping and the production of shp files.

2.1.3.1.1.2 Nursery areas

Revised information

In North Aegean Sea, anchovy nursery areas have been studied mainly within the framework of the SARDONE project (FP6 EU funded project). Specifically suitable nursery areas were indicated mainly inside gulfs and closed basins, largely associated to the more productive coastal waters (Giannoulaki et al., 2010). Suitable juvenile grounds were mainly located over the continental shelf, at sites presenting enrichment processes like areas in the vicinity of river mouths. Also, at Lebanese waters Bariche et al. (2006) report high abundance of anchovy juveniles during August at the Daoura region (north of Beirut).

In the Adriatic, one of the main areas that have been described as a hotspot for early life stages (larvae, postlarvae and juveniles) of anchovy is the Gulf of Manfredonia (Marano et al., 1998). The Po river mouth area is potentially an area that could support an high concentration of early life stages but few works on this have been carried out so far (Coombs et al., 1997; Morello and Arneri, 2009). In the northern Spanish Mediterranean waters (GSA06), anchovy juveniles are known to display a more coastal distribution (49-95 m depth) than spawners (55-110 m depth) in areas where the continental shelf is wide, like the surroundings of the Ebro mouth. Anchovy juveniles may appear mixed with adults or segregated (Abad et al 1998a). In the Alboran Sea (GSA01), anchovy juveniles show a patchy spatial distribution and are mainly located in the vicinity of the bay of Málaga and Almería (Rubín 1996).

Data analysis

Surveys and periods used for modeling

Acoustic surveys data were used for the identification and the modeling of nursery grounds of anchovy. A summary Table with the surveys used is summarized below. Details on these surveys characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)**
C. Aegean Sea and Ionian Sea	Anchovy	1998, 1999	July (1998), May-June (1999)	68 transects	Acoustic survey
C. Aegean Sea and Ionian Sea	Sardine	1999, 2000	December	68 transects	Acoustic survey
North Aegean Sea	Greek National Fisheries Data Collection Program	2003-2006, 2008	June	70 transects (2003) 76 transects (2004-2006, 2008)	Acoustic survey
North Aegean Sea	SARDONE	2007-2008	July	8 transects (2007) 6 transects (2008)	Acoustic survey
North Aegean Sea	SARDONE	2007, 2009	December (2007), February (2009)	20 transects (2007) 18 transects (2009)	Acoustic survey

Spanish Mediterranean waters

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey**
GSA01,GSA06	ECOMED	2003-2009	Mid November-mid December		Acoustic survey

Adriatic Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ichthyoplankton surveys)
GSA 17 and 18	MIPAF project 4A42	1998-2001	NW Adriatic: October-November SW Adriatic: July-September	Total number of hauls: 109	Acoustic survey
GSA 17 and 18	No project	2002	SW Adriatic: September-October	Total number of hauls: 22	Acoustic survey
GSA 18 (Montenegro waters)	Montenegro Government project	2002, 2004	SE Adriatic: July-August	Total number of hauls: 20	Acoustic survey
GSA 17 and 18	MIPAF project 6A67	2004-2006	NW Adriatic: September SW Adriatic: August-September	Total number of hauls: 100	Acoustic survey
GSA 18 (Montenegro in 2005, Montenegro and Albania since 2008)$^{(3)}$	SE Adriatic survey	2005, 2008, 2010	July-August	Total number of hauls: 48	Acoustic survey
GSA 17 and 18		2007, 2008	NW Adriatic: September SW Adriatic: June-July	Total number of hauls: 77	Acoustic survey
GSA 17 and 18	SARDONE	2007-2009	NW Adriatic: November, February SW Adriatic: June, February	Total numbers of hauls: 79	Acoustic survey

(1) in the framework of FAO AdriaMed project

Monitoring surveys in the Spanish Mediterranean waters or within the framework of targeted juvenile surveys held in the Gulf of Lions, the Adriatic Sea and the Echo was assigned to anchovy juveniles based on the catches of pelagic identification hauls, held within the framework of the acoustic surveys. The age structure of the catches verified that the majority of anchovy was age 0 (unpublished data of the Instituto Español de Oceanografía). Data from the targeted juveniles' acoustic surveys in the Adriatic Sea, the Gulf of Lions and the North Aegean Sea obtained from mid November to mid December 2007 were used for validation purposes of the model that was based on the Spanish data. Furthermore, acoustic data from targeted juvenile surveys in the Adriatic Sea, the Gulf of Lions and the North Aegean Sea obtained from mid-January 2009 to mid-February 2009 were also used to model the anchovy juveniles' habitat during the winter period. During the targeted juvenile surveys the minimum sampling depth was set at 10 m.

Anchovy juveniles' echoes discrimination was based on the characteristic echogram shape of the schools and the catch composition of concurrent pelagic trawls (Table 1) (Simmonds and MacLennan, 2005). Anchovy smaller than 105 mm (Aegean Sea, Gulf of Lions and Adriatic Sea) were considered as juveniles, based on the estimated approximate length at first maturity (Somarakis *et al*., 2006a; Sinovčić and Zorica, 2006; Morello and Arneri, 2009). Studies during the '90s in the Catalan coast (GSA06) indicated length at first maturity (L_{50}) at 12.5 cm (0.9 sd) for females and 12.7 cm (0.7 sd) for males (Pertierra 1992 in Pertierra and Lleonart 1996) while in the Alboran Sea (GSA01) it was smaller, between 10.3 and 11.4 cm for males and between 10.8 and 11.1 cm for females (Giráldez and Abad 1995).

In a subsequent step, data from the Aegean and the Adriatic Sea collected during the period 1998-2000 (see Tables above) were used to model anchovy juvenile habitat during the past period and are presented as a separate model results.

Environmental data

Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

Since available survey data were located in certain areas i.e. the Spanish Mediterranean Waters, the northern Aegean Sea, the western part of the Adriatic Sea and the Gulf of Lions we decided to apply habitat suitability modeling techniques and use environmental data in order to obtain an idea of anchovy potential nursery grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent nursery areas based on annual distribution maps.

For this purpose, Generalized Additive Models (GAMs, Hastie and Tibshirani, 1990) were applied to define the set of environmental factors that describe anchovy's distribution in the study areas. Details on the application of GAMs are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Modeling approach.

Model validation. In a subsequent step, the selected model was tested and evaluated for its predictive performance for areas and periods not included in model selection. For this purpose, we estimated the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000). They were measured in relation to two threshold criteria: (i) the maximization of the specificity-sensitivity sum (MDT) and (ii)) the prevalence values (Jiménez-Valverde *et al.,* 2008; Lobo *et al.,* 2008).

The GAMs for the potential nursery habitat were validated using data from a) the North Aegean Sea (not included in the model), b) the western Adriatic Sea and the Gulf of Lions in late autumn 2007. A specific probability of habitat adequacy for anchovy juveniles was estimated for each sampled coordinate. All metrics estimation was performed using the "Presence/Absence" library of R statistical language.

Mapping. Details on mapping are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis, Modeling approach, mapping.

2.1.3.1.2 Sardina pilchardus

2.1.3.1.2.1 Spawning areas

Revised information

Sardine spawning in the Eastern part of the Mediterranean have been studied mainly by means of ichthyoplankton surveys in the central part of Aegean and Ionian Sea during the early 2000s (Ganias et al., 2003a; Somarakis et al. 2006b; Ganias et al., 2007). Spawning seems to be generally restricted to nearshore waters and the major spawning locations have been identified in inshore waters with preferred spawning depths between 40 and 90 m.

The presence of sardine eggs has been observed throughout the continental shelf of the Adriatic Sea (Gamulin and Hure, 1983). According to several studies there are high density areas in the northern Adriatic, off Dugi Otok Island and in the southern part around the mid-Dalmatian Islands, extending offshore to Palagruza. The Jabuka Pit and the southern Adriatic trench are the only two areas where no sardine eggs have ever been reported and they may constitute a physical barrier to migrations. In the Gulf of Tunis, sardine eggs were present only during autumn and winter. During autumn, two patches of relatively high abundance were located northwest of Cape Fartas and north of Sidi Bou Said at depths of between 50 and 75 m. In winter, eggs were concentrated in the northwestern part of the gulf, with a maximum abundance observed near Zembra Island and north of Cape Bon. No eggs were found in the southern and western parts of the Gulf. Overall, sardine eggs were more abundant in the 75-100 m stratum (Zarrad *et al.* 2008).

The known spatial distribution of sardine eggs and larvae in the Spanish Mediterranean waters (GSA06 and GSA01) is largely coastal and mainly confined to the continental platform (Sabatés 1990b, Rubín 1996). From the fragmented information it can be inferred that sardine may reproduce all along the Catalan Sea and in the Gulf of Lions. Eggs are mainly located over the shelf, from coastal areas to a depth of 100 m, but also near the shelf-break in areas where the shelf is narrow and under particular environmental conditions (Palomera, 1992; Olivar et al., 2001, 2003; Palomera et al. 2007).

The following list presents the available information concerning the spawning grounds of the sardine in the Mediterranean that are included in the web-based GIS viewer (GIS viewer) at http://mareaproject.net/mediseh/viewer/med.html.

Eastern Mediterranean

Area	**Species**	**Stage (Spawners or Juveniles)**	**Periods (year, months, season)**	**Format (e.g shapefile)**	**Type of survey (trawls/acoustic/ichthyoplankton survey)**	**Source**
C. Aegean Sea and Ionian Sea	*S. pilchardus*	eggs, larvae	2000-2001, December, February	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2006a
N. Aegean Sea	*S. pilchardus*	eggs	2003-2006, June	shapefile	Ichthyoplankton survey	Schismenou *et al.* 2008

Central Mediterranean

Area	**Species**	**Stage**	**Periods**	**Format**	**Type of survey**	**Source**
Adriatic Sea	*S. pilchardus*	eggs	March-April 1985	shapefile	Ichthyoplankton survey	Casavola *et al.*1985
Adriatic Sea	*S. pilchardus*	eggs	Seasonal survey 1973-1976	shapefile	Ichthyoplankton survey	Gamulin and Hure 1983

Area	Species	Stage	Periods	Format	Type of survey	Source
Adriatic Sea	*S. pilchardus*	eggs	December-February 1979-1980	shapefile	Ichthyoplankton survey	Piccinetti *et al.* 1980
Adriatic Sea	*S. pilchardus*	eggs		shapefile	Ichthyoplankton survey	Regner *et al.* 1987
Adriatic Sea	*S. pilchardus*	eggs	February, March, December 1979 and January-February 1980	shapefile	Ichthyoplankton survey	Piccinetti *et al*. 1981
Adriatic Sea	*S. pilchardus*	eggs	Review	shapefile	Review	Skrivanic and Zavodnik 1973
Adriatic Sea	*S. pilchardus*	Spawners	Monthly samplings from November 2006 to October 2007	shapefile	Beach seine sampling	Pesic *et al.*2010
Adriatic Sea	*S. scombrus*	eggs	Seasonal survey 1973-1976	shapefile	Ichthyoplankton survey	Gamulin and Hure 1983
Gulf of Tunis	*S. pilchardus*	eggs, larvae	August, October, February, April 2002-2003	shapefile	Ichthyoplankton survey	Zarrad *et al.* 2008

Western Mediterranean

Area	Species	Life stage	Periods	Format	Type of survey	Source
Catalan coast	*S. pilchardus*	eggs	April- October 1983	shapefile	ichthyoplankton	Sabatés 1990b
Málaga and Almería	*S. pilchardus*	eggs	March-Nov 1982-1984	shapefile	ichthyoplankton	Rubín 1996
Málaga and Almería	*S. pilchardus*	larvae	March-Nov 1982-1984	shapefile	ichthyoplankton	Rubín 1996
Alboran and Balearic Sea	*S. pilchardus*	eggs	May 1982	shapefile	ichthyoplankton	Lago de Lanzos and Solá 1986
Alboran and Balearic Sea	*S. pilchardus*	larvae	May 1982	shapefile	ichthyoplankton	Lago de Lanzos and Solá 1986
Balearic Sea	*S. pilchardus*	eggs	November 1984	shapefile	ichthyoplankton	Lago de Lanzos and García 1986
Balearic Sea	*S. pilchardus*	larvae	November 1984	shapefile	ichthyoplankton	Lago de Lanzos and García 1986
Mediterranean Sea	*S. pilchardus*	eggs	December 2006-2008	shapefile	acoustic	Tugores et al 2011

Data analysis

Surveys and periods used for modeling

Ichthyoplankton surveys data were used for the identification and the modeling of spawning grounds of sardine. A summary Table with the surveys used is summarized below. Details on these surveys characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)**
C. Aegean Sea and Ionian Sea	Sardine	1999, 2000	December	160 WP2 stations per survey	Ichthyoplankton survey

Spanish Mediterranean waters

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey**
GSA1,GSA6	ECOMED	2003-2009	Mid November-mid December	CUFES Stations	Ichthyoplankton survey

In the Spanish Mediterranean waters, fish eggs were collected simultaneously to acoustic surveys using an on board installed continuous, underway fish–egg sampler (CUFES, Model C-120, Ocean Instruments Inc.) during early winter from 2006 to 2008. The sampling scheme followed the same transect scheme adopted for the Spanish acoustic surveys. Water was continuously pumped from 5 m below the sea surface. Samples were taken every 3 nm but when the most offshore CUFES station was positive for sardine eggs, transect was continued further offshore until a null station of sardine eggs was found (no presence of sardine eggs). The collected eggs were stored in 4% seawater-buffered formalin solution. Individual fish eggs were visually classified to species and sardine eggs were counted and stored in preservation solution. Sardine-egg concentration along the survey transects was recorded as numbers of eggs per 10 m^3.

Environmental data

Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

Since available survey data were located practically in only the Spanish Mediterranean Waters we decided to apply habitat suitability modeling techniques and use environmental data in order to obtain an idea of sardine potential spawning grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent spawning areas based on annual distribution maps.

For this purpose, Generalized Additive Models (GAMs, Hastie and Tibshirani, 1990) were applied to define the set of environmental factors that describe sardine eggs’ distribution in the study areas. Details on the application of GAMs are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Modeling approach.

Model validation. In a subsequent step, the selected model was tested and evaluated for its predictive performance for a period not included in model selection. For this purpose, we estimated the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000). They were measured in relation to two threshold criteria: (i) the maximization of the specificity-sensitivity sum (MDT) and (ii)) the prevalence values (Jiménez-Valverde *et al.,* 2008; Lobo *et al.,* 2008).

The GAMs for sardine potential spawning habitat were validated using data from the Spanish Mediterranean waters in December 2009. A specific probability of habitat adequacy for sardine spawning was estimated for each sampled coordinate. All metrics estimation was performed using the "Presence/Absence" library of R statistical language.

Mapping. Details on mapping are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis, Modeling approach, mapping.

2.1.3.1.2.2 Nursery areas

Revised information

In the Eastern Mediterranean, the nursery grounds of sardine have been studied mainly in Aegean Sea where sardine nurseries were determined within the framework of the SARDONE project (FP6 EU funded project). The highest concentrations and abundances of sardine juveniles in Aegean Sea during June were identified in the north part of the Thracian Sea plateau, consisting of shallow areas (<70 m bottom depth) associated with waters of high productivity in the vicinity of river runoffs. At Lebanese waters, Bariche *et al.* (2006) also report a nursery area for sardine at the Daoura region (north of Beirut) with higher abundance of sardine juveniles during May and June.

In the Alboran Sea, sardine juveniles are known to present a patchy spatial distribution, mainly on the continental platform but they also appear close to the shelf break in demersal hauls (Rubín, 1996). Recent work on habitat modeling, using environmental variables and acoustic data, has indicated as persistent suitable nurseries in the Western Mediterranean the inner, north western part of the Gulf of Lions, the coastal waters of Morocco, Algeria and Tunisia (Giannoulaki *et al.,* 2011).

Sardine juveniles have been found in the past inshore along the eastern Adriatic Sea especially in the channels such as Krka river estuary, Novigrad Sea, Karin Sea Bay, Boka Kotorska Bay. The only well defined nursery area in the Italian coast is the Gulf of Manfredonia but the dynamics that can influence sardine in this area are still not clear (Morello and Arneri, 2009). The recent results of the SARDONE project showed that there are also persistent nursery areas in the coastal waters of the north western part of the Adriatic and around the coastal waters of the mid-Dalmatian islands in the eastern part (Giannoulaki *et al.,* 2011).

Below, there is a summary table of all areas on the revised information for sardine nursery grounds (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html):

Eastern Mediterranean

Area	**Species**	**Stage (Spawners or Juveniles)**	**Periods (year, months, season)**	**Format (e.g shapefile)**	**Type of survey (trawls/acoustic/ichthyoplankton survey)**	**Source**

Area	Species	Stage (Spawners or Juveniles)	Periods (year, months, season)	Format (e.g shapefile)	Type of survey (trawls/acoustic/ichthyoplankton survey)	Source
N. Aegean Sea	*S. pilchardus*	juveniles	2007-2008, July	shapefile	Acoustic survey	SARDONE 2010

Central Mediterranean

Area	Species	Stage	Periods	Format	Type of survey	Source
Adriatic Sea	*S. pilchardus*	juveniles	Review	shapefile	Review	Morello and Arneri 2009
Adriatic Sea	*S. pilchardus*	juveniles	April 1981, June-August 1983, April 1984	shapefile	Pelagic trawls	Kacic *et al.* 1985
Adriatic Sea	*S. pilchardus*	juveniles	Monthly samplings from May 1986 to April 1987	shapefile	Pelagic trawls	Kacic *et al.* 1987
Adriatic Sea	*S. pilchardus*	juveniles	2007-2008, July	shapefile	Acoustic survey	SARDONE 2010

Western Mediterranean

Area	Species	Life stage	Periods	Format	Type of survey	Source
Ligurian Sea	*S. pilchardus*	juveniles		shapefile	Landings	Romanelli *et al.* 1998
Málaga and Almería	*S. pilchardus*	juveniles	March-Nov. 1991-1994	shapefile	pelagic and demersal hauls	Rubín, 1996
Gulf of Lions	*S. pilchardus*	juveniles	2007-2008, July	shapefile	Acoustic survey	SARDONE 2010

Data analysis

Surveys and periods used for modeling

Acoustic surveys data were used for the identification and the modeling of nursery grounds of sardine. A summary Table with the surveys used is summarized below. Details on these surveys characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)
North Aegean Sea	Greek National Fisheries Data Collection Program	2003-2006, 2008	June	70 transects (2003) 76 transects (2004-2006, 2008)	Acoustic survey
North Aegean Sea	SARDONE	2007-2008	July	8 transects (2007) 6 transects (2008)	Acoustic survey

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)
North Aegean Sea	SARDONE	2007, 2009	December (2007), February (2009)	20 transects (2007) 18 transects (2009)	Acoustic survey

Adriatic Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ichthyoplankton surveys)
GSA 18 (Montenegro waters)	Montenegro Government project	2002, 2004	SE Adriatic: July-August	Total number of hauls: 20	Acoustic survey
GSA 18 (Montenegro in 2005, Montenegro and Albania since 2008)(1)	SE Adriatic survey	2005, 2008, 2010	July-August	Total number of hauls: 48	Acoustic survey
GSA 17 and 18	No project	2007, 2008	NW Adriatic: September SW Adriatic: June-July	Total number of hauls: 77	Acoustic survey
GSA 17 and 18	SARDONE	2007-2009	NW Adriatic: November, February SW Adriatic: June, February	Total numbers of hauls: 79	Acoustic survey

(1) in the framework of FAO AdriaMed project

Acoustic data, from standard monitoring surveys carried out in summer in the Gulf of Lions (collected within the SARDONE framework), the north Aegean Sea and the south western part of the Adriatic Sea, were used to model the presence of sardine juveniles in the Mediterranean Sea. In particular, two different models were selected using data derived from (i) the Aegean Sea from June (2003-2008) and (ii) the Gulf of Lions during July (2004-2008).

Anchovy juveniles' echoes discrimination was based on the characteristic echogram shape of the schools and the catch composition of concurrent pelagic trawls (Simmonds and MacLennan, 2005). Sardine smaller than 125 mm (Aegean Sea, Gulf of Lions and Adriatic Sea) were considered as juveniles, based on the estimated approximate length at first maturity for the European sardine in the Mediterranean. In the east part of Aegean Sea, during the 90s, length at first sexual maturity for sardine is reported at 12.0, 12.4, 12.2 cm for males and 11.3, 12.2, 12.2 cm for females at the Edremit Bay, Izmir Bay and Büyük Menderes Delta respectively (Cinahgir, 1996). In the Central Aegean and Ionian Sea, studies based on macroscopic examination of the gonads and gonads histology indicated size at first maturity approximate at 11.8 cm for females (Ganias *et al.,* 2003b; 2007) as shown by fitted logistic curves to length along with maturity estimates (Machias *et al.,* 2007). Recent studies on sardine juveniles in North Aegean Sea indicated that size at first maturity is smaller, approximating 100 mm based on the macroscopic examination of the gonads (Nikolioudakis *et al.,* 2011).

At the Adriatic Sea, Muzinic (1954), back in the '50s, reported that the first sexual maturity occurs between 13 and 14 cm. Sinovcic *et al.* (2003, 2008) have been carrying out detailed studies in the nursery areas of the Krka river estuary (Croatia). The smallest sizes at first maturity were 7.1 cm for male specimens and 7.3 cm for female. The overall L_{50} was estimated at around 7.9 cm.

A preliminary study on the reproductive biology of sardine, based on data collected off the southern coast of Sicily, represented the first attempt to investigate the reproductive features of the sardine population in this area (Basilone *et al.,* 2004). During the period January 2000 through December 2002, gonadosomatic index (GSI) evolution was studied and size at first maturity (SFM) was estimated for separate sexes and total. Total length at first maturity estimates assessed over two consecutive spawning events (2000-2001 and 2001-2002) were 11.55 cm for all the sampled specimens, 11.60 cm for males and 11.54 cm for females.

Size at first maturity in the coast of Castellón (GSA06) was 11.3 cm for females and 11.7 cm for males (Larrañeta, 1976). In Alboran Sea (GSA01), the size at first maturity for female sardine varied between 12.5 and 13.8 cm while for males it was between 12.8 and 13.6 cm (Abad and Giráldez, 1993).

Environmental data

Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

Since available survey data were located in certain areas i.e. the northern Aegean Sea, the western part of the Adriatic Sea and the Gulf of Lions, we decided to apply habitat suitability modeling techniques and use environmental data in order to obtain an idea of sardine potential nursery grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent nursery areas based on annual distribution maps.

For this purpose Generalized Additive Models (GAMs, Hastie and Tibshirani, 1990) were applied to define the set of environmental factor that describe the most suitable habitat for sardine juveniles. Details on the application of GAMs are described in the respective section 2.1.3.1.1. Anchovy, Spawning grounds, Data Analysis, Modeling Approach.

Model validation. The GAMs for the potential nursery habitat of sardine were validated using data from i) the North Aegean Sea (2004 – 2008) for the June model and from ii) the western Adriatic Sea (2008), the northern Aegean Sea (2007-2008) and the Gulf of Lion (2003-2008) for the July model. Details on the application of model validation are described in the respective section **2**.1.3.1.1. Anchovy, Spawning grounds, Data Analysis, Model Validation.

Mapping. Details mapping are described in the respective section 2.1.3.1.1. Anchovy, Spawning grounds, Data Analysis, Mapping.

2.1.3.1.3 Scomber scombrus

2.1.3.1.3.2 Nursery areas

Revised information

In the western part of the Mediterranean the work of Sardŭ *et al.* (2006) indicated that suitable areas for juvenile *Scomber scombrus* are identified to be in association with the outflow of Ebro river. In the central Mediterranean, according to Bottari *et al.* (2004) the juvenile of the species are identified to be present at the coast of Bari in Adriatic Sea as well as in the Gulf of Gabes (Hajjej *et al.* 2010). No specific information is available concerning the Eastern part of the Mediterranean and the spatial distribution of the nursery grounds of *Scomber scombrus.*

Below there is a summary Table for all areas on the revised information for *Scomber scombrus* nursery grounds (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html)**:**

Central Mediterranean

Area	**Stage**	**Periods**	**Format**	**Type of survey**	**Source**
Bari (Adriatic Sea)	juveniles	monthly 2000-2001	shapefile	Purse seine survey	Bottari *et al.* 2004
Gulf of Gabes	juveniles	Monthly 2008-2009	shapefile	Trawl survey, Purse seine survey	Hajjej *et al.* 2010

Western Mediterranean

Area	**Life stage**	**Periods**	**Format**	**Type of survey**	**Source**
Ebro river	juveniles	2003, June, September	shapefile	Trawl survey	Sardŭ *et al.* 2006

Data analysis

Surveys and periods used for modeling

Scomber scombrus spawns during the winter-early spring, thus summer period corresponds to high juveniles abundance.

The model was based on pelagic hauls data held during acoustic surveys in the GSAs 17, 18, 22 referring to the summer period 2001-2010 (see the Table below).

Pelagic trawl surveys data were used for the identification and the modeling of nursery grounds of *Scomber scombrus*. A summary Table with the surveys used is summarized below. Details on these surveys characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)
North Aegean Sea	SARDONE	2008	June	10 Pelagic trawls	Acoustic survey
Thracian Sea	REPROdUCE	2010	May, July	6 Pelagic trawls (May) 9 Pelagic trawls (May)	Acoustic survey
North Aegean Sea	Greek National Fisheries Data Collection Program	2003-2006, 2008	May - July	103 Pelagic trawls	Acoustic survey

Adriatic Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ichthyoplankton surveys)
GSA 17 and 18	MIPAF project 4A42	1998-2001	NW Adriatic: October-November SW Adriatic: July-September	Total number of hauls: 109	Acoustic survey
GSA 17 and 18		2002	SW Adriatic: September-October	Total number of hauls: 22	Acoustic survey
GSA 18 (Montenegro waters)	Montenegro Government project	2002, 2004	SE Adriatic: July-August	Total number of hauls: 20	Acoustic survey
GSA 17 and 18	MIPAF project 6A67	2004-2006	NW Adriatic: September SW Adriatic: August-September	Total number of hauls: 100	Acoustic survey
GSA 18 (Montenegro in 2005, Montenegro and Albania since 2008)	FAO AdriaMed project	2005, 2008, 2010	July-August	Total number of hauls: 48	Acoustic survey
GSA 17 and 18		2007, 2008	NW Adriatic: September SW Adriatic: June-July	Total number of hauls: 77	Acoustic survey

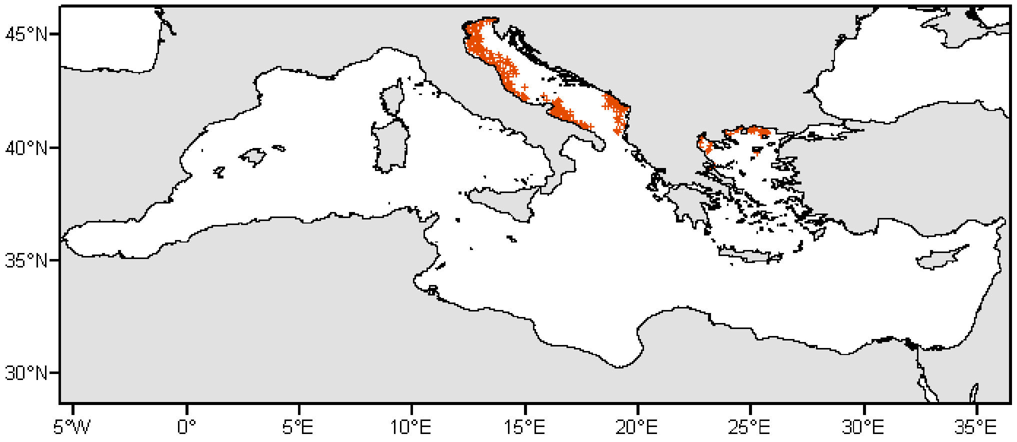

Fig. 2.1.3.1.3.2.1. Positions of pelagic trawl hauls within the period 2001-2010 that were used for the modeling of *Scomber scombrus* nursery grounds.

In Aegean Sea, juvenile's abundance data were collected on board the R/V Philia by means of pelagic trawl hauls held within the framework of acoustic surveys (North Aegean Sea and Evoikos gulf: June-July 2003-2008 and 2010). A mid-water pelagic trawl with a vertical opening of 10 m and 8 mm codend was used for this purpose.

In the Adriatic Sea pelagic trawl data were collected on board the R/V Dallaporta within the framework of acoustic surveys (western part of the Adriatic Sea: June-September 2001-2002, 2004-2010). A mid-water pelagic trawl with a vertical opening of 7m and a 18mm codend mesh size was used (MEDIAS, 2009). Concerning the surveys conducted during the SARDONE project (2007-2009), a pelagic trawl with a vertical opening of 2.1 m and a 5 mm codend mesh size was used (SARDONE, 2010).

Concerning the size at first maturity for *Scomber scombrus,* no specific study has been taken place in the Eastern part of the Mediterranean. The review work of Colette and Nauen (1983) refers that in the eastern part of the Mediterranean the maturity of *Scomber scombrus* may be attained at approximately 30 cm. Some available information is based on unpublished data in Adriatic (Meneghesso, 2011). The results of the analysis of samples from commercial catches (bottom trawls, pelagic trawls, longlines) from Chioggia and Ancona ports, collected in the period 2009-2010, indicated that the minimum length of mature individuals is 18 cm for male and 17 cm for female. Bottari *et al.* (2004) found on specimens collected from commercial landings, that the smallest mature female was 20 cm of FL and the smallest male was 20.5 cm. Since no data were available to estimate L_{50} based on available literature review, individuals with Total length <20cm were selected as juveniles at the GSAs 17, 18 and 22.

Environmental data

Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

In consistency to the modeling approach followed to all target small pelagic fish we applied habitat suitability modeling techniques and used environmental data in order to obtain an idea of *Scomber scombrus* potential juvenile grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent juvenile areas based on annual distribution maps**.**

Data from pelagic hauls held during acoustic surveys in the GSAs 17, 18, 22 were used to determine *Scomber scombrus* juvenile presence. Specifically, the entire set of 355 hauls performed over the period 2001–2010 was used. Only hauls with sufficient *Scomber scombrus* juveniles measurements were considered as positive. Specifically, we considered as presence only these hauls containing over 20% juvenile's catch of the total catch of *S. scombrus.* So, at each haul location x, an indicator of *Scomber scombrus* juveniles presence I(x) was defined as I(x) = 1, if the percentage of juveniles catch was over 20%, and I(x) = 0 otherwise. Using this criterion, we retained a total of 67 positive *Scomber scombrus* juvenile's hauls from the acoustic surveys in all GSAs conducted between 2001 and 2010.

In a subsequent step, the Maximum Entropy Model (MAXENT –Philips *et al.* 2006) was applied as appropriate due to the very small number of available presence data that impaired other statistical approaches not suitable to apply. Maxent was chosen primarily because it allows a more generative approach and it shows a relative insensitivity to noisy data and the small sample size available (Philips *et al.*, 2006). This approach is widely used to model species geographic distributions (i.e. occurrence) in the terrestrial and aquatic environments. The dedicated software Maxent (Phillips et al., 2006) was used to investigate the environmental factors limiting species' distributions. The algorithm used in Maxent aims to find the largest spread (or maximum entropy) in a geographic dataset (i.e. the species or habitat locations), in relation to a set of "background" environmental variables (i.e. the model predictors). Maxent starts with a uniform distribution of probability values over the entire "background grid", and conducts an optimization routine that iteratively improves model fit, measured as the gain. The gain is the likelihood (deviance) statistic that maximizes the probability of presence in relation to the background data, corrected for the case where the probabilities of all pixels are equal (uniform distribution). For the specific dataset and in the framework of MEDISEH, MAXENT was applied using the absence data available (i.e. stations with zero abundance) as background points along with the respective satellite environmental and bathymetry variables at each sampling point.

A model for juvenile *Scomber scombrus* occurrence was developed, using Maxent default settings, but randomly setting aside 25% of presence points for model validation (i.e. "test" data, as opposed to the "training" data used to develop the model).

Model validation. The evaluation of the Maximum Entropy Model was based on the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000) as estimated from randomly selected dataset which used 25% of the observations. Finally, the AUC of the test data averaged over the replicate runs (10 replicates) was used.

Mapping. Annual probability maps were obtained for the whole Mediterranean. A mean probability map was estimated based on the annual probability maps and up to 400 m depth. Additionally, a persistence map was defined based on the mean probability and variability maps following Bellier *et al.* (2007). Persistence maps describe preferential (high mean, low std), occasional (high mean, high std) and rare (low mean, low std) juvenile grounds and up to 400 m depth. Details on mapping are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Modeling approach.

2.1.3.1.4 Scomber colias

2.1.3.1.4.1 Spawning areas

Revised information

Limited information is available concerning the Eastern part of the Mediterranean and the spatial distribution of the spawning grounds of *Scomber colias*. Ichthyoplankton surveys in the central part of Aegean Sea that were held within the framework of a project (Investigation of the abundance and distribution of the demersal stocks of primary importance to the Greek fishery at North Aegean Sea (DG Fisheries Studies MA-1-90)) during the early 90s indicated as a spawning ground the area between the mainland, Evoia Island and Sporades islands (Project report). Similarly, ichthyoplankton surveys in the North Aegean Sea during the period 1995-1996 indicated areas with high larvae concentrations at the offshore waters of the Samothraki plateau (Somarakis et al. 2002). High annual variability was also observed in these spawning grounds. A recent ichthyoplankton survey at North Aegean Sea (Danelli et al. 2010) that refers to the summer of 2008 indicated as spawning grounds for *Scomber colias* the coastal areas of Thracian Sea, Strymonikos Gulf, the western part of Thernaikos Gulf as well as the south part of Limnos island and the western part of Sporades islands.

Information on the spawning and early life stages ecology of *Scomber colias* is limited and fragmentary for the Adriatic stocks. In fact, in spite of its wide distribution and commercial importance in the Adriatic Sea, only a few biological studies have focused on the reproductive patterns of the Adriatic population. Muzinic (1979a) in the late '70s reported that the spawning areas had been located in the central and southern Adriatic and not only in relative shallow fishing areas but also in waters showing greater depths.

Concerning western Mediterranean, ichthyoplankton surveys in the Spanish waters during the early summer period 1992 indicated areas with high larvae concentrations at the Catalan coast (Olivar and Sabates 1997).

Below there is a summary Table for all areas on the revised information for *Scomber colias* spawning grounds (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html)**:**

Eastern Mediterranean

Area	**Species**	**Stage (Spawners or Juveniles)**	**Periods (year, months, season)**	**Format (e.g shapefile)**	**Type of survey (trawls/acoustic/ichthyoplankton survey)**	**Source**
C. Aegean Sea and Ionian Sea	*S. colias*	larvae	1998-1999, June, July	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2011a
Thracian Sea-Strymonikos gulf	*S. colias*	larvae	1993-1996, June	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2011b
Thracian Sea-Strymonikos gulf and Limnos	*S. colias*	larvae	2003-2006, June	shapefile	Ichthyoplankton survey	Isari *et al.* 2008
Thermaikos gulf	*S. colias*	larvae	1995-1996, June	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2002

Western Mediterranean

Area	**Species**	**Life stage**	**Periods**	**Format**	**Type of survey**	**Source**
Catalan coast	*S. colias*	larvae	1992, May, June	shapefile	Ichthyoplankton survey	Olivar and Sabates 1997

Data analysis

Surveys and periods used for modeling

The model was based on ichthyoplankton data collected during ichthyoplankton surveys in the GSA 22 referring to the summer period 2006, 2008 and 2010 (see the Table below).

Ichthyoplankton surveys data were used for the identification and the modeling of spawning grounds of *Scomber colias*. A summary Table with the surveys used is summarized below. Details on these surveys characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)**
North Aegean Sea	Greek National Fisheries Data Collection Program	2006, 2008	June	200 WP2 stations per survey	Ichthyoplankton survey
Thracian Sea	REPROdUCE	2010	May, July	83 WP2 stations per survey	Ichthyoplankton survey

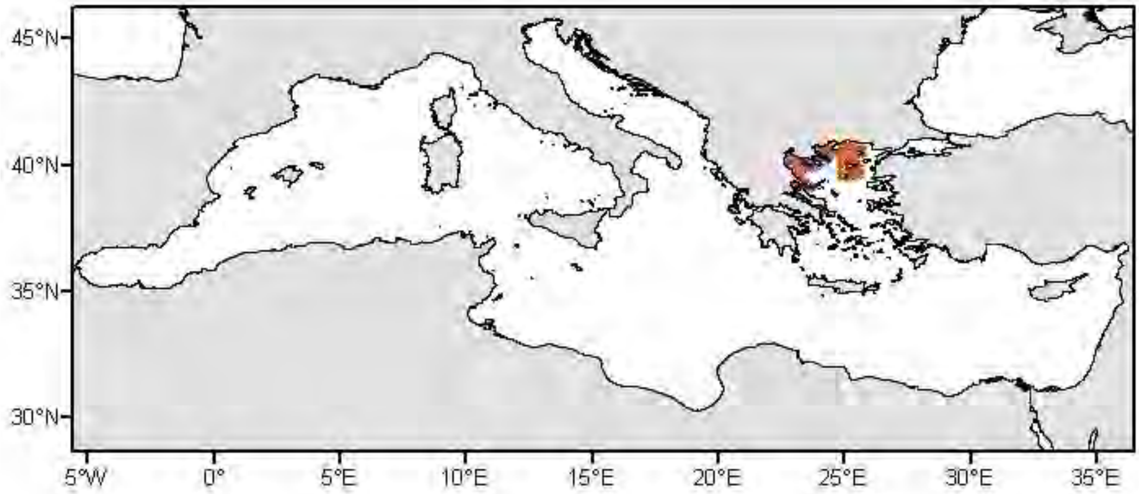

Fig. 2.1.3.1.4.1.1. Positions of ichthyoplankton stations within the period 2006, 2008, 2010 that were used for the modeling of *Scomber colias* spawning grounds. Details can be found in Annex 2.1.2.

Egg data were collected from Daily Egg Production Method (DEPM) surveys carried out in the North Aegean Sea in summer 2006, 2008 and 2010 for the estimation of the spawning stock biomass of the North Aegean anchovy stock (Somarakis *et al*., 2007). A 10×5 nmi grid of stations was sampled by vertical plankton hauls using a WP2 sampler (mouth opening, 0.255 m^2; mesh size, 0.200 mm). Samples were preserved in 4% buffered formaldehyde solution for later analysis and enumeration of chub mackerel eggs in the laboratory.

Environmental data

Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

In consistency to the modeling approach followed to all target small pelagic fish we applied habitat suitability modeling techniques and used environmental data in order to obtain an idea of *Scomber colias* potential spawning grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent juvenile areas based on annual distribution maps.

Data from ichthyoplankton surveys in the GSA 22 were used to determine *Scomber colias* eggs' presence. Specifically, the entire set of 465 stations performed over the period 2006, 2008, 2010 was used. We concluded to the following abundance level for accepted eggs presence. Stations were considered as absences when the eggs' abundance was limited at 1 egg/ m^2, not supported by the presence of larvae and the adjacent stations did not exhibit any presence of *S. colias* eggs. The rest of the stations were accepted as presences. Using this criterion, we retained a total of 137 positive *Scomber colias* eggs' stations from the ichthyoplankton surveys in GSA 22 conducted in 2006, 2008 and 2010.

In a subsequent step, Maximum Entropy Models (MAXENT –Philips *et al.* 2006) was applied due to the very small number of available presence data that made other statistical approaches not suitable to apply. Maxent was chosen primarily because it allows a more generative approach and it shows a relative insensitivity to noisy data and the small sample size available (Philips *et al.,* 2006). For the specific dataset and in the framework of MEDISEH, MAXENT was applied using the absence data available (i.e. stations with zero abundance) as background points along with the respective satellite environmental and bathymetry variables at each sampling point.

A model for *Scomber colias* eggs occurrence was developed, using Maxent default settings, but randomly setting aside 25% of presence points for model validation (i.e. "test" data, as opposed to the "training" data used to develop the model). Details on the application of Maxent model are described in the respective section 2.1.3.1.3.2 *Scomber scombrus*, nursery grounds, Data Analysis Modeling approach.

Model validation. The evaluation of the Maximum Entropy Model was based on the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000) as estimated from randomly selected dataset which used 25% of the observations. Finally, the AUC of the test data averaged over the replicate runs (10 replicates) was used.

Mapping. Annual probability maps were obtained for the whole Mediterranean. A mean probability map was estimated based on the annual probability maps and up to 400 m depth. Additionally, a persistence map was defined based on the mean probability and variability maps following Bellier *et al.* (2007). Persistence maps describe preferential (high mean, low std), occasional (high mean, high std) and rare (low mean, low std) spawning grounds up to 400 m depth. Details on mapping are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Modeling approach.

2.1.3.1.4.2 Nursery areas

Revised information

Limited information is available on the spatial distribution of the nursery grounds of *Scomber colias* in the Eastern Mediterranean. The results of the work of Kiparissis *et al.* (2000) that was based on landings indicated higher abundance of young individuals (age 0 and 1) in the landings deriving from the North Aegean Sea and Saronikos gulf compared to those of the Cretan Sea where age 0 was completely lacking. At Lebanese waters, Bariche *et al.* (2006) also reported a nursery area for *Scomber colias* at the Daoura region (north of Beirut). Additionally, in the Turkish Mediterranean coast, according to purse seine surveys in the period 1997-1998 the juveniles of the species are present at the coast of Izmir (Sever *et al.* 2006). In the Adriatic Sea, the presence of some young fish in the inshore and offshore mid Dalmatian Island area had been noted (Muzinic, 1979). According to the work of Perrotta *et al.* (2005) in 1992 and 1997, suitable areas for the chub mackerel juveniles in the Spanish waters are identified at the Catalan coast.

Below there is a summary Table for all areas on the revised information for *Scomber colias* nursery grounds (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html)**:**

Eastern Mediterranean

Area	Species	Stage (Spawners or Juveniles)	Periods (year, months, season)	Format (e.g shapefile)	Type of survey (trawls/acoustic/ichthyoplankton survey)	Source
Lebanon	*S. colias*	juveniles	2003, May-July	shapefile	Purse seine survey	Bariche *et al.* 2007
Izmir (Turkey)	*S. colias*	juveniles	1997-1998, seasonal sampling	shapefile	Purse seine survey	Sever *et al.* 2006

Western Mediterranean

Area	Species	Life stage	Periods	Format	Type of survey	Source
Catalan coast	*S. colias*	juveniles	1992, 1997, April_July (1992), December (1997)	shapefile	Fisheries survey	Perrotta *et al.* 2005

Data analysis

Surveys and periods used for modeling

Scomber colias spawns during the summer thus autumn period corresponds to high juveniles abundance

Pelagic trawl surveys data were used for the identification and the modeling of nursery grounds of *Scomber colias*. A summary Table with the surveys used is summarized below. Details on these surveys characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)
North Aegean Sea	Greek National Fisheries Data Collection Program	2003-2006, 2008	May - July	103 Pelagic trawls	Acoustic survey
North Aegean Sea	SARDONE	2008	July	10 Pelagic trawls	Acoustic survey

Adriatic Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ichthyoplankton surveys)
GSA 17 and 18	MIPAF project 4A42	1998-2001	NW Adriatic: October-November SW Adriatic: July-September	Total number of hauls: 109	Acoustic survey
GSA 17 and 18	No project	2002	SW Adriatic: September-October	Total number of hauls: 22	Acoustic survey
GSA 18 (Montenegro waters)	Montenegro Government project	2002, 2004	SE Adriatic: July-August	Total number of hauls: 20	Acoustic survey
GSA 17 and 18	MIPAF project 6A67	2004-2006	NW Adriatic: September SW Adriatic: August-September	Total number of hauls: 100	Acoustic survey
GSA 18 (Montenegro in 2005, Montenegro and Albania since 2008)	FAO AdriaMed project	2005, 2008, 2010	July-August	Total number of hauls: 48	Acoustic survey
GSA 17 and 18	No project	2007, 2008	NW Adriatic: September SW Adriatic: June-July	Total number of hauls: 77	Acoustic survey

Western Mediterranean Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ichthyoplankton surveys)
GSA 1,6	MEDIAS	2009-2010	June-July		Acoustic survey

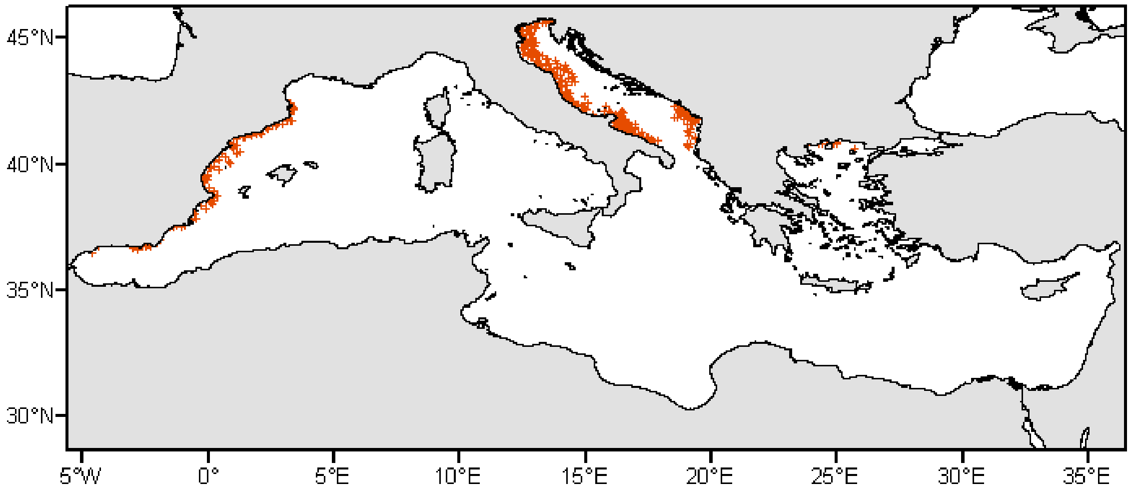

Fig. 2.1.3.1.4.2.1. Positions of pelagic trawl hauls within the period 2000-2010 that were used for the modeling of *Scomber colias* nursery grounds. Details can be found in Annex 2.1.2.

In Aegean Sea, juvenile's abundance data were collected on board the R/V Philia by means of pelagic trawl hauls held within the framework of acoustic surveys (North Aegean Sea and Evoikos gulf: June-July 2003-2008 and 2010). A mid-water pelagic trawl with a vertical opening of 10 m and 8 mm codend was used for this purpose.

In the Adriatic Sea pelagic trawl data were collected on board the R/V Dallaporta within the framework of acoustic surveys (western part of the Adriatic Sea: June-September 2001-2002, 2004-2010). A mid-water pelagic trawl with a vertical opening of 7m and a 18mm codend mesh size was used (MEDIAS, 2009). Concerning the surveys conducted during the SARDONE project (2007-2009), a pelagic trawl with a vertical opening of 10m and a 9mm codend mesh size was used (SARDONE, 2010).

Concerning the Spanish Mediterranean waters, juvenile data collected on board the R/V Cornide de Saavedra during the acoustic surveys in the summer period 2009-2010. A pelagic trawl with a vertical opening of 16m and a 20mm codend mesh size was used (MEDIAS, 2009).

Concerning the length at first maturity of *Scomber colias*, there are no studies for the Eastern Mediterranean Sea. For other areas, first maturity is reported after age 2 at approximately 20 cm (Castro Hernandez and Santana Ortega 2000). This is close to the minimum landings size (EC regulation 2006 at 18 cm). Recently Cikes Kec and Zorica (2012), analyzing samples collected from commercial landings in the eastern Adriatic, found that the smallest analysed sexually mature male was 17.9 cm, while the smallest female had a fork length of 18.3 cm. The fork length at which 50% of the chub mackerel population attained maturity was estimated to be 18.3 cm, with smaller sizes for males (16.8 cm) than for females (20.4 cm).

Therefore, according to literature review, individuals with Total length <20cm were selected as juveniles at the GSAs 17, 18 and 22. Concerning the GSAs 1 and 6, we concluded to a higher threshold (30cm) following the results of length frequency analysis (i.e. the first peak in the length frequency histogram has been used).

Environmental data

Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

In consistency to the modeling approach followed to all target small pelagic fish we applied habitat suitability modeling techniques and used environmental data in order to obtain an idea of *Scomber colias* potential juvenile grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent juvenile areas based on annual distribution maps.

Data from 302 pelagic hauls performed during the period 2000–2010 within the framework of acoustic surveys in GSAs 1, 6, 17, 18, 22 were used to determine *Scomber colias* juvenile presence. Only hauls with sufficient *Scomber colias* juveniles measurements were considered as positive. Specifically, we considered as presence only these hauls containing over 20% juvenile's catch of the total catch of *S. colias.* So, at each haul location x, an indicator of *Scomber colias* juveniles presence I(x) was defined as I(x) = 1, if the percentage of juveniles catch was over 20%, and I(x) = 0 otherwise. Using this criterion, we retained a total of 60 positive *Scomber colias* juvenile's hauls from the acoustic surveys in all GSAs conducted between 2000 and 2010.

In a subsequent step, Maximum Entropy Models (MAXENT –Philips *et al.* 2006) was applied due to the very small number of available presence data that made other statistical approaches not suitable to apply. Maxent was chosen primarily because it allows a more generative approach and it shows a relative insensitivity to noisy data and the small sample size available (Philips *et al.,* 2006). For the specific dataset and in the framework of MEDISEH, MAXENT was applied using the absence data available (i.e. stations with zero abundance) as background points along with the respective satellite environmental and bathymetry variables at each sampling point.

A model for juvenile *Scomber colias* occurrence was developed, using Maxent default settings, but setting aside 25% of presence points for model validation (i.e. "test" data, as opposed to the "training" data used to develop the model). Details on the application of Maxent model are described in the respective section 2.1.3.1.3.2 *Scomber scombrus*, nursery grounds, Data Analysis Modeling approach.

Model validation. The evaluation of the Maximum Entropy Model was based on the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000) as estimated from randomly selected dataset which used 25% of the observations. Finally, the AUC of the test data averaged over the replicate runs (10 replicates) was used.

Mapping. Annual probability maps were obtained for the whole Mediterranean. A mean probability map was estimated up to 400 m depth based on the annual probability maps. Additionally, a persistence map was defined based on the mean probability and variability maps following Bellier *et al.* (2007). Persistence maps describe preferential (high mean, low std), occasional (high mean, high std) and rare (low mean, low std) juvenile grounds. Details on mapping are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Modeling approach.

2.1.3.1.5 Trachurus trachurus

2.1.3.1.5.1 Spawning areas

Revised information

Limited information is available concerning the Eastern part of the Mediterranean and the spatial distribution of the spawning grounds of *Trachurus trachurus*. Published work based on landings and the macroscopic examination of gonads indicates Saronikos Gulf in Central Aegean Sea as a spawning ground for the species during the early '90s.

A study on the reproductive biology of the species in the Adriatic has been done by Alegria Hernandez (1983) in the '80s. According to these studies, horse mackerel spawns in the open Adriatic between 100 and 200 m isobaths at temperature of 12-16 °C and salinity of 28.5-38.80. From the results of a series of bottom trawl surveys carried out in the early 70's a high number of juveniles have been found in the waters around Palagruza Island (Jukic and Piccinetti, 1981). No information is available from the Strait of Sicily concerning the spawning and nursery grounds of the species.

In the Catalan coast (GSA06), horse mackerel (*T. trachurus*) eggs are known to distribute on the continental platform and close to the shelf break (Sabatés 1990b). Horse mackerel larvae were generally found in waters with bottom depth between 100 m and 500 m. Larvae were scare in the surroundings of the Ebro River and in the Gulf of Roses whereas they were highly abundant in between (Sabatés 1990a).

The following list presents the available information concerning the spawning grounds of *Trachurus trachurus* in the Mediterranean (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html):

Eastern Mediterranean

Area	**Species**	**Stage (Spawners or Juveniles)**	**Periods (year, months, season)**	**Format (e.g shapefile)**	**Type of survey (trawls/acoustic/ichthyoplankton survey)**	**Source**
Thracian Sea-Strymonikos gulf	*T. trachurus*	larvae	1993-1996, June	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2011b
Thracian Sea-Strymonikos gulf and Lemnos	*T. trachurus*	larvae	2003-2006, June	shapefile	Ichthyoplankton survey	Isari *et al.* 2008
Thermaikos gulf	*T. trachurus*	larvae	1995-1996, June	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2002
Saronikos gulf	*T. mediterraneus*	juveniles	1989-1991, all	shapefile	Trawl survey	Karlou-Riga 2000

Western Mediterranean

Area	**Species**	**Life stage**	**Periods**	**Format**	**Type of survey**	**Source**
Catalan coast	*T.trachurus*	eggs	April- October 1983	shapefile	ichthyoplankton	Sabatés 1990b
Catalan coast	*T.trachurus*	larvae	June 1983	shapefile	ichthyoplankton	Sabatés 1990a
Catalan coast	*T. trachurus*	larvae	1992, May, June	shapefile	Ichthyoplankton survey	Olivar and Sabates 1997

Data analysis

No survey data were available from any area to determine the spawning grounds of *Trachurus trachurus.*

2.1.3.1.5.2 Nursery areas

Revised information

Limited information is available concerning the Eastern part of the Mediterranean and the spatial distribution of the nursery grounds of *Trachurus trachurus*. Landings information collected during the end of '90s imply the presence of nursery grounds for *Trachurus trachurus* at the coastal waters of the island of Naxos in the Cyclades (Moutopoulos and Stergiou 2002). In the Adriatic, results from a series of bottom trawl surveys carried out in the early 70's a high number of juveniles have been found in the waters around Palagruza Island (Jukic and Piccinetti, 1981).

The following list presents the available information concerning the nursery grounds of the *Trachurus trachurus* in the Mediterranean (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html):

Eastern Mediterranean

Area	**Species**	**Stage (Spawners or Juveniles)**	**Periods (year, months, season)**	**Format (e.g shapefile)**	**Type of survey (trawls/acoustic/ichthyoplankton survey)**	**Source**
Egypt	*T. trachurus*	juveniles	1998, all	shapefile	Trawl survey	Abdallah 2002
Lebanon	*T. trachurus*	juveniles	2003, May-August	shapefile	Purse seine survey	Bariche *et al.* 2007
Kusadasi (Turkey)	*T. trachurus*	juveniles	2007, October	shapefile	Trawl survey	Aydin and Tosunoglu 2010

Central Mediterranean

Area	**Species**	**Stage**	**Periods**	**Format**	**Type of survey**	**Source**
Strait of Sicily	*T. trachurus*	juveniles	March, April, July 2002	shapefile	visual census	Sinopoli *et al.* 2011
Adriatic Sea	*T. trachurus*	juveniles	November 1972-1973, October 1975	shapefile	Bottom trawl survey	Jukic and Piccinetti 1981

Western Mediterranean

Area	**Species**	**Life stage**	**Periods**	**Format**	**Type of survey**	**Source**
Ebro river	*T. trachurus*	juveniles	2003, June, September	shapefile	Trawl survey	Sardű *et al.* 2006

Data analysis

Surveys and periods used for modeling

Trachurus trachurus spawns during the winter-early spring thus summer period corresponds to high juveniles abundance. Thus MEDITS trawl survey data were used for the identification and the modeling of nursery grounds of *Trachurus trachurus*. A summary Table with the survey data used is summarized below. Details on MEDITS survey characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)**
North Aegean Sea	SARDONE	2009	February	6 Pelagic trawls	Acoustic survey
GSA 20, 22, 23	MEDITS	2000-2008	June-July	780 Demersal trawls	Trawl survey
GSA 20, 22, 23	Greek National Fisheries Data Collection Program	2003-2006, 2008	May, October-November, February-March	821 Commercial Demersal trawls	Trawl survey

Spanish Mediterranean waters

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey**
GSA 1, 6 and 5	MEDITS	2000-2012	June-July		Trawl survey

Adriatic Sea

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey (e.g. trawls/acoustic/ichthyoplankton surveys)**
GSA 17 and 18	MEDITS	2000-2010	June-July	Total numbers of hauls: 2694	Trawl survey

Strait of Sicily

Area	**Name of survey**	**Years**	**Survey period**	**Number of stations**	**Type of survey (e.g. trawls/acoustic/ Ichthyo-plankton surveys)**
GSA 16 + GSA 15	MEDITS	2000-2010	June-July	61	Trawl survey

[1] partial coverage of shelf areas. (2) full coverage of shelf areas in the framework of MedSudMed project.

Gulf of Lions, Corsica Island, Sardinia, Ligurian Sea and Tyrrhenian Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)
GSAs 7, 8	MEDITS	1994-2011	June-July	2756 Demersal trawls	Trawl survey
GSAs 9, 10, 11	MEDITS	1994-2011	June-July	10186 Demersal trawls	Trawl survey

The selection of juveniles for *Trachurus trachurus* was based on the size at first maturity (L_{50}) for females. Published information from the Mediterranean was revised for this purpose and in addition catch data (length frequency distribution combined with maturity information) from all available MEDITS surveys were analyzed within the framework of MEDISEH for this purpose.

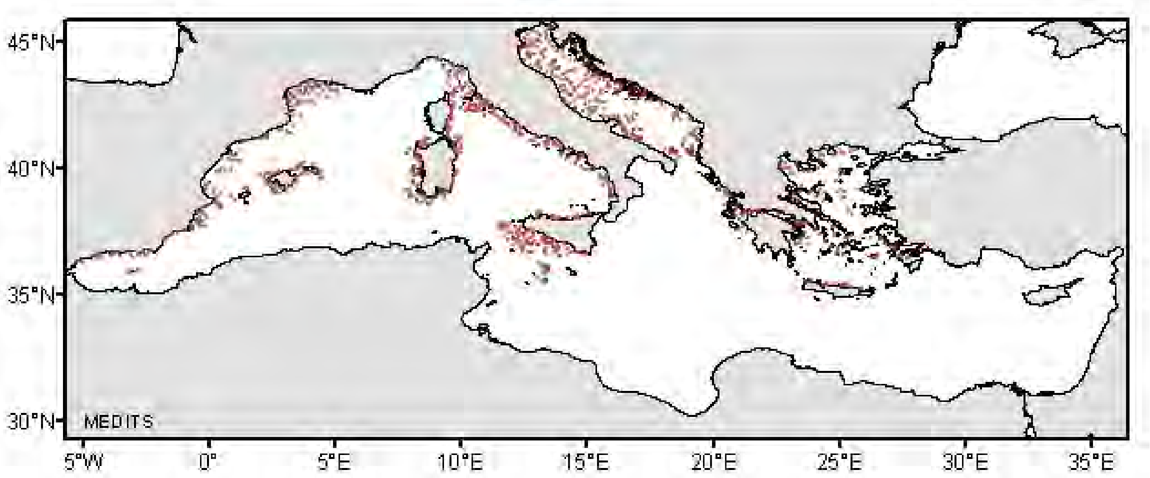

Fig. 2.1.3.1.5.2.1 Positions of MEDITS trawl hauls within the period 2000-2010 that were modeling of the nursery grounds of T. trachurus trachurus. Details can be found in Annex 2.1.2.

In a subsequent step we had to identify *Trachurus trachurus* juveniles and separate them from adults in the surveys mentioned above. This was agreed to be defined based on bibliographic research and survey data. Specifically:

Concerning the size at first maturity for *Trachurus trachurus* published work at Saronikos Gulf during the erly ‘90s studies indicated an approximate size at 21.1 cm for females (Karlou and Economidis 1996; Abaunza *et al.*, 2003). Studies at the eastern part of Aegean Sea, at Kusadasi coast, more recent studies showed that the mean L_{50} values of horse mackerel varied from 14.7, 15.9 and 17.1 cm TL (Aydin and Tosunoglu 2010) depending on the type of the codend used (i.e. diamond, square and hexagonal, respectively). Carbonara *et al*. 2012 report an approximate size of L50 for females at 18.9 cm in GSA 10 and at 20 cm in GSA 18. Concerning the Strait of Sicily no data about *Trachurus trachurus* were available from published paper or grey literature. At Spanish Mediterranean waters, size at first maturity (L_{50}) was estimated at 16 cm in the GSA06 (MEDITS, 2007) which is in accordance to old publications from the Catalan coast that refer L_{50} at 15.5-16 cm (Abaúnza et al 2003 and reference therein). In the GSA01, L_{50} based on landings in 2006 was estimated between 20 and 23 cm (IEO 2009, internal report). At the same time we obtained length data from MEDITS trawl surveys along with maturity information. The length at first maturity (L_{50}) was estimated per GSA using the logistic regression; all individual with gonad stages other than immature were considered as reproductive individuals. This was used as a response variable and the total length as the explanatory variable. The analysis was applied to fish only caught during the spawning season and the scipts RoME and R-RSI that were constructed within the framework of MEDISEH were used for this purpose. Different L_{50} was estimated per GSA but as an average for the whole sampling period. Individuals with length<L_{50} were selected as juveniles.

Length at first maturity results for the period 2000-2010 are shown in the Table below:

Survey	**Area**	***L50 (mm)***
MEDITS + Commercial Data	GSAs 1, 6, 5	168
MEDITS	GSA7	185
MEDITS	GSA8	179
MEDITS + Commercial Data	GSA9	186
MEDITS + Commercial Data	GSA10	185
MEDITS	GSA11	180
MEDITS + Commercial Data	GSA15-16	180
MEDITS	GSA17	150
MEDITS + Commercial Data	GSA18	185
MEDITS + Commercial Data	GSA20	160
MEDITS + Commercial Data	GSA22-23	160

Environmental data

Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

In consistency to the modeling approach followed to all target small pelagic fish we applied habitat suitability modeling techniques and used environmental data in order to obtain an idea of *Trachurus trachurus* potential juvenile grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent juvenile areas based on annual distribution maps.

Specifically, the entire set of 8266 trawls performed over the period 2000–2010 within the MEDITS survey was used to determine *Trachurus trachurus* juvenile presence. Based on the inspection of annual density maps in each GSA we defined a density level where *Trachurus*

trachurus juveniles were considered as present. Thus at each haul location x, an indicator of *Trachurus trachurus* juveniles presence I(x) was defined as I(x) = 1 if the *Trachurus trachurus* juveniles catch was 100 ind/km^2 (in high abundance areas) or 50 ind/km2 (in low abundance areas like GSAs 20,22,23), and I(x) = 0 otherwise. Then, trawls with sufficient *Trachurus trachurus* juveniles measurements were considered as positive. Using this criterion, we retained a total of 3305 positive *Trachurus trachurus* juvenile's hauls from the MEDITS surveys in all GSAs conducted between 2000 and 2010.

In a subsequent step Generalized Additive Models (GAMs, Hastie and Tibshirani, 1990) were applied to define the set of environmental factors that describe *Trachurus trachurus* juveniles' distribution in the study areas. GAMs were applied in a presence absence approach and as “presence” we considered the positive hauls as defined above.

A training dataset for the model was constructed using hauls held within the period 2000-2010 and GSAs 7,8,10,11,15,16,17,18,22,23.

Technical details on the application of GAMs are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Modeling approach.

Model validation. In a subsequent step, the selected model was tested and evaluated for its predictive performance for GSAs and periods not included in model selection i.e. GSAs 1,6,5,9,20. For this purpose, we estimated the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000). They were measured in relation to two threshold criteria: (i) the maximization of the specificity-sensitivity sum (MDT) and (ii)) the prevalence values (Jiménez-Valverde *et al.,* 2008; Lobo *et al.,* 2008).

A specific probability of habitat adequacy for *Trachurus trachurus* juveniles' was estimated for each sampled coordinate. Based on these values all metrics estimation was performed using the “Presence/Absence” library of R statistical language.

Mapping. Annual probability maps were obtained for the whole Mediterranean. Mean probability maps were estimated based on the annual probability maps and up to 400 m depth. Habitat allocation maps (Bellier et al 2007) with persistent (high mean, low std), occasional (high mean, high std) and rare habitat (low mean, low std).

2.1.3.1.6 Trachurus mediterraneus

2.1.3.1.6.1 Spawning areas

Revised information

In the eastern Mediterranean Sea known spawning grounds for *Trachurus mediterraneus* have been identified both in the coastal and offshore waters of North Aegean Sea. Areas within the continental shelf of Samothraki plateau, Thermaikos Gulf (Somarakis *et al.,* 2002), Strymonikos gulf and the gulf of Ierissos (Koutrakis et al. 2004) as well as Pagasitikos Gulf (Caragitsou *et al.*, 2001). Furthermore, the work of Tsikliras *et al.* (2009) that refers to the early 00s and a small area in North Aegean Sea indicated also the Gulf of Kavala as a spawning ground for the species. In the Adriatic Sea Arneri and Tangerini (1983) showed a wide distribution of mature specimens except for the upper part of the Adriatic. The absence of spawners in that part of the Adriatic was also confirmed by Viette *et al.* (1997). In the western Mediterranean *Trachurus mediterraneus* is known to spawn on the continental platform and close to the shelf break of Catalan Sea being more scarce at certain coastal areas, i.e. the south Ebro, the Gulf of Roses and Tarragona port (Sabatés 1990b). Areas with high larvae concentrations were also indicated at the Catalan coast, according to ichthyoplankton surveys in the Spanish waters during the early summer period 1992 (Olivar and Sabates 1997).

Below there is a summary Table for all areas on the revised information for *Trachurus mediterraneus* spawning grounds (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html):

Eastern Mediterranean

Area	**Species**	**Stage (Spawners or Juveniles)**	**Periods (year, months, season)**	**Format (e.g shapefile)**	**Type of survey (trawls/acoustic/ichthyoplankton survey)**	**Source**
C. Aegean Sea and Ionian Sea	*T. mediterraneus*	larvae	1998-1999, June, July	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2011a
Thracian Sea-Strymonikos gulf	*T. mediterraneus*	larvae	1993-1996, June	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2011b
Thracian Sea-Strymonikos gulf and Lemnos	*T. mediterraneus*	larvae	2003-2006, June	shapefile	Ichthyoplankton survey	Isari *et al.* 2008
Thermaikos gulf	*T. mediterraneus*	larvae	1995-1996, June	shapefile	Ichthyoplankton survey	Somarakis *et al.* 2002

Western Mediterranean

Area	**Species**	**Life stage**	**Periods**	**Format**	**Type of survey**	**Source**
Catalan coast	*T.mediterraneus*	eggs	April- October 1983	shapefile	ichthyoplankton	Sabatés 1990b
Catalan coast	*T. mediterraneus*	larvae	1992, May, June	shapefile	Ichthyoplankton survey	Olivar and Sabates 1997

Data analysis

Surveys and periods used for modeling

Trachurus mediterraneus spawns from May till August so summer surveys are appropriate to identify spawning grounds. Two kind of surveys were used in order to identify suitable areas for the spawning grounds of the species a) ichthyoplankton surveys that were held in Aegean Sea in 2006, 2008 and 2010 and b) MEDITS bottom trawl surveys (summer 2000-2011).

Specifically:

Larvae abundance data collected during the ichthyoplankton surveys carried out in the Aegean Sea during June and July of 2004, 2005, 2006, 2008 and 2010 were used (Figure 2.1.3.1.6.1.1). Details on the survey can be found in Annex 2.1.2.

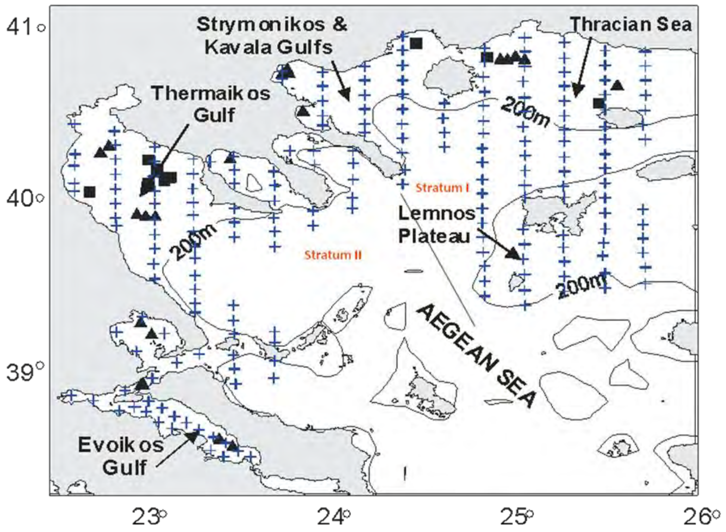

Fig. 2.1.3.1.6.1.1 Map of ichthyoplankton survey held in the North Aegean Sea showing stations position.

MEDITS trawl survey data were used for the identification and the modeling of spawning grounds of *Trachurus mediterraneus*. A summary Table with the survey data used is summarized below. Details on MEDITS survey characteristics and indicative survey design maps are presented in Annex 2.1.2.

Aegean Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)
North Aegean Sea	SARDONE	2009	February	6 Pelagic trawls	Acoustic survey
GSA 20, 22, 23	MEDITS	2000-2008	June-July	780 Demersal trawls	Trawl survey
GSA 20, 22, 23	Greek National Fisheries Data Collection Program	2003-2006, 2008	May, October-November, February-March	821 Commercial Demersal trawls	Trawl survey

Adriatic Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ichthyoplankton surveys)
GSA 17 and 18	MEDITS	2000-2010	June-July	Total numbers of hauls: 2694	Trawl survey

Strait of Sicily

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ Ichthyo-plankton surveys)
GSA 16 + GSA 15	MEDITS	2000-2010	June-July	61	Trawl survey

[1)] partial coverage of shelf areas. (2) full coverage of shelf areas in the framework of MedSudMed project.

Gulf of Lions, Corsica Island, Sardinia, Ligurian Sea and Tyrrhenian Sea

Area	Name of survey	Years	Survey period	Number of stations	Type of survey (e.g. trawls/acoustic/ ichthyoplankton surveys)
GSAs 7, 8	MEDITS	1994-2011	June-July	2756 Demersal trawls	Trawl survey
GSAs 9, 10, 11	MEDITS	1994-2011	June-July	10186 Demersal trawls	Trawl survey

Spanish Mediterranean waters

Area	Name of survey	Years	Survey period	Number of stations	Type of survey
GSA 1, 6 and 5	MEDITS	2000-2012	June-July	1534	Trawl survey

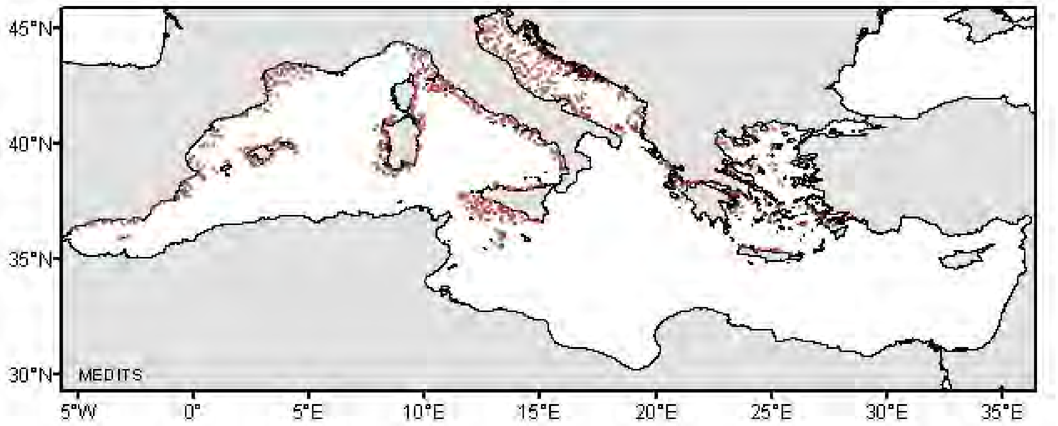

Fig. 2.1.3.1.6.1.2. Positions of MEDITS trawl hauls within the period 2000-2010 that were modeling of the nursery grounds of T. trachurus trachurus. Details can be found in Annex 2.1.2.

In a subsequent step we had to identify *Trachurus mediterraneus* spawners. This was agreed to be defined based on bibliographic research and survey data analysis. Specifically:

Published work on the size at first maturity for *Trachurus mediterraneus* was extremely limited in the Mediterranean Sea. Viette *et al.* (1997) reported that in the Gulf of Trieste (Italy) the smallest mature male was 15.6 cm long (TL) and the smallest mature female was 16 cm. At Spanish Mediterranean waters the size at first maturity (L50) was estimated to be 16 cm in the GSA06 (MEDITS, 2007). In the GSA01, the L50 based on landings in 2006 was estimated to be 16 cm (IEO 2009, internal report). Moreover, an old study based on commercial hauls data refers the the smallest fish with undetermined sex was 14 cm and the biggest was 16.5 cm (Carrillo 1978).

Thus it was considered appropriate the selection of spawners for *Trachurus mediterraneus* to be based on the size at first maturity (L_{50}) for females (L_{50} or length at which 50% of the individuals are mature). Catch data (length frequency distribution combined with maturity information) from all available MEDITS surveys were analyzed within the framework of MEDISEH for this purpose. Specifically:

The logistic curve (Tokai, 1997): PL= exp(a+b*L)/(1+exp(a+b*L)) was applied for this purpose. Where PL is the proportion of mature individuals for a given size class L. Logistic curves were fitted by maximizing the log-likelihood function, using RSI script (Facchini *et al.*, 2012). Concerning GSAs 01, 05 and 06 (Spanish waters) monthly biological samplings from commercial catches collected within the Data Collection Framework during all the year were used.

Lengths at first maturity results for the period 2000-2010 are shown in the Table below:

Survey	**Area**	***L50 (mm)***
MEDITS + Commercial Data	GSAs 1, 6, 5	150
MEDITS	GSA7	165
MEDITS	GSA8	155
MEDITS	GSA9	160
MEDITS	GSA10	160
MEDITS	GSA11	155
MEDITS	GSA15-16	145
MEDITS	GSA17	150
MEDITS	GSA18	155
MEDITS	GSA20	140
MEDITS	GSA22-23	160

Environmental data

Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

Due to the different amount of data available in each case two different modeling approaches were followed.

Ichthyoplankton data

In the case of the ichthyoplankton surveys and larvae abundance data the Maximum Entropy Model (Philips *et al.,* 2006) was applied due to the very small number of available presence data that made other statistical approaches not suitable to apply. Maxent was chosen primarily because it allows a more generative approach and it shows a relative insensitivity to noisy data and the small sample size available (Philips *et al.,* 2006). This approach is widely used to model species geographic distributions (i.e. occurrence) in the terrestrial and aquatic environments. The dedicated software Maxent (Phillips *et al.,* 2006) was used to investigate the environmental factors limiting species' distributions. The algorithm used in Maxent aims to find the largest spread (or maximum entropy) in a geographic dataset (i.e. the species or habitat locations), in relation to a set of "background" environmental variables (i.e. the model predictors). Maxent starts with a uniform distribution of probability values over the entire "background grid", and conducts an optimization routine that iteratively improves model fit, measured as the gain. The gain is the likelihood (deviance) statistic that maximizes the probability of presence in relation to the background data, corrected for the case where the probabilities of all pixels are equal (uniform distribution). For the specific dataset and in the framework of MEDISEH, MAXENT was applied using the absence data available (i.e. stations with zero abundance) as background points along with the respective satellite environmental and bathymetry variables at each sampling point.

Bottom trawl data

In consistency to the modeling approach followed to all target small pelagic fish we applied habitat suitability modeling techniques and used environmental data in order to obtain an idea of *Trachurus mediterraneus* potential spawning grounds throughout the Mediterranean Sea and in a subsequent step analyze persistent spawning areas based on annual distribution maps.

In the case of the MEDITS trawl surveys and *Trachurus mediterraneus* spawners the approach was similar to the one applied for *Trachurus trachurus* juveniles.

Specifically, the entire set of 11304 trawls performed over the period 2000–2010 within the MEDITS survey was used to determine *Trachurus mediterraneus* spawners' presence. Based on the inspection of annual density maps in each GSA we defined a density level where *Trachurus mediterraneus* spawners were considered as present. Thus at each haul location x, an indicator of *Trachurus mediterraneus* spawners presence I(x) was defined as I(x) = 1 if the *Trachurus mediterraneus* spawners catch was 50 ind/km^2 (in high abundance areas and I(x) = 0 otherwise. Then, trawls with sufficient *Trachurus mediterraneus* spawners measurements were considered as positive. Using this criterion, we retained a total of 1590 positive *Trachurus mediterraneus* spawners' hauls from the MEDITS surveys in all GSAs conducted between 2000 and 2010.

In a subsequent step Generalized Additive Models (GAMs, Hastie and Tibshirani, 1990) were applied to define the set of environmental factors that describe *Trachurus mediterraneus* spawners' distribution in the study areas. GAMs were applied in a presence absence approach and as "presence" we considered the positive hauls as defined above.

A training dataset for the model was constructed using hauls held within the period 2000-2010 and GSAs 7,8,9,10,11,18,20,22,23 and a test dataset for model evaluation using hauls held within the same period in GSAs 17, 1, 5 and 6. Technical details on the application of GAMs are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Modeling approach.

Model validation. In the case of ichthyoplankton surveys and larvae abundance data the evaluation of the Maximum Entropy Model was based on the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000) as estimated from randomly selected dataset which used 25% of the observations.

In the case of bottom trawl data *Trachurus mediterraneus* spawners the selected model was tested and evaluated for its predictive performance for GSAs and periods not included in model selection i.e. GSAs 1,6,5,17. For this purpose, we estimated the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000). They were measured in relation to two threshold criteria: (i) the maximization of the specificity-sensitivity sum (MDT) and (ii)) the prevalence values (Jiménez-Valverde *et al.,* 2008; Lobo *et al.,* 2008).

Finally in both cases, a specific probability of habitat adequacy for *Trachurus mediterraneus* spawning grounds was estimated for each sampled coordinate. Based on these values all metrics estimation was performed using the "Presence/Absence" library of R statistical language.

Mapping. For both cases annual probability maps were obtained for the whole Mediterranean. Mean probability maps for the whole Mediterranean and up to 400 m depth were estimated based on the annual probability maps. Habitat allocation maps (Bellier *et al.,* 2007) with persistent (high mean, low std), occasional (high mean, high std) and rare habitat (low mean, low std).

2.1.3.1.6.2 Nursery areas

Revised information

Limited information is available concerning the Eastern part of the Mediterranean and the spatial distribution of the nursery grounds of *Trachurus mediterraneus*. The study of Stergiou *et al.* (2004) that it is based on landings information from different gears indicate a nursery area for *Trachurus mediterraneus* in Cyclades islands between the islands of Naxos and Paros. Moreover, studies at the estuaries of the North Aegean Sea (i.e. Strymon river, Porto Lagos lagoon and Rihios river) have been indicated the occurrence of local nurseries for *Trachurus mediterraneus* at the late '90s (Koutrakis and Tsikliras, 2003). No data were available from the Central and the Western part of the basin concerning the species nurseries.

Data analysis

Surveys and periods used for modeling

Acoustic surveys oriented to estimate the stock of small pelagic fish were annually performed in the Spanish Mediterranean continental shelf during late autumn (i.e. from mid November to mid December) (Figure 2.1.3.1.6.2.1). Data from 2003 to 2009 were used to model the potential habitat of juvenile Mediterranean horse mackerel.

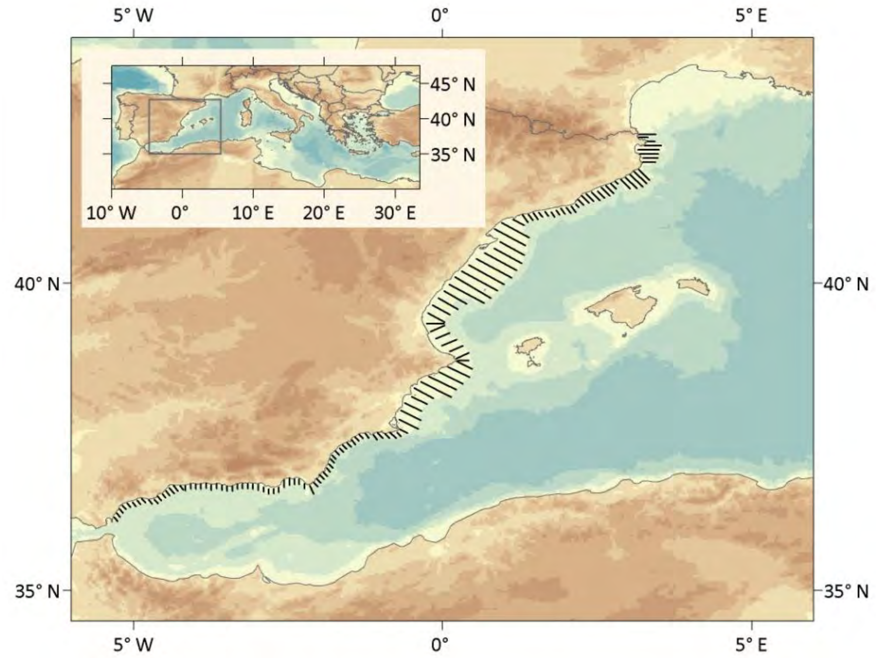

Fig. 2.1.3.1.6.2.1. Sampling design of Spanish Mediterranean acoustic data surveys.

The spawning season of Mediterranean horse mackerel is known to take place during summer. This was also confirmed using monthly biological samplings from commercial catches collected during all year in the Alboran Sea (GSA01) and obtained within the Data Collection Framework that were analyzed in order to determine the seasonal changes in gonadal development and the percentage of maturing or mature individuals as well as the length at first maturity or length at which 50% of the females are mature (L_{50}). The mean gonadosomatic index (GSI) for female Mediterranean horse mackerel was calculated on a monthly basis, using the formula: GSI = 100(ovary weight)/(body weight-ovary weight). Only the data compiled during these spawning periods was used to calculated L_{50} for females, from the logistic curve PL= exp(a+b*L)/(1+exp(a+b*L)), where PL is the proportion of mature individuals for a given size class L. Logistic curves were fitted by maximising the log-likelihood function using Solver in EXCEL (Tokai 1997). Results confirmed that Mediterranean horse mackerel showed in the Western Mediterranean a clear spawning period in summer, between June and August. The estimated L_{50} was at 15.0 cm TL (2.5 cm MR). This value is very similar to 15.1 cm estimated in the Balearic Islands (GSA05) combining commercial catches (2005-2006) and MEDITS data (2007-2008, 2010-2011) (IEO unpublished data). Other published L_{50} estimates in the Mediterranean Sea show values between 17.1 and 22.4 cm and 20.5 cm for the Spanish Mediterranean area (Ragonese *et al.*, 2004). However, these higher values are estimates from MEDITS survey which refers to one month period during the summer, not covering the whole spawning period of this species. Thus, we consider more accurate the estimates from DCF data estimated during the present project.

Subsequently, the ECOMED acoustic surveys were considered appropriate to detect the recruitment (juvenile) fraction of the *Trachurus mediterraneus* population. This is also confirmed in the length frequency distribution of the pelagic trawl catch in the respective surveys (Fig. 2.1.3.1.6.2.2).

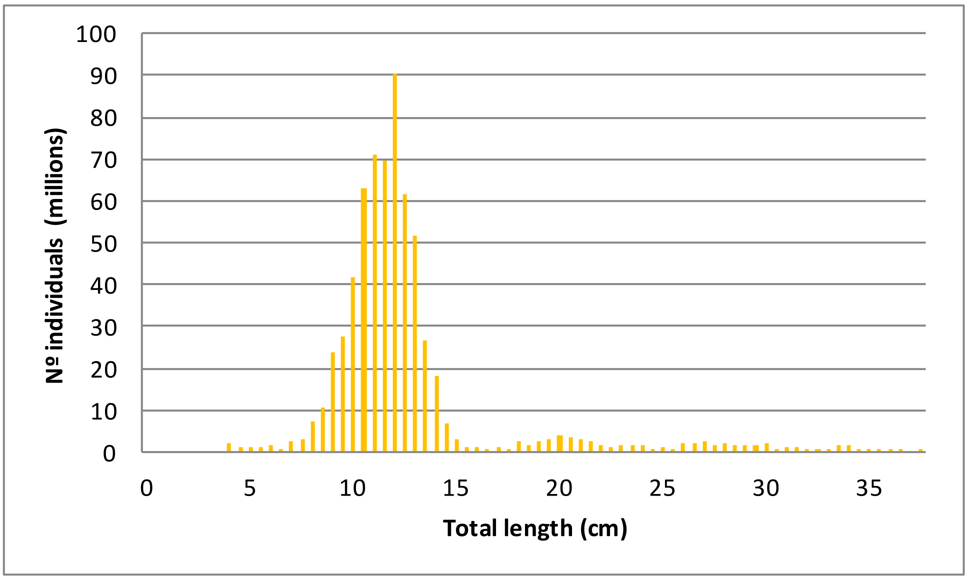

Fig. 2.1.3.1.6.2.2. Size distribution of Mediterranean horse mackerel caught during the ECOMED acoustic surveys. x axis: Total length (TL) in cm; y axis: Number of individuals in millions.

Acoustic density is continuously recorded along parallel equidistant transects with a split beam echosounder at 38 kHz and integrated every one nautical mile (EDSU) (Details on the survey are cited in Annex 2.1.2). These acoustic data were split into species using the catch composition from pelagic trawls. The L_{50} as estimated from monthly biological samples from commercial catches collected throughout the year within the Data Collection Framework, was used to identify the presence of juvenile Mediterranean horse mackerel (individuals < 15 cm TL) and assign the echo per Elementary Sampling Unit (ESDU).

Environmental data

Monthly averages of environmental data were used to model Mediterranean horse mackerel nurseries. Variables considered for modeling were sea surface temperature, sea level anomaly, chlorophyll-a concentration, photosynthetic active radiation, sea surface salinity. Bathymetric data were also considered. Environmental variables used are described in detail in Section: 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Environmental variables.

Modeling approach

Trachurus mediterraneus nurseries were modeled applying a presence-absence Generalized Additive model (GAM) similar to the approach followed for the other small pelagic target species. A double penalty was applied to the penalized regression and the degree of smoothing was chosen based on the observed data and the restricted maximum likelihood (REML). A final model was built by testing all variables that were considered biologically meaningful, starting from a simple initial model with one explanatory variable. The best model was selected based on the minimization of the restricted maximum likelihood (REML) and the maximization of the level of deviance explained (0–100%; the higher the percentage, the more deviance explained) (Marra and Wood, 2011). The dataset contained about a 50% of presence of juvenile Mediterranean horse mackerel which is considered within the limits for the output model being considered reliable. Technical details on the application of GAMs are described in the respective section 2.1.3.1.1.1 Anchovy, Spawning grounds, Data Analysis Modeling approach.

At the same time for comparison purposes the MAXENT approach was also applied using decadal environmental data and projected to every year (2003-2009). However, comparison of results by means of a Taylor diagram showed than Maxent results were less accurate compared to GAMs. Thus, only the GAMs results are presented in the respective Results section and shown in the GIS viewer (http://mareaproject.net/mediseh/viewer/med.html) and the MAREA ftp server (http://www.mareaproject.net/).

Model validation: The predictive performance of the final model was tested by means of the area under the curve (AUC) of the receiver operating characteristic curve (ROC) (Guisan and Zimmermann, 2000). In a subsequent step, the selected model was tested and evaluated for its predictive performance for periods not included in model selection. Specifically, acoustic data from 2004 to 2008 was used to construct the model and 2003 and 2009 data were used only for validation purposes. For this purpose, we estimated the Receiver Operating Characteristic curve (ROC) and the AUC metric, the area under the ROC (Guisan and Zimmerman, 2000). They were measured in relation to two threshold criteria: (i) the maximization of the specificity-sensitivity sum (MDT) and (ii)) the prevalence values (Jiménez-Valverde *et al.,* 2008; Lobo *et al.,* 2008). A specific probability of habitat adequacy for *Trachurus mediterraneus* juveniles' was estimated for each sampled coordinate. Based on these values all metrics estimation was performed using the "Presence/Absence" library of R statistical language.

Mapping. Annual probability maps were obtained for the whole Mediterranean. Mean probability maps for the whole Mediterranean and up to 400 m depth were estimated based on the annual probability maps. Habitat allocation maps (Bellier *et al.,* 2007) with persistent (high mean, low std), occasional (high mean, high std) and rare habitat (low mean, low std).

2.1.3.2 Results

2.1.3.2.1 Engraulis encrasicolus

2.1.3.2.1.1 Spawning grounds

Modeling Results (D 2.1.1, D 2.1.2)

The selected model is described in the Table 2.1.3.2.1.1.1 and in Fig. 2.1.3.2.1.1.1.A. The selected GAM for anchovy eggs in June included as main effects: SST and the interactive effect of Depth (cube root transformed) with CHLA (log transformed). Depth was the variable that initially entered the model explaining most of the total variation. Model results indicated a higher probability of finding eggs with increasing SST. The interaction plot of Depth and CHLA indicated increasing probability of spawning with increasing values of CHLA in the 40-160m bathymetric range. Besides the areas that were included in model estimation, the model was validated here with presence/absence data derived from the Aegean DEPM survey in June 2008. Validation results indicated good model performance (Table 2.1.3.2.1.1.2).

The selected GAM for anchovy eggs in July included as main effects Depth (cube root transformed), CHLA (log transformed) and SST. Depth was the variable that initially entered the model explaining most of the total variation (Table 2.1.3.2.1.1.1). Model results indicated higher probability of anchovy spawning with increasing values of CHLA, at waters of 40 to 160 m depth but at lower values of SST (Fig. 2.1.3.2.1.1.1.B). Additionally to surveys used for modeling, the model was also validated with presence/absence data derived from an ichthyoplankton survey held in the Strait of Sicily in July 2006 and Montenegro in July 2008 and 2010 (Leonori *et al.,* 2011b; 2012). Validation results indicated good model performance (Table 2.1.3.2.1.1.2).

Table 2.1.3.2.1.1.1. GAM model selection for anchovy eggs: analysis of deviance for GAM covariates and their interactions of the final models fitted.

Period	Model	Res. Df	Res. Deviance	Deviance explained %	AIC	P-value
June	N. Aegean Sea model					
	s(Depth, CHLA)+s(SST)	510.1	420.3	41.9	444.3	<<0.000
July	Strait of Sicily					
	s(Depth, SST)+s(CHLA)	632.8	611.8	24.8	642.2	<<0.000

Table 2.1.3.2.1.1.2. Mean values of sensitivity and specificity accuracy measures ± standard error (sterr) for two threshold criteria: MDT (maximize the specificity-sensitivity sum) and prevalence values. The estimated area under the ROC curve (AUC) for each model is also indicated. In the case of eggs models only one area and one year not included in model selection was used for validation.

Model	AUC	MDT Sensitivity	MDT Specificity	Prevalence Sensitivity	Prevalence Specificity
June	0.89	0.51	0.92	0.77	0.64
July (Strait of Sicily)	0.80	0.82	0.70	0.73	0.73
July (Montenegro)	0.62	0.67	0.55	0.54	0.63

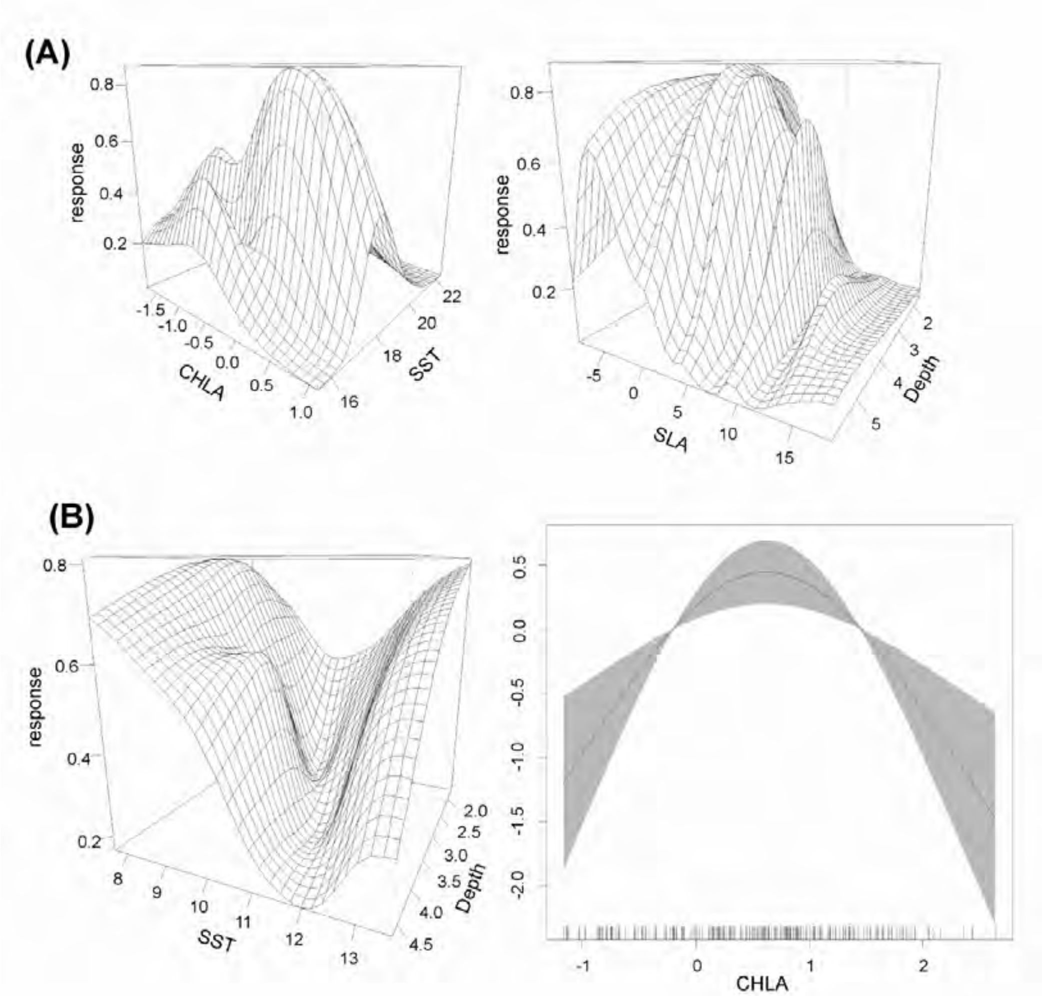

Fig. 2.1.3.2.1.1.1. Coefficients of the Generalized Additive Models (GAMs) for anchovy eggs in (A) June and (B) July. CHLA: log transformed Surface chlorophyll concentration (in mg m^{-3}) SST: Sea Surface Temperature (°C), SLA: Sea Level Anomaly (in cm), Depth: Cube root transformed Bottom Depth (in m), PAR: Photosynthetically Active Radiation (in Einstein m^{-2} day^{-1}). The interaction plots are also shown. Black thick lines indicate the value of GAMs coefficient. Shadowed areas represent the confidence intervals at p = 0.01. The rug under the single variable effects plots indicates the density of points for different variable values.

In a subsequent step, annual probability maps were obtained (see Annex 2.1.3) and the mean probability maps for June and July were estimated (Fig. 2.1.3.2.1.1.2.). Habitat suitability maps (hereafter called persistence maps) of anchovy spawning are presented in Figures 2.1.3.2.1.1.3. In each map three levels are indicated: preferential, occational and rare habitat areas. Maps indicate similar favourable (preferential and occational) areas in both June and July. Details of the maps can easily be seen in the following link in the web based toolbox (GIS viewer) at http://mareaproject.net/mediseh/viewer/med.html.

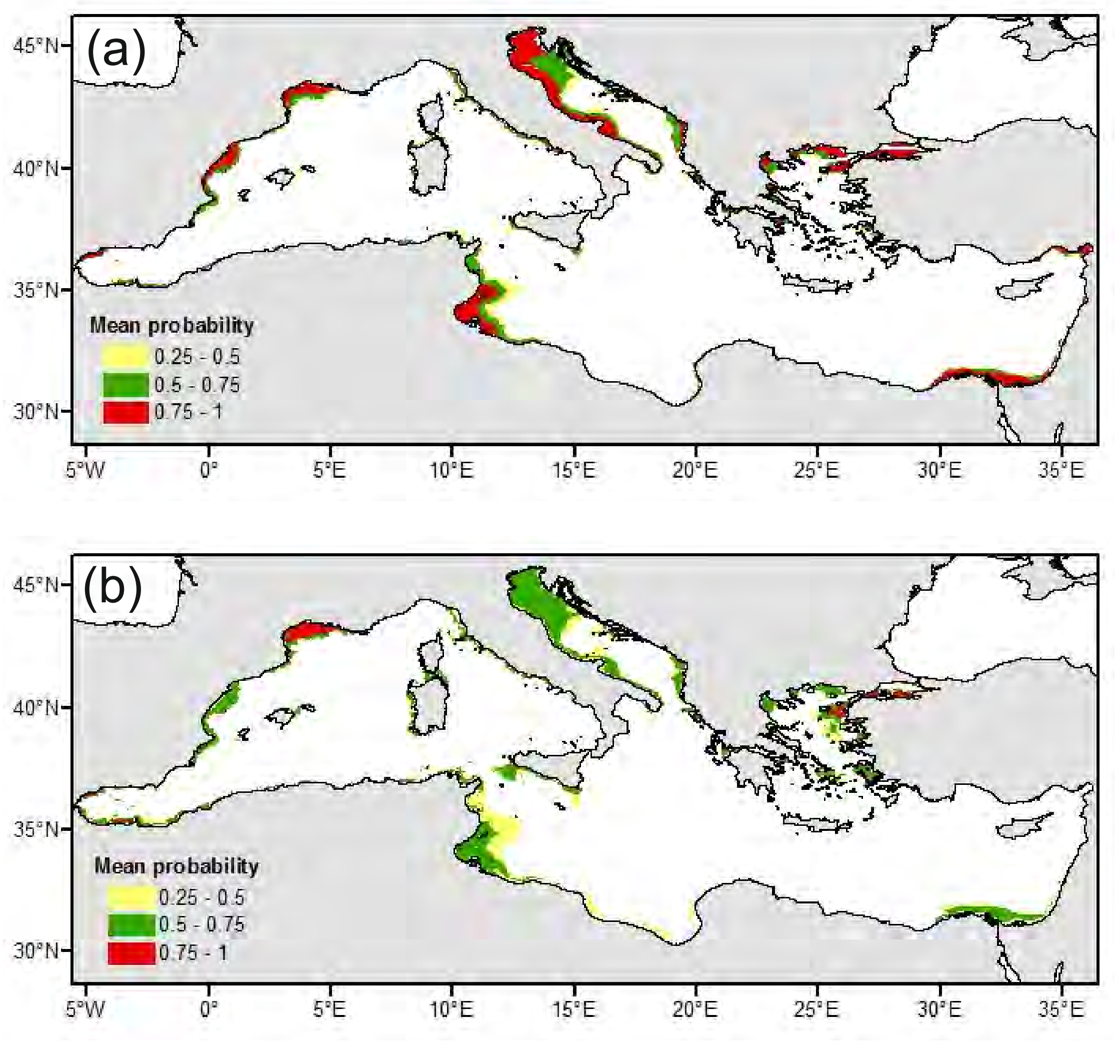

Fig. 2.1.3.2.1.1.2. Mean probability maps of anchovy spawning (egg) habitat in the Mediterranean Sea for the period 2003-2008. (A). June (B) July (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

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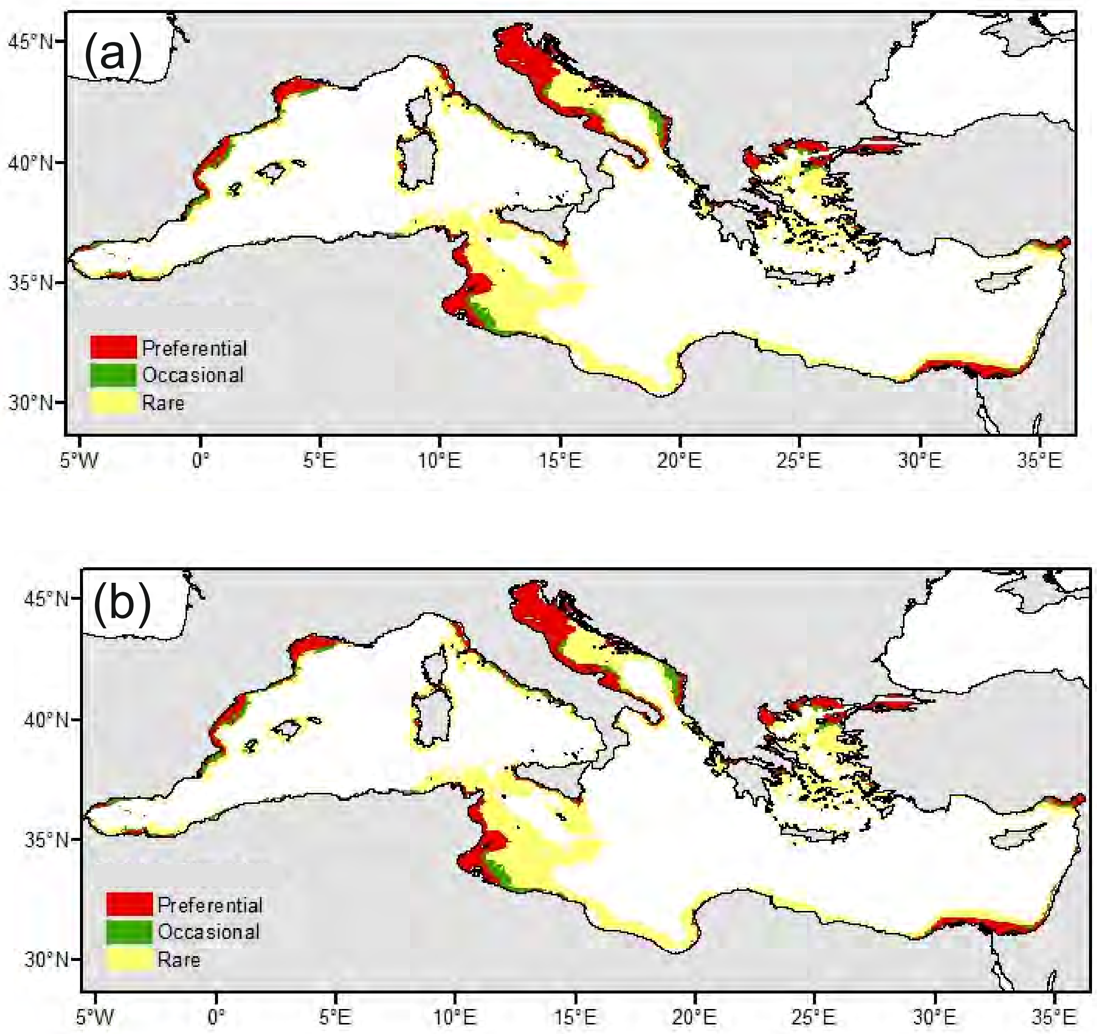

Fig. 2.1.3.2.1.1.3. Persistent habitat maps of anchovy spawning (egg) habitat in the Mediterranean Sea for the period 2003-2008. (A). June (B) July (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

In the Aegean Sea besides the northern part and the coastal areas within gulfs that are known spawning grounds for anchovy (Somarakis *et al.,* 2006a, spots with high probability of anchovy eggs were also identified in the coastal areas of Asia Minor, along the Turkish coasts (e.g., Izmir Bay) where information is largely missing. In the Adriatic Sea areas with higher probability of anchovy spawning were consistently indicated in the northern and the western part of the basin as well as around the coastal waters of the mid-Dalmatian islands in the eastern part. In the Strait of Sicily potential spawning grounds were consistently indicated along the coastal waters of Sicily, being more extended in the west and east part also verifying the results of past work in the area (Cuttitta *et al.,* 2003; Basilone *et al.,* 2006; Grammauta *et al.,* 2008). In the western Mediterranean, suitable spawning areas were located in the Gulf of Lions and off the Catalan coast, the Alboran Sea and to a lesser extent the Italian coasts of the Ligurian and Tyrrhenian Seas. Past information from this part of the basin also supports the indicated preferable spawning sites (García and Palomera, 1996; Olivar *et al.,* 2001; Palomera *et al.,* 2007).

Ecological Characterization (D2.1.3)

Depth, SST and CHLA were the variables being important in both cases. A consistent preference for 40 - 160 m bathymetric range and more productive waters was indicated. SST preference is most likely related to the available range of values in each area that is associated with more productive waters. Habitat adequacy maps produced from each model presented a high degree of overlapping, generally indicating the same areas, which depict reasonably well the species' spawning grounds as known from past studies and publications (Schismenou *et al.,* 2008).

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between anchovy spawning grounds and fishing restricted areas (FRAs), where purse seine fishing and pelagic trawl (main gears targeting anchovy) are prohibited, was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 up to 12 months in an annual basis. Purse seines restrictions showed 8.54 % overlapping with persistent spawning areas in June, percentage that can increase up to 16.26 % when occasional areas are included. For July, the percentage of overlapping with persistent areas is smaller (6.75%) and up to 11.28% when occasional areas are included). These areas are shown in Figures 2.1.3.2.1.1.4 - 2.1.3.2.1.1.5 and can be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html. Pelagic trawl restrictions showed 20.79 % overlapping with persistent spawning areas in June, percentage that can increase up to 47.99 % when occasional areas are included. For July, the percentage of overlapping with persistent areas is higher (22.84%) and up to (62.72%) when occasional areas are included. The higher overlap with pelagic trawl prohibition is explainable since the use of the specific gear is prohibited in Greece, Spain and Turkey. These areas can be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html.

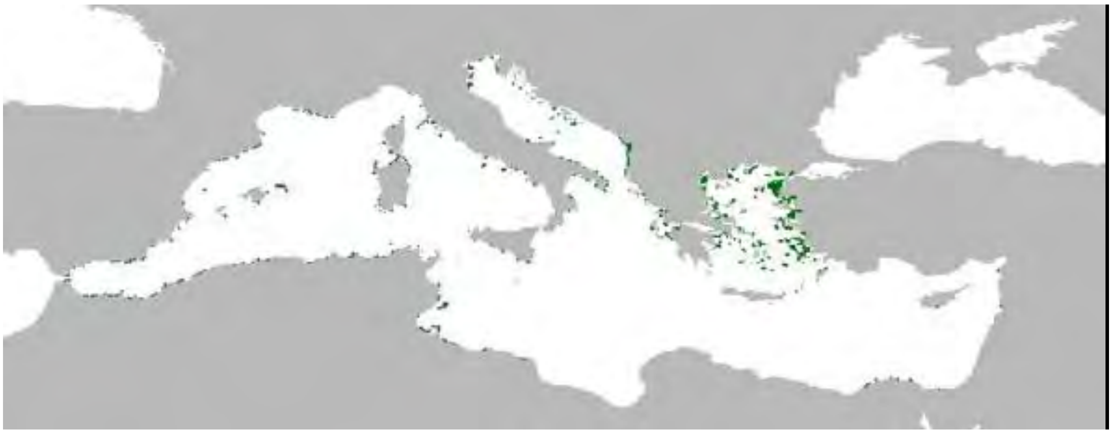

Fig. 2.1.3.2.1.1.4. Overlapping between anchovy spawning areas during July and Fishing Restricted Areas and Marine Protected Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

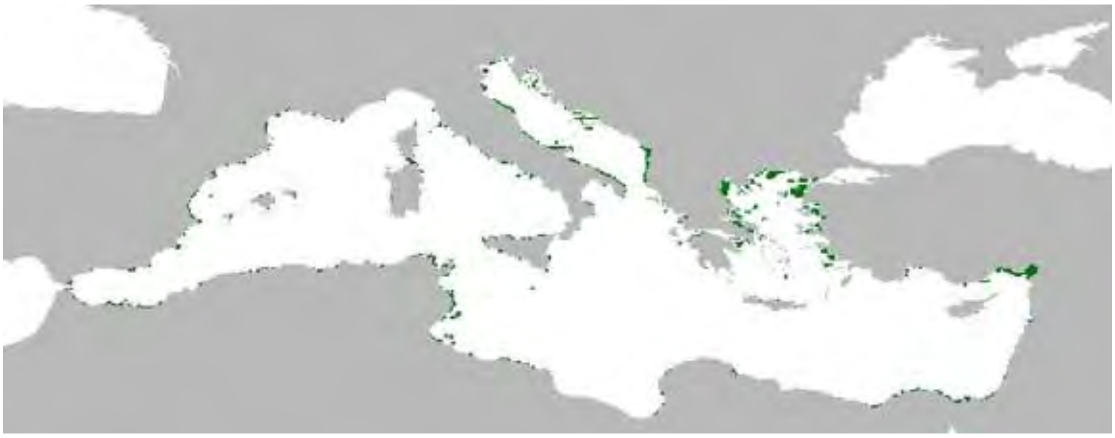

Fig. 2.1.3.2.1.1.5. Overlapping between anchovy spawning areas during June and Fishing Restricted Areas and Marine Protected Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

2.1.3.2.1.2 Nurseries grounds (2000-2010)

Modeling Results (D 2.1.1, D 2.1.2)

The selected GAM for anchovy nurseries in late autumn Depth (cube root transformed) and the interactive effect of SLA with CHLA (log transformed). Depth was the variable that initially entered the model explaining most of the total variation (Table 2.1.3.2.1.2.1). Model results indicated higher probability of finding anchovy juveniles present in waters < 150 m combined with SLA values of -5 to 5 cm and at SST values of 17 to 19 ^{o}C when co-exist with CHLA values of 0.36 to 2 mg m^{-3} (Fig. 2.1.3.2.1.2.1.A). Besides data from Spanish Mediterranean waters that were included in the model estimation, the model was also validated with presence/absence data from suitable surveys in the North Aegean Sea, the Adriatic Sea and the Gulf of Lions held in the mid November to mid December 2007. Results indicated good to high model performance (Table 2.1.3.2.1.2.2).

Table 2.1.3.2.1.2.1. GAM model selection for anchovy nurseries: analysis of deviance for GAM covariates and their interactions of the final models fitted.

Period	Model	Res. Df	Res. Deviance	Deviance explained %	AIC
mid Nov-mid Dec	Spanish Mediterranean waters				
	s(Depth, SLA)+s(CHLA,SST)	4761.7	4708.4	28.1	4818.9

Table 2.1.3.2.1.2.2. Mean values of sensitivity and specificity accuracy measures ± standard error (sterr) for two threshold criteria: MDT (maximize the specificity-sensitivity sum) and prevalence values. The estimated area under the ROC curve (AUC) for each model is also indicated.

Model	AUC	MDT Sensitivity	MDT Specificity	Prevalence Sensitivity	Prevalence Specificity
Late autumn	0.86±0.12	0.82±0.09	0.82±0.14	0.80±0.13	0.80±0.12

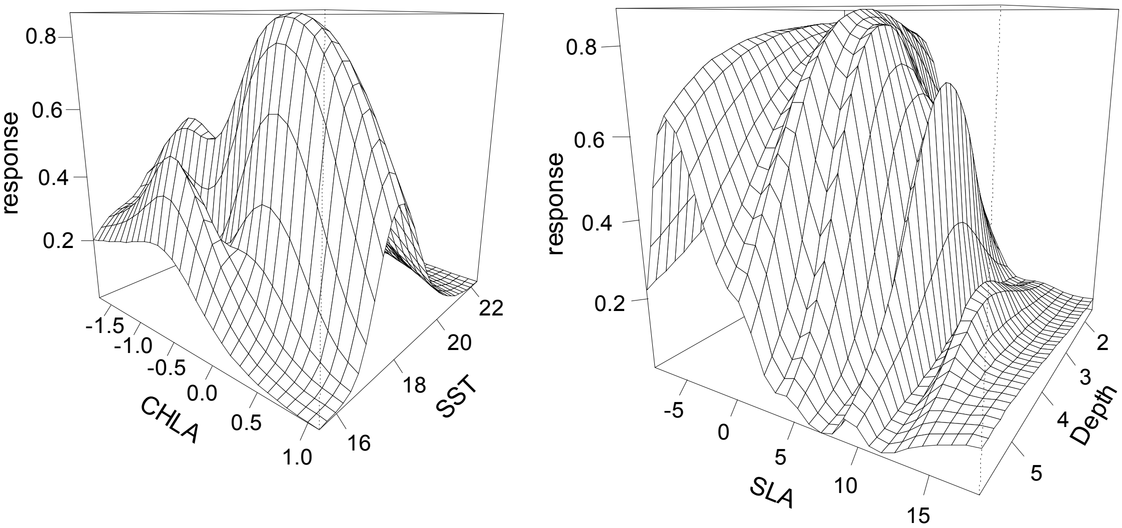

Fig. 2.1.3.2.1.2.1. Coefficients of the Generalized Additive Models (GAMs) for anchovy nurseries in Late autumn (mid November – mid December) CHLA: log transformed Surface chlorophyll concentration (in mg m^{-3}) SST: Sea Surface Temperature (^{o}C), SLA: Sea Level Anomaly (in cm), Depth: Cube root transformed Bottom Depth (in m). The interaction plots are also shown.

In a subsequent step annual probability maps were obtained (see Annex 2.1.3). Baesd on these maps the mean probability maps for late autumn were estimated (Fig. 2.1.3.2.1.2.2.) as well as habitat suitability maps (hereafter called persistence maps) of anchovy nurseries (Fig. 2.1.3.2.1.2.3). In the map three levels are indicated: preferential, occational and rare habitat areas.

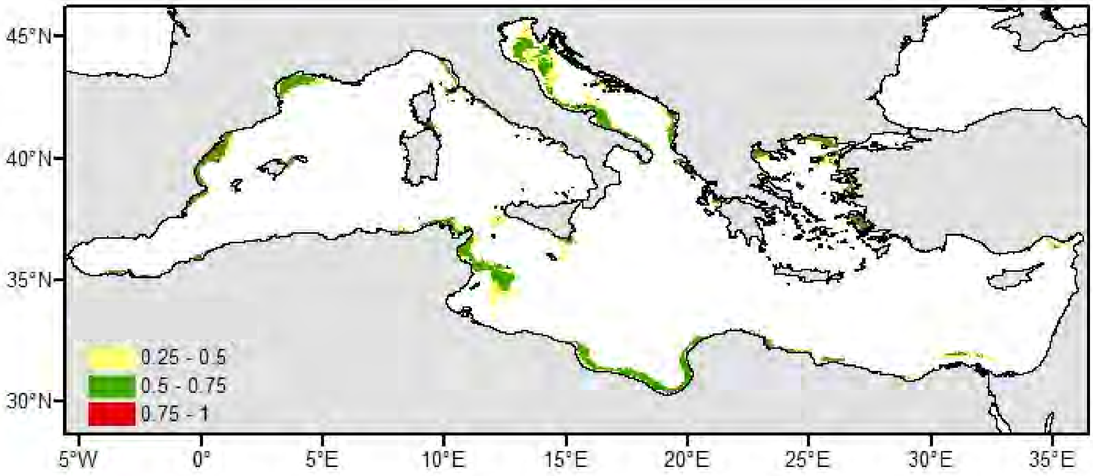

Fig. 2.1.3.2.1.2.2. Mean probability maps of anchovy nurseries habitat in the Mediterranean Sea for the period 2003-2008 during late autumn (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

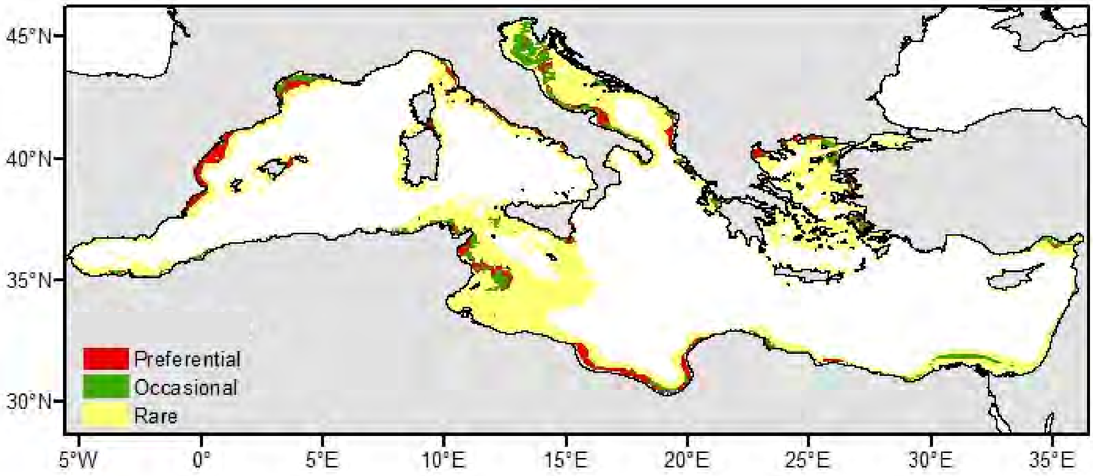

Fig. 2.1.3.2.1.2.3. Persistent habitat maps of anchovy nurseries in the Mediterranean Sea for the period 2003-2008 during late autumn (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

In the Western Mediterranean suitable nursery areas were identified in association with the outflow of the Rhone river in the Gulf of Lions and the Ebro river southwards in the Spanish waters, being in agreement with the results of past habitat modeling work in the area (Bellido *et al.,* 2008). In the Adriatic Sea, suitable nurseries were located in the inner part of the continental shelf in the coastal part of the basin. They were closely associated with the Po river outflow area, also extending southwards along the coasts of the western and the eastern part of the Adriatic Sea and in agreement with known nursery grounds in the area (Morello and Arneri, 2009 and references therein). Suitable areas in the Strait of Sicily were also located in coastal waters being wider in the north and south part where the continental shelf is wider.

Details of the maps can easily be seen in the following link in the web based toolbox (GIS viewer) at http://mareaproject.net/mediseh/viewer/med.html.

Ecological Characterization (D2.1.3)

In the Mediterranean Sea anchovy spawns from spring to autumn with a peak in June/ July (Palomera *et al.,* 2007; Somarakis *et al.,* 2004). Therefore, late autumn and winter are periods that juveniles are found in the populations in high percentages. Although the winter model was built on one year of data, both models results and habitat suitability maps indicated that anchovy nurseries were located in high productivity waters within the continental shelf. These habitats were more extended in late autumn (i.e., up to 160 m depth) compared to later in season (15-90 m depth). Bathymetry and SST along with productivity were the variables that largely determined anchovy nurseries. Potential nurseries presented high interannual variability implying the vulnerability of these areas to changing environmental conditions.

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between anchovy nursery grounds and fishing restricted areas (FRAs) where pusre seines and pelagic trawls are prohibited was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 up to 12 months in an annual basis. Purse seines restrictions showed 7.24 % overlapping with persistent nurseries and up to 17.68% when occasional nurseries are included. These areas are shown in Fig 2.1.3.2.1.2.4. Pelagic trawls restrictions showed 23.91% overlapping with persistent nurseries and up to 45.06% when occasional nurseries are included. These areas can also be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html.

Fig. 2.1.3.2.1.2.4. Overlapping between anchovy nurseries areas and Fishing Restricted Areas and Marine Protected Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html**).**

2.1.3.2.1.3 Nurseries grounds (1998-2000)

Modeling Results (D 2.1.1, D 2.1.2)

The final selected GAM model included as main effects: Depth (Cubic root transformed), SLA, SST and PAR. Depth was the variable that initially entered the model explaining most of the total variation (Table 2.1.3.2.1.3.1). The output plots of the model (Fig. 2.1.3.2.1.3.1) indicate a high probability of finding anchovy juveniles present in shallow water (<65 m), PAR values above Ein m^{-2} day^{-1}, SLA below 7 cm and SST values below 17.3 °C. Additionally to surveys used for modeling, the model was validated with presence/absence data derived from acoustic survey carried out in the Northern Aegean Sea and in the Northern Adriatic Sea in 2001. The validation results show moderate model performance (Table 2.1.3.2.1.3.2). The moderate predictive ability of the model can be justified by the low spatial resolution of some covariates in certain areas used in the model.

Table 2.1.3.2.1.3.1. GAM model selection for anchovy juveniles (1998 – 2000): analysis of deviance for GAM covariates

Period	Model	Res. Df	Res. Deviance	Deviance explained %	AIC
Late autumn	North Aegean and Adriatic Sea s(Depth)+s(SLA)+s(PAR)+s(SST)	1242.7	1275.36	24.7	1297.93

Table 2.1.3.2.1.3.2. Mean values of sensitivity and specificity accuracy measures ± standard error for two threshold criteria: MDT (maximize the specificity-sensitivity sum) and prevalence values. The estimated area under the ROC curve (AUC) for each model is also indicated.

Model	AUC	MDT Sensitivity	MDT Specificity	Prevalence Sensitivity	Prevalence Specificity
Late autumn	0.66±0.02	0.88±0.02	0.38±0.01	0.97±0.01	0.13±0.01

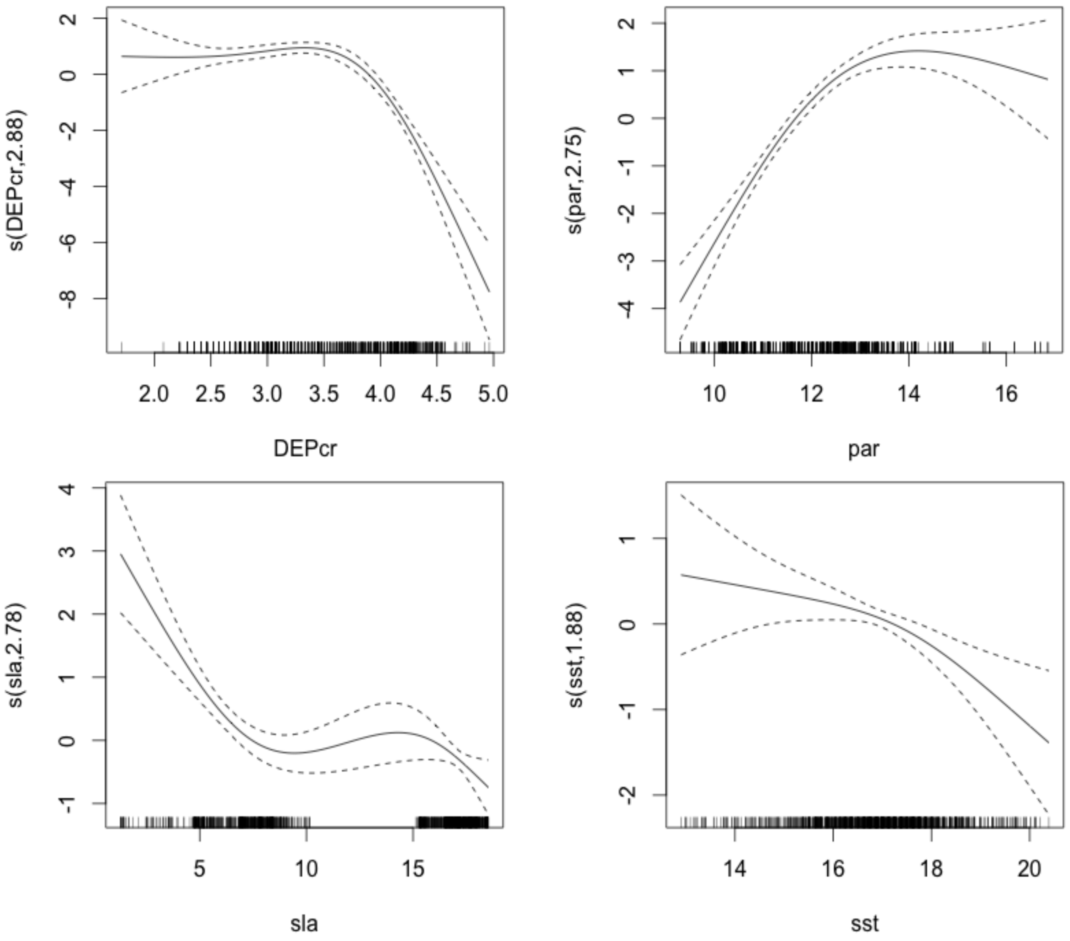

Fig. 2.1.3.2.1.3.1. Coefficients of the Generalized Additive Models (GAMs) for anchovy nurseries in Late autumn (mid November – mid December 1998 - 2000). DEPcr: Cube root transformed Bottom Depth (in m), par: Photosintetically active radiation (in Ein m^{-2} day^{-1}) sla: Sea Level Anomaly (in cm), sst Sea Surface Temperature (in °C). Black thick lines indicate the value of GAMs coefficient. Dotted lines represent the confidence intervals at $p = 0.01$. The rug under the single variable effects plots indicates the density of points for different variable values

In a subsequent step, annual probability maps were obtained (see Annex 2.1.3) and the mean probability map (1998-2001) was estimated (Fig. 2.1.3.2.1.3.2). Moreover, habitat allocation map of anchovy juveniles is presented in figure 2.1.3.2.1.3.3. In the map three levels are indicated: preferential, occasional and rare habitat areas. Details of the map can be easily seen in the following link in the web based toolbox (GIS viewer) at http://mareaproject.net/mediseh/viewer/med.html.

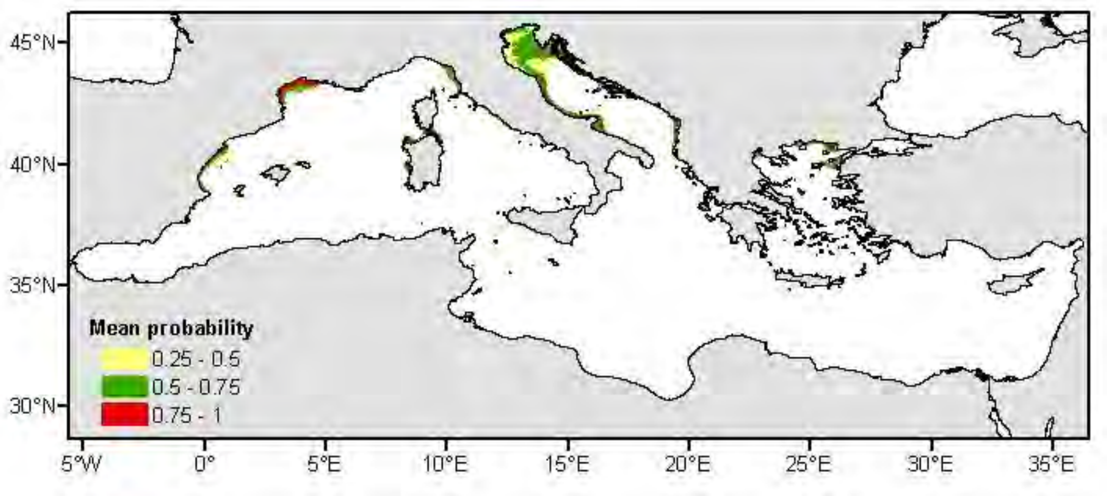

Fig. 2.1.3.2.1.3.2. Mean probability maps of anchovy nurseries habitat in the Mediterranean Sea for the period 1998-2000 during late autumn (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

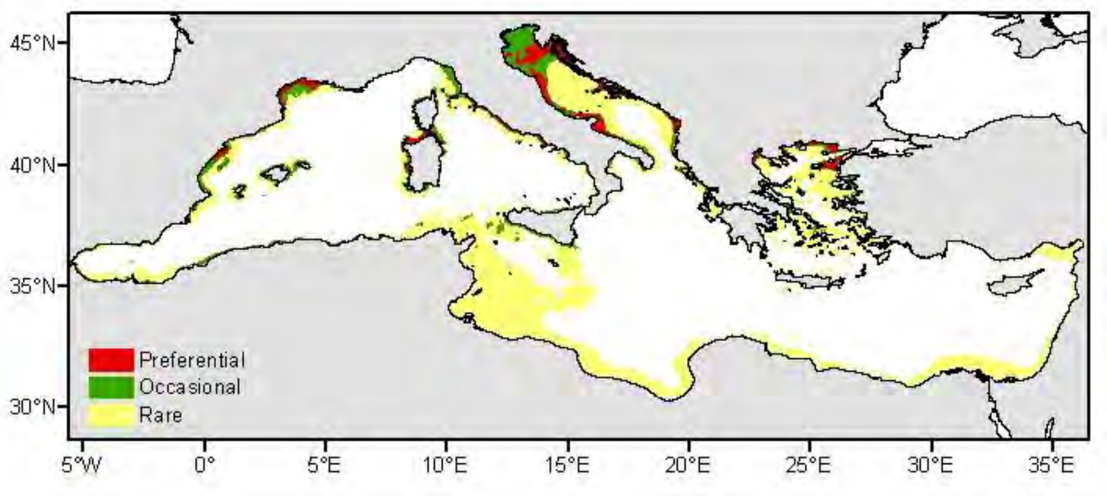

Fig. 2.1.3.2.1.3.3. Persistent habitat maps of anchovy nurseries in the Mediterranean Sea for the period 1998-2000 during late autumn (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

Since the range of the satellite data used to construct the habitat suitability maps in the southern part of the Mediterranean Sea was considerably outside the range of the data used to build the model, the prediction of probability in that area should not to be considered reliable. The visual inspection of the habitat maps indicates the presence of several persistent areas associated with high probability of finding anchovy juveniles. These areas were located in the northern coastal areas of Aegean Sea, in both eastern and western side of the Adriatic Sea, in the coastal waters of the Gulf of Lions, the Catalan Sea and the central Tyrrenian Sea. The areas detected as persistent nursery areas were similar to the nursery areas detected by the more recent model (see section **2.1.3.2.1.2 Nurseries grounds (2000-2010)**).

Ecological Characterization (D2.1.3)

Depth (shallow waters< 65 m) and PAR (highest values in the range) were the variables that largely explain most of the total variation. These results indicate a preference for areas that potentially can support high level of productivity. The analysis of the habitat suitability maps highlighted the presence of persistent suitable locations in both western and eastern part of the basin mostly associated with the existence of point sources of nutrients that enhance productivity locally (e.g. Rhone river in the Gulf of Lion, Ebro river in the Spanish Mediterranean waters, Po river in the North Adriatic Sea). These results are also in good agreement with what has been already described in past works and studies (see section 2.1.3.2.1.2 Nurseries grounds (2000-2010))

2.1.3.2.2 Sardina pilchardus

2.1.3.2.2.1 Spawning grounds

Modeling Results (D 2.1.1, D 2.1.2)

The final selected GAM was based on pooled egg data from the Spanish Mediterranean waters from 2006 to 2008 and included as main effects: depth (cubic root transformed) and SLA as well as the interactive effect of CHLA (log transformed) with SST. SST is the variable initially entered the model, explaining most of the total variation (Table 2.1.3.2.2.1.1). Plots of the best fitting smooths indicate a higher probability of finding sardine eggs present in SLA values greater than -1.5 cm and less than 4.9 cm (within the available ones) and in waters between 30 and 110 m deep. The interaction plot between CHLA and SST also indicates higher probability of finding sardine eggs present at SST values of 14 to 17 ^{o}C when co-existing with CHLA values within 1 to 2.7 mg m^{-3} (Fig. 2.1.3.2.2.1.1).

Areas and years included in the model estimation as well as areas and years that were not included in the GAM estimation were considered for model validation. Results are shown in Table 2.1.3.2.2.1.2. The selected models showed moderate to good prediction ability as the estimated AUC, sensitivity and specificity values were on average >0.70 (Table 2.1.3.2.2.1.2) (Segurado et al. 2006). Moreover, the validation results for 2009 and 2010, years outside the study period, showed low AUC values. This result is mostly due to a high increase in SST (i.e., 0.5 ^{o}C to 1^{o}C) compared to the average SST of the study period. However, the sensitivity/specificity values estimated at 0.65 indicate that the model at a suitable threshold can still attribute more than 60% of the true presence and the true absence accurately.

Table 2.1.3.2.2.1.1 GAM model selection for sardine spawning grounds: analysis of deviance for GAM covariates and their interactions of the final models fitted.

Parameter	Res. Df	Res. Deviance	Deviance explained %	P-value
s(CHLA, SST)+s(SLA)+s(Depth)	729.13	537.56	43.0%	<<0.000

Table 2.1.3.2.2.1.2. Mean values of sensitivity and specificity accuracy measures ± standard error (sterr) for two threshold criteria: MDT (maximize the specificity-sensitivity sum) and prevalence values. The estimated area under the ROC curve (AUC) for each model is also indicated.

Year	**Area**	**AUC**	MDT Sensitivity	MDT Specificity	Prevalence Sensitivity	Prevalence Specificity
2006	N. and S. Spanish Medit.	0.82	0.97	0.54	0.78	0.65
2007	N. and S. Spanish Medit.	0.83	0.80	0.71	0.80	0.71
2008	N. and S. Spanish Medit.	0.93	0.83	0.98	0.87	0.85
2009	N. and S. Spanish Medit.	0.63	0.65	0.61	0.62	0.64

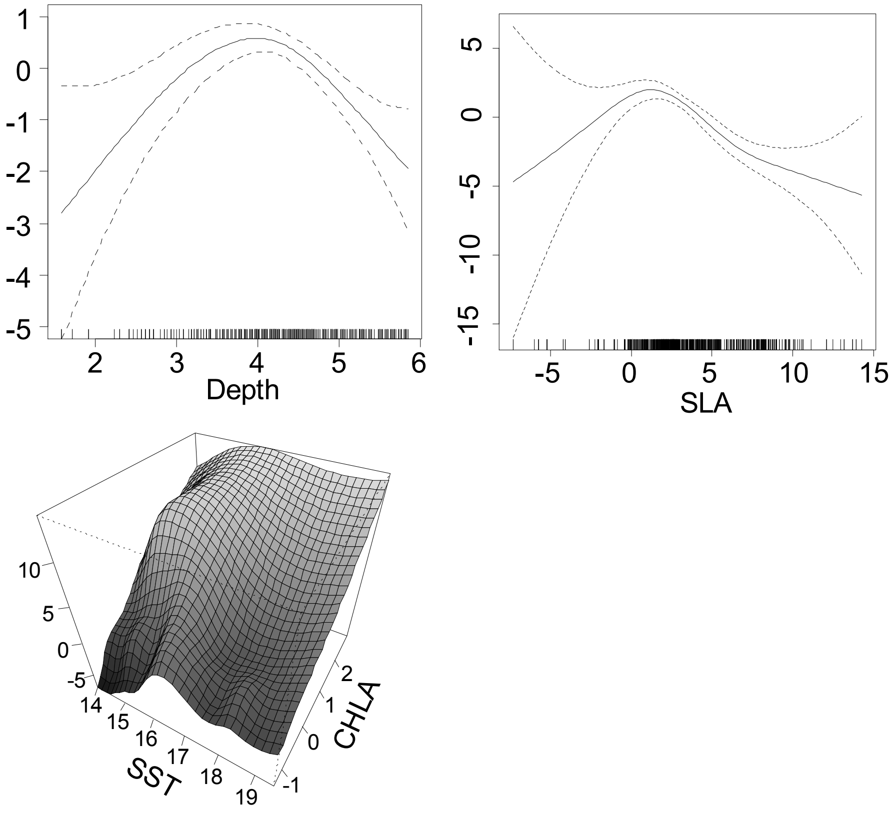

Fig. 2.1.3.2.2.1.1. Coefficients of the Generalized Additive Models (GAMs) for sardine spawning grounds in Late autumn (mid November – mid December) CHLA: log transformed Surface chlorophyll concentration (in mg m^{-3}) SST: Sea Surface Temperature (^{o}C), SLA: Sea Level Anomaly (in cm), Depth: Cube root transformed Bottom Depth (in m). The interaction plots are also shown.

In a subsequent step annual probability maps were obtained (see Annex 2.1.3). Baesd on these maps the mean probability map for late autumn sardine spawning grounds were estimated (Fig. 2.1.3.2.2.1.2.) as well as habitat suitability map (hereafter called persistence maps) of sardine spawning (Fig. 2.1.3.2.2.1.3). In each map three levels are indicated: preferential, occational and rare habitat areas.

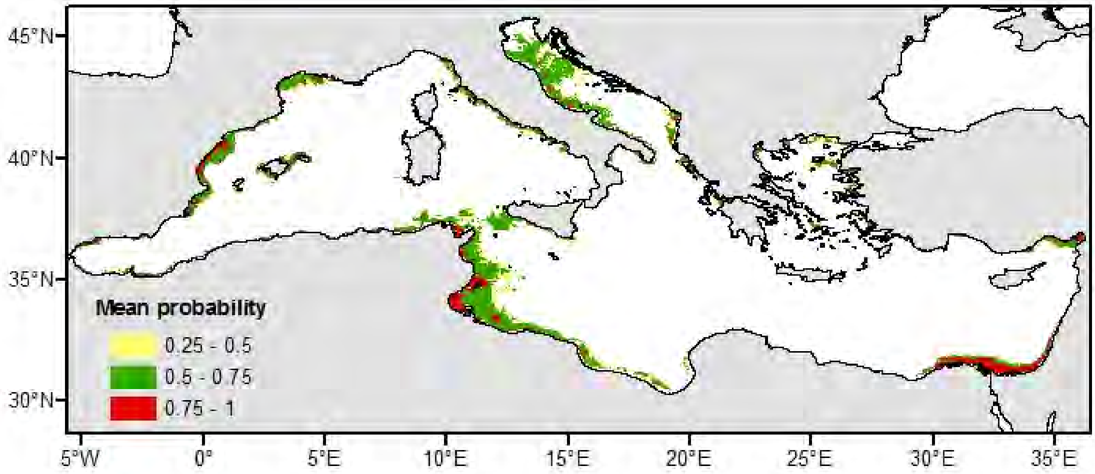

Fig. 2.1.3.2.2.1.2. Mean probability maps of sardine spawning (egg) habitat in the Mediterranean Sea for the period 2003-2006 during early winter **(See also web based GIS viewer** http://mareaproject.net/mediseh/viewer/med.html**).**

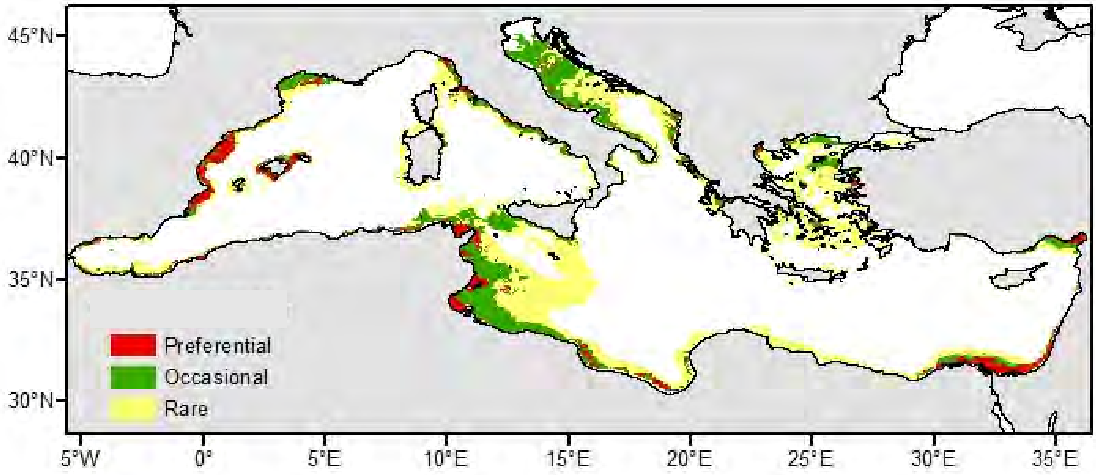

Fig. 2.1.3.2.2.1.3. Persistent habitat maps of sardine spawning (egg) habitat in the Mediterranean Sea for the period 2003-2006 during early winter **(See also web based GIS viewer** http://mareaproject.net/mediseh/viewer/med.html**).**

In the western Mediterranean areas suitable for sardine spawning were consistently identified in the surroundings of the Ebro River Delta and the North Alboran Sea (Figs. 2.1.3.2.2.1.2, 2.1.3.2.2.1.3), a pattern that matches the past sardine spawning grounds in the Spanish waters (Pérez de Rubín 1996, Olivar et al. 2003, Vargas-Yáñez and Sabatés, 2007). Annual variation of the spawning habitat of sardine in the North Alboran Sea is most likely associated with the variability of the local upwelling and the way it affects the circulation in the area (Pérez de Rubín 1996).

In the eastern part of the Mediterranean areas suitable for sardine spawning were identified inside the gulfs and the inshore waters of the North Aegean Sea. Predicted persistent sites are sustained by the known spawning grounds of sardine during early winter in the North Aegean during the late 90s (Somarakis et al. 2006a. In the Adriatic, potential spawning grounds of sardine were indicated in the extended continental shelf of the North

Adriatic as well as in the coastal waters of the western and the eastern part, covering consistently the exterior part of the mid-Dalmatian islands (Morello and Arneri 2009 and references therein).

Ecological Characterization (D2.1.3)

The spawning of sardine is known to be related to temperature and chlorophyll-a concentration but it has also been related to bottom depth (Palomera et al. 2007, Ganias 2009, Bernal et al. 2007, Planque et al. 2007). Modeling results indicated preference for waters characterized by moderate downwelling (SLA from -1.5 cm to 4.9 cm), coastal waters between 30 and 110 m deep and at SST values of 14 to 17 ^{o}C when co-existing with moderate CHLA values within 1 to 2.7 mg m^{-3} (Fig. 2.1.3.2.2.1.1). This is largely in accordance with the known information on sardine This range of SST agrees with the known temperature preferendum related to sardine spawning in the Mediterranean Sea where sardine is known to spawn when surface temperature falls well below 20ºC (Olivar et al. 2003). Specifically, studies have showed a preference for temperatures 12 to 14ºC with spawning occurring up to 19ºC in the Catalan sea (Palomera et al. 2007) and a similar temperature range 17 to 19 ^{o}C during December in the Aegean Sea (Somarakis *et al.* 2006a. In the Adriatic, the temperature preferendum lies within 12 to 16 ^{o}C based on studies carried out mainly in the 70s and 80s (Morello and Arneri 2009 and references therein). During the 90s, a study also indicated that sardines leave shallow areas of the most northern part of the Adriatic Sea when temperatures falls below 10.5ºC (Tičina *et al.* 2000).

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between sardine spawning grounds and fishing restricted areas (FRAs) and Marine Protected Areas (MPAs) where purse seine fishing, pelagic trawls and bottom trawls (i.e. gears targeting sardine) are prohibited was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 up to 12 months in an annual basis. Purse seines restrictions showed 8.36 % overlapping with persistent spawning and up to 14.06% when occasional spawning grounds are included. Similarly, 12.72 % overlapping between bottom trawls restrictions and persistent spawning and up to 22.32% when occasional spawning grounds are included. These areas are shown in Figures 2.1.3.2.2.1.4 - 2.1.3.2.2.1.5**.** In the case of pelagic trawls 21.81 % overlapping was estimated with persistent spawning and up to 38.45% when occasional spawning grounds are included. The higher percentage of overlapping observed with pelagic trawls is expected since this gear is totally prohibited in Spain, Greeece and Turkish territorial waters. These areas can also be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html).

Fig. 2.1.3.2.2.1.4. Sardine spawning grounds that are under Fishing Restricted Areas and Marine Protected Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

Fig. 2.1.3.2.2.1.5. Sardine spawning grounds that are under Fishing Restricted Areas and Marine Protected Areas where bottom trawls are prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

2.1.3.2.2.2 Nurseries grounds (2000-2010)

Modeling Results (D 2.1.1, D 2.1.2)

June model – The final selected GAM model included as main effects: SLA, Chl *a* (log-transformed) and the interactive effect of Depth (cubic root transformed) and PAR (see Table 2.1.3.2.2.2.1). All the variables were statistical significant.

The output of the models showed a high probability of finding sardine juveniles present in SLA values of -6 to 0 cm and Chl *a* values of 0.47 to 1 mg m^{-3}. The interaction plot between Depth and PAR also indicated a higher probability of finding sardine juveniles present in shallow waters (<65 m) when coexisting with PAR values of 48 to 56 Ein m^{-2} (Fig. 2.1.3.2.2.2.1).

July model – The final selected GAM model included as main effects: SLA, Chl *a* (log-transformed) and the interactive effect of Depth (cubic root transformed) and SST (see Table 2.1.3.2.2.2.1). All the variables were statistical significant.

Output plots indicated a high probability of finding sardine juveniles present in the highest available values SLA values of -1 to 3 cm and Chl *a* values of 0.345 to 2.718 mg m^{-3}. The interaction plot between SST and Depth indicated high probability of finding sardine juveniles present in the highest available values of SST (20 to 26°C) when coexisting with shallower waters (<60 m) (Fig. 2.1.3.2.2.2.1).

Table 2.1.3.2.2.2.1. Final GAM models selected. Analysis of deviance for GAM covariates and their interactions of the final model fitted.

	Parameters	Residual Df	Residual Deviance	Deviance explained	AIC	P-value
July	s(Depth, SST)+s(SLA)+s(CHLA)	1297.85	1007.63	45.1%	1081.92	<<0.000
June	s(Depth,PAR)+s(SLA)+s(CHLA)	433.15	137.91	51.1%	201.61	<<0.000

Each model was validated based on the estimated values of AUC obtained from each ROC plot concerning areas and years included in the model estimation as well as areas that were not included in the model estimation. The AUC values showed good discrimination ability for both models since it exceeded 0.75 for the cases that were not included in the model selection (see Table 2.1.3.2.2.2.2). The lowest prediction ability was observed for areas where sardine juveniles presence was very low and spatially limited. Estimated specificity and sensitivity values based on MDT and prevalence values also indicated good discrimination ability for all the models.

Table 2.1.3.2.2.2.2. Mean values of sensitivity and specificity accuracy measures ± standard error (sfor two threshold criteria: MDT (maximize the specificity-sensitivity sum) and prevalence values. The estimated area under the ROC curve (AUC) for each model is also indicated. A: Areas and years included in model selection, B: areas and years not included in model selection.

Model	Areas	MDT Sensitivity	MDT Specificity	Prevalence Sensitivity	Prevalence Specificity	AUC
June	A	0.90±0.02	0.77±0.05	0.62±0.01	0.96±0.01	0.91±0.027
	B	0.82±0.08	0.71±0.17	0.52±0.12	0.86±0.04	0.75±0.08
July	A	0.83±0.04	0.84±0.04	0.82±0.01	0.77±0.08	0.90±0.03
	B	0.49±0.16	0.88±0.06	0.38±0.12	0.86±0.03	0.77±0.05

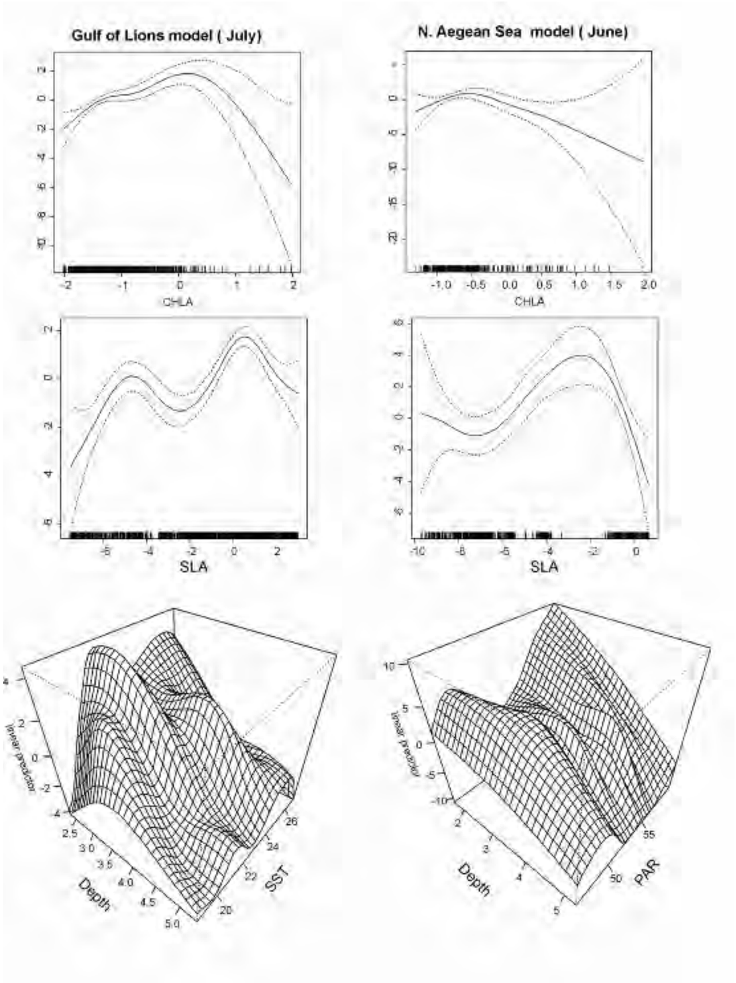

Fig. 2.1.3.2.2.2.1. Coefficients of the Generalized Additive Models (GAMs) for sardine juveniles in June and July. CHLA: log transformed Surface chlorophyll concentration (in mg m^{-3}) SST: Sea Surface Temperature (^{o}C), SLA: Sea Level Anomaly (in cm), Depth: Cube root transformed Bottom Depth (in m), PAR: Photosynthetically Active Radiation (in Einstein m^{-2} day^{-1}). The interaction plots are also shown. Black thick lines indicate the value of GAMs coefficient. Dotted lines represent the confidence intervals at p = 0.05. The rug under the single variable effects plots indicates the density of points for different variable values.

In a subsequent step annual probability maps were obtained (see Annex 2.1.3) and the mean probability map (i.e. June 2003-2008, July 2004-2008) was estimated (Fig. 2.1.3.2.2.2.2). Moreover habitat allocation map of sardine juveniles is presented in figure 2.1.3.2.2.2.3. In the map three levels are indicated: preferential, occasional and rare habitat areas. Details of the map can be easily seen in the following link in the web based toolbox (GIS viewer) at http://mareaproject.net/mediseh/viewer/med.html.

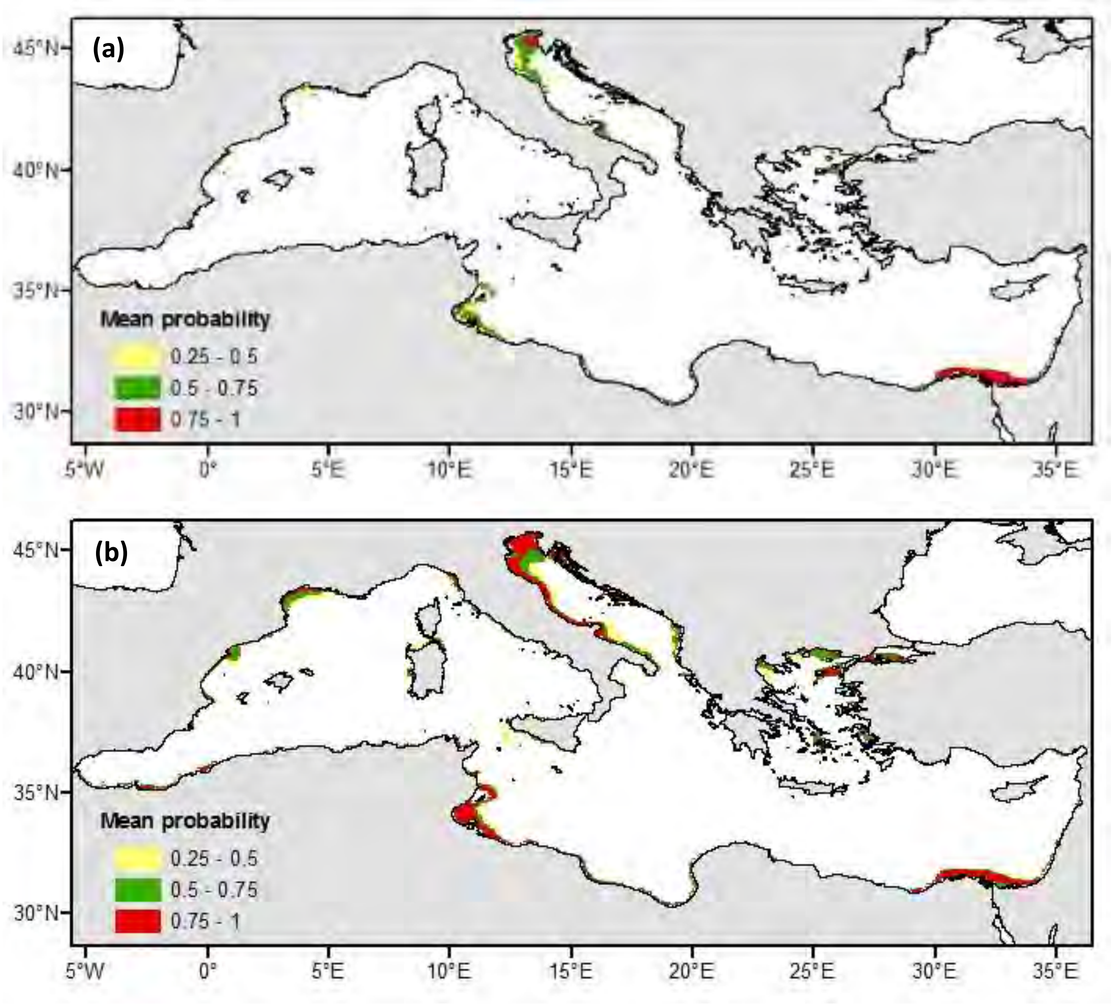

Fig. 2.1.3.2.2.2.2. Mean probability maps of juvenile sardine habitat in the Mediterranean Sea for the period 2003-2008 in (a) June and (b) July (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

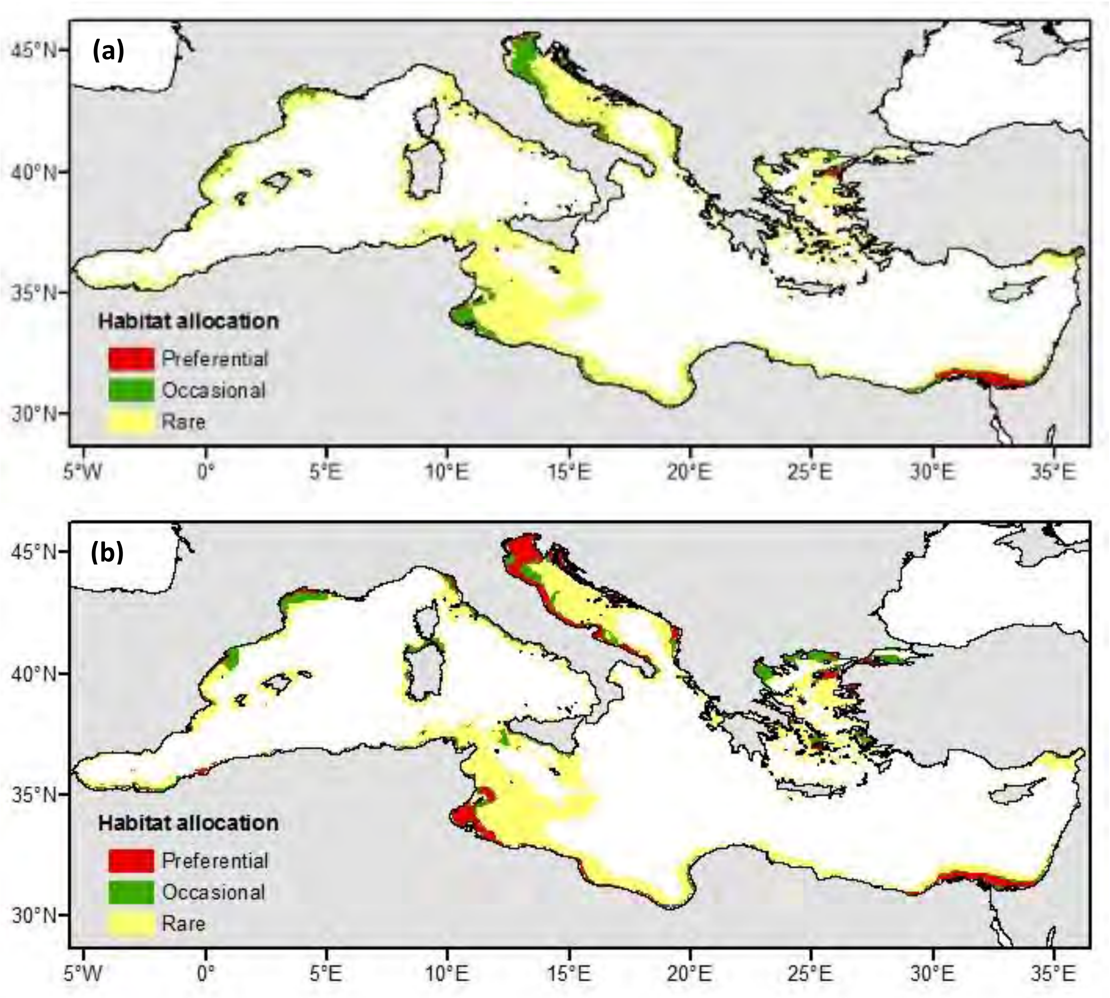

Fig. 2.1.3.2.2.2.3. Persistent habitat maps of juvenile sardine habitat in the Mediterranean Sea for the period 2003-2008 in (a) June and (b) July **(See also web based GIS viewer** http://mareaproject.net/mediseh/viewer/med.html**).**

The mean probability and the habitat allocation map estimated for the two models identified certain areas that were persistently associated with high probability of sardine juvenile presence. These areas were located in the coastal waters of the Gulf of Lions, the Catalan Sea, the northern part of the Adriatic Sea, the coastal waters of the western and eastern Adriatic, and the gulfs and coastal waters of the North Aegean Sea. Other suitable areas were indicated in the coastal waters of Morocco, Algeria, Tunisia and Libya and in the Eastern Mediterranean along the Egyptian coastline, mainly off the Nile River Delta.

Locations presenting high variability as sardine nurseries were the coastal waters of the North Alboran Sea, the Sicily Channel, the western part of the Italian peninsula, the Cretan shelf in Greek seas and areas along the coastline of Levantine. These areas seem to represent occasionally suitable locations for sardine juveniles.

Differences in the persistent⁄recurrent locations between June and July were mainly identified in the Western Mediterranean, the Strait of Sicily as well as the Levantine. In the Western Mediterranean and the Strait of Sicily, suitable areas were more extended in July compared to June, whereas the opposite was observed in the Levantine

Ecological characterization (D2.1.3)

The most important parameters selected in the GAM models that largely define the habitat for sardine juveniles were depth and chlorophyll concentration. In particular, the most suitable nursery areas were associated with very shallow (<65 m) and productive waters. The visual inspection of habitat suitability maps highlighted the presence of persistent suitable locations in both western and eastern part of the basin mostly associated with the existence of point sources of nutrients that enhance productivity locally.

In the northwestern part of the Gulf of Lions, the presence of two large rivers, the Rhone and the Muga Rivers, together with an existing upwelling along the coast (Forget and André, 2007) results in a local increase of productivity.

In the North Aegean Sea, the more consistent nursery locations were identified at the coastal areas of the gulfs (i.e. Thermaikos Gulf, Strymonikos Gulf and North Evoikos Gulf) and the inner part of Thracian Sea – these areas are also under strong river influence. Also consistent was the area between the islands, subjected to the inflow of the Limnos-Imvros Stream (LIS) that carries nutrient-rich Black Sea Water into the Thracian Sea. The indicated areas generally agree with the results of a preliminary study on sardine nurseries in Aegean Sea based on trawl catches (Tsagarakis *et al.,* 2008).

In the north part of the Mediterranean basin, the most persistent nursery areas were located in the coastal waters of the northwestern part of the Adriatic, area characterized by the presence of the Po river runoff, and around the coastal waters of the mid-Dalmatian islands in the eastern part. These areas coincide with known sardine distribution grounds in the Adriatic based on acoustic surveys (Ticina *et al.,* 2005; Leonori *et al.,* 2007a,b, 2010, 2011a) as well as fishery information. In Spanish waters, persistent nursery areas are located in the Catalan Sea as well as near the mouth of the Ebro River. These areas coincide with known distribution grounds of sardine juveniles (Giraldez *et al.,* 2005; Alemany *et al.,* 2006). Similarly, in the south part of the basin along the North African coast where information on small pelagic nursery grounds is generally lacking, persistent areas are indicated in the coastal waters of Morocco and Algeria, the Gulf of Gabes in Tunisia and the Nile Delta area. These areas match the distribution grounds of sardine, as landings information from local fisheries confirm (El Haweet, 2001; Ben Abdallah and Gaamour, 2005; Ramzi *et al.,* 2006).

These findings agree with the general argument that pelagic fish nurseries are located in areas of favorable food concentrations where oceanographic factors combine favorably within an optimal environmental window (Cury and Roy, 1989; Guisande *et al.,* 2004; Freon *et al.,* 2005). Moreover, similarly to large upwelling ecosystems, the juvenile grounds of sardine are mainly situated in inshore, coastal waters (Barange *et al.,* 1999; Checkley *et al.,* 2009 and references therein).

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between sardine nursery grounds and fishing restricted areas (FRAs), where purse seine fishing, pelagic trawls and bottom trawls (i.e. gears targeting sardine) are prohibited, was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 -12 months in an annual basis. Purse seines FRAs showed 20.6% (in June) and 8.83% (in July) overlapping with persistent nurseries and up to 31.37% (in June) and 17.29% (in July) when occasional nursery grounds are included. Similarly, bottom trawls FRAs showed 24.85% (in June) and 19.6% (in July) overlapping with persistent nurseries and up to 47.13% (in June) and 39.14% (in July) when occasional nursery grounds are included. These areas are shown in Figures 2.1.3.2.2.2.4 - 2.1.3.2.2.2.7**.** Concerning pelagic trawls FRAs showed 32.96% (in June) and 16.98% (in July) overlapping with persistent nurseries and up to 52.27% (in June) and 44.33% (in July) when occasional nursery grounds are included. The higher percentage for pelagic trawls is expected since this gear is totally prohibited in Spain, Greeece and Turkish territorial waters. These areas can be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html).

Figure 2.1.3.2.2.2.4. Sardine nurseries during July that are under Fishing Restricted Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

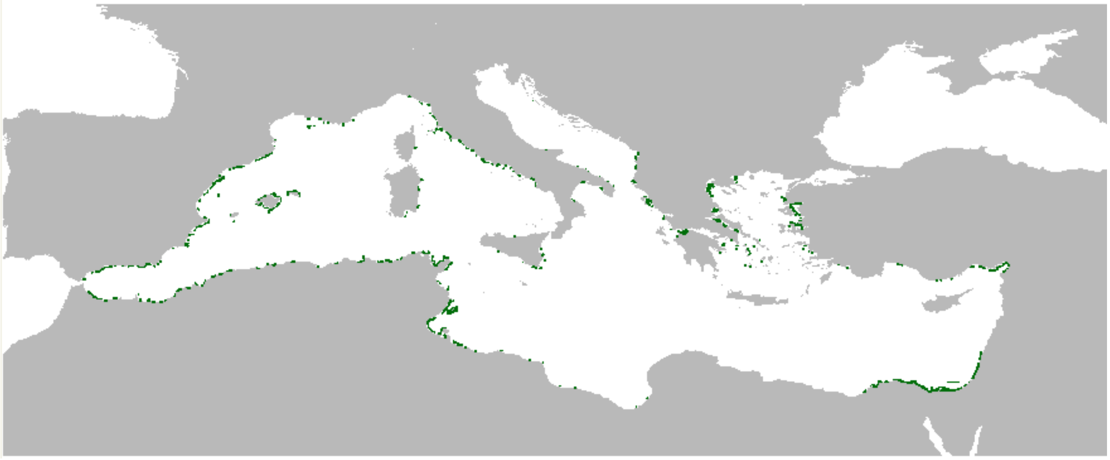

Figure 2.1.3.2.2.2.5. Sardine nurseries during June that are under Fishing Restricted Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

Figure 2.1.3.2.2.2.6. Sardine nurseries during June that are under Fishing Restricted Areas where bottom trawl fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

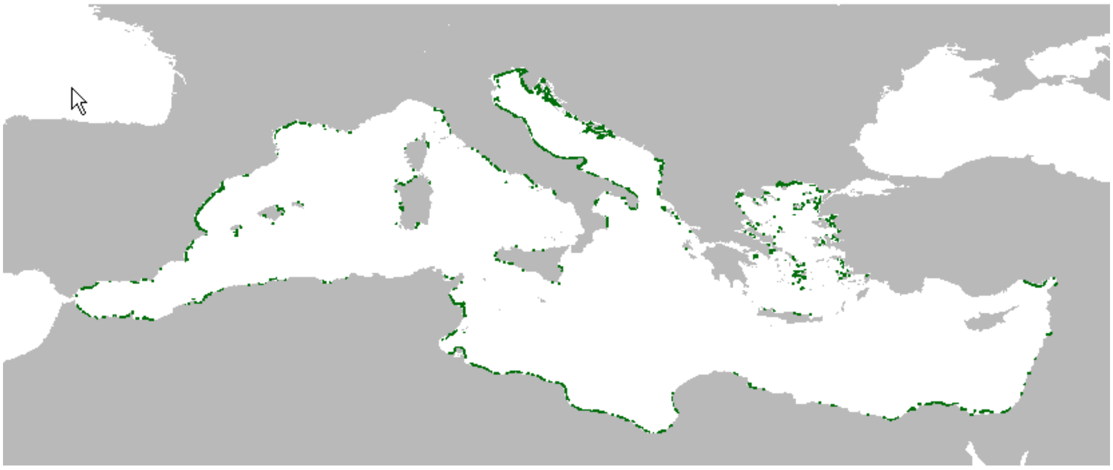

Figure 2.1.3.2.2.2.7. Sardine nurseries during July that are under Fishing Restricted Areas where bottom trawl fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

2.1.3.2.3 Scomber scombrus

2.1.3.2.3.1 Nurseries grounds

Modeling Results (D 2.1.1, D 2.1.2)

Maxent is generating a probability distribution over all pixels in the grid, starting from the uniform distribution and repeatedly improving the fit to the data. In order to run MAXENT, we selected as background points the absence data from the surveyed area. A randomly selected 25% of the available data was used as test dataset. Given the small sample size MAXENT was run 10 times on both training and test data (using default settings).

The final fitted MAXENT model included as main effects: CHL (sea surface chlorophyll concentration), PAR (Photosynthetically Active Radiation), SLA (Sea Level Anomaly), SST (Sea

Surface temperature) and SLO (Bottom slope). CHL was the variable that contributed more to the model (Table 2.1.3.2.3.1.1). The results of this model indicated a higher probability of finding juvenile mackerel present at 0.25 to 3 mg m^{-3} CHL, PAR of 28 to 32 and 40 to 64 Einstein m^{-2} day^{-1}, at 0 to 8cm SLA (implying the presence of downwelling formations), SST>20°C and SLO<2.5 degrees (Fig. 2.1.3.2.3.1.1).

Table 2.1.3.2.3.1.1. MAXENT model selection for juvenile *Scomber scombrus*: estimates of relative contributions of the variables to the MAXENT model.

Variable	**Percent contribution**
CHL	71.3
PAR	20.4
SLA	4.4
SST	2.7
SLO	1.2

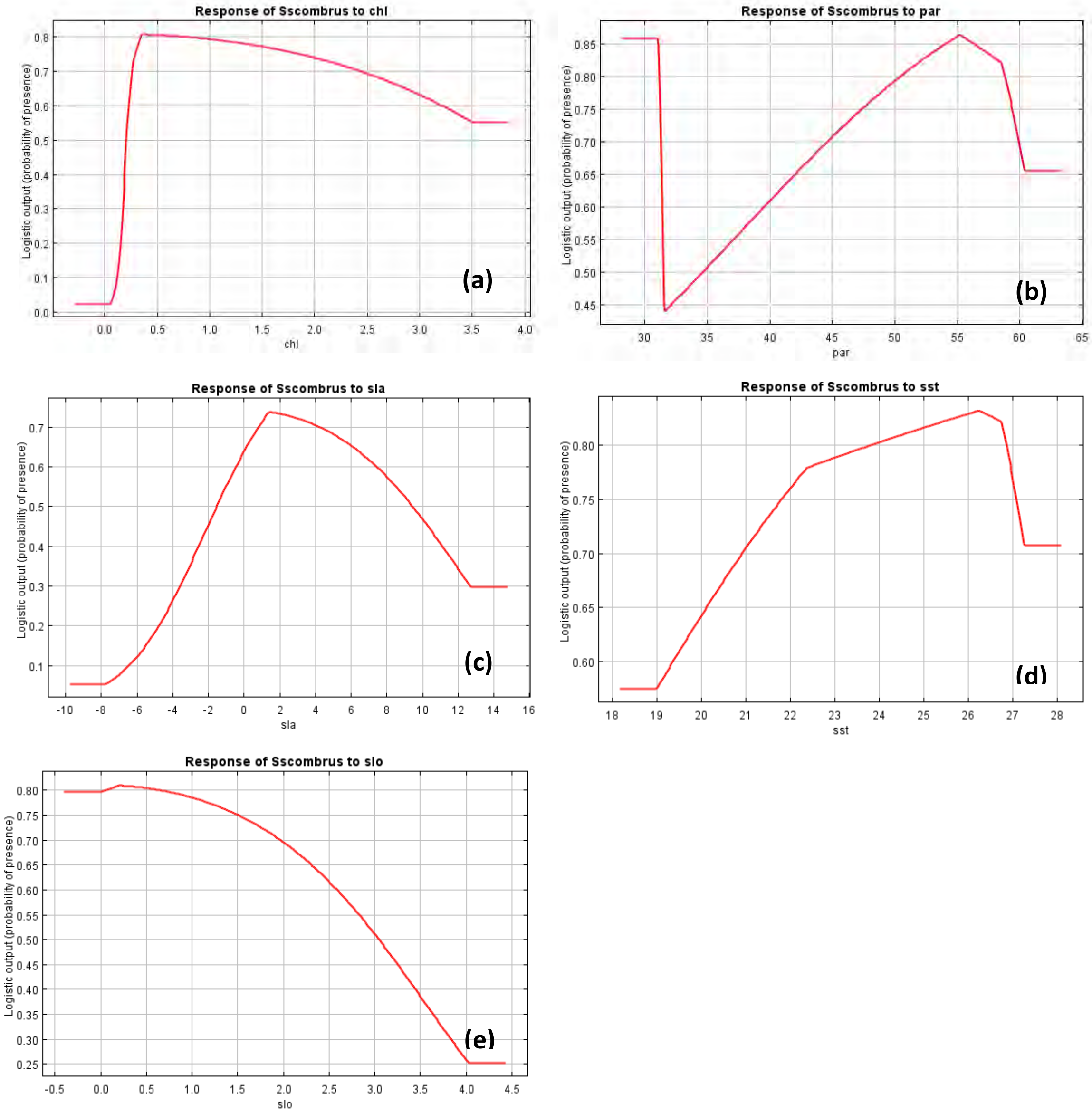

Fig. 2.1.3.2.3.1.1. Coefficients of the Maxent model for juvenile mackerel in summer: (a) CHL, sea surface chlorophyll concentration (in mg m^{-3}); (b) PAR, Photosynthetically Active Radiation (in Einstein m^{-2} day^{-1}); (c) SLA, sea level anomaly (in cm); (d) SST, sea surface temperature (in ^{o}C) and SLO, bottom slope (in degrees).

The omission rate on test samples shows a good match to the predicted omission rate (straight black line) for test data drawn from the Maxent distribution itself (Fig. 2.1.3.2.3.1.2). The average AUC of the test data (25% of the observations) derived from the replicate runs (10 replicates) is 0.826, and the standard deviation is 0.063, which indicates good model performance (Fig. 2.1.3.2.3.1.3). The training dataset gain was estimated at 2.2. The gain expresses how many times higher is the average likelihood of the presence samples compared to a random background pixel. Its low value in the specific model was assigned to the fact that we used as background pixels the absence sampling stations from the survey and the respective environmental data at these sites. The background points often closely located to the presence sampling stations combined with the coarse spatial resolution available for certain environmental predictors (e.g. in Chl-a is up to 9 km) may assign similar or the same values to both presence and absence pixels. This decreases the possibility of high discrimination between presence samples and background pixels.

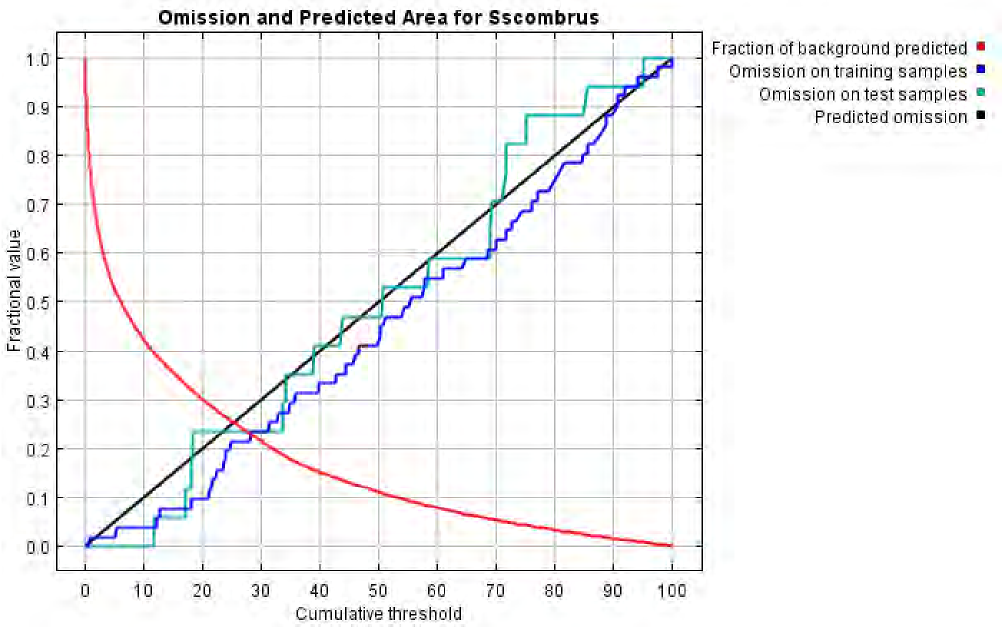

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Fig. 2.1.3.2.3.1.2. Omission and predicted area for juvenile *Scomber scombrus* Maxent model output

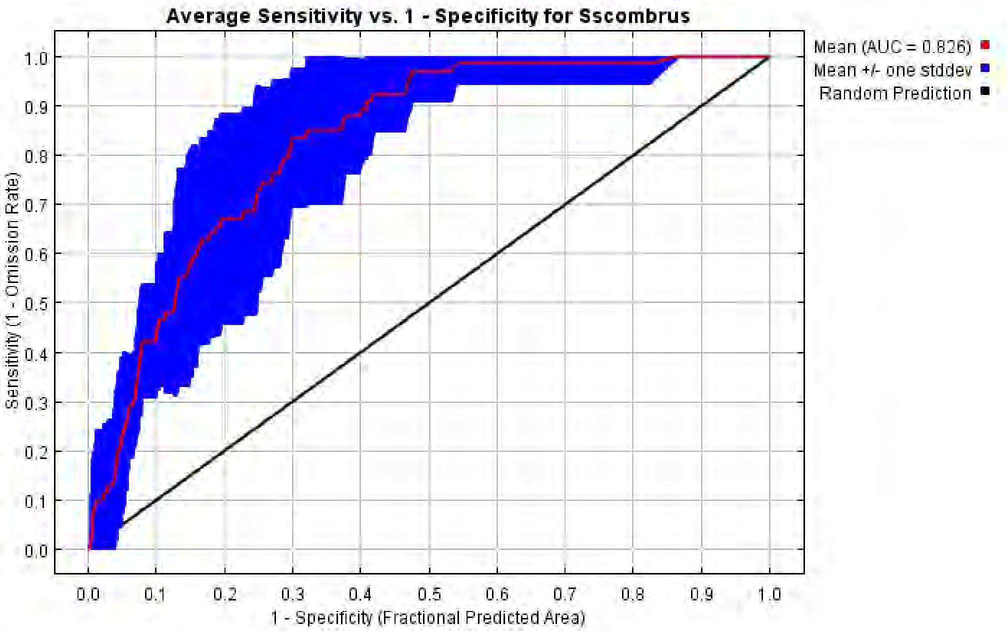

Fig. 2.1.3.2.3.1.3. The receiver operating characteristic (ROC) curve for the test data (25% of the observations) averaged over the replicate runs.

In a subsequent step annual probability maps were obtained (see Annex 2.1.3) and the mean probability map for the early summer period was estimated (Fig. 2.1.3.2.3.1.4). Persistence map of mackerel nursery grounds is presented in figure 2.1.3.2.3.1.5. At this map three levels are indicated: preferential, occasional and rare habitat areas. Details of the maps can easily be seen in the following link in the web based toolbox (GIS viewer) at http://mareaproject.net/mediseh/viewer/med.html.

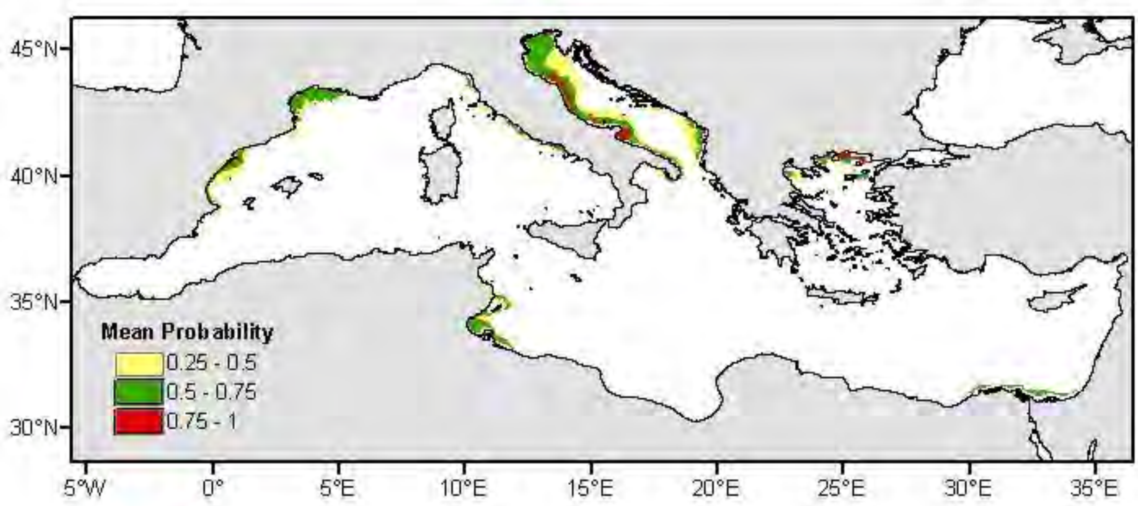

Fig. 2.1.3.2.3.1.4. Mean probability map of juvenile mackerel in the Mediterranean Sea for the early summer period 2001–2010 (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html).

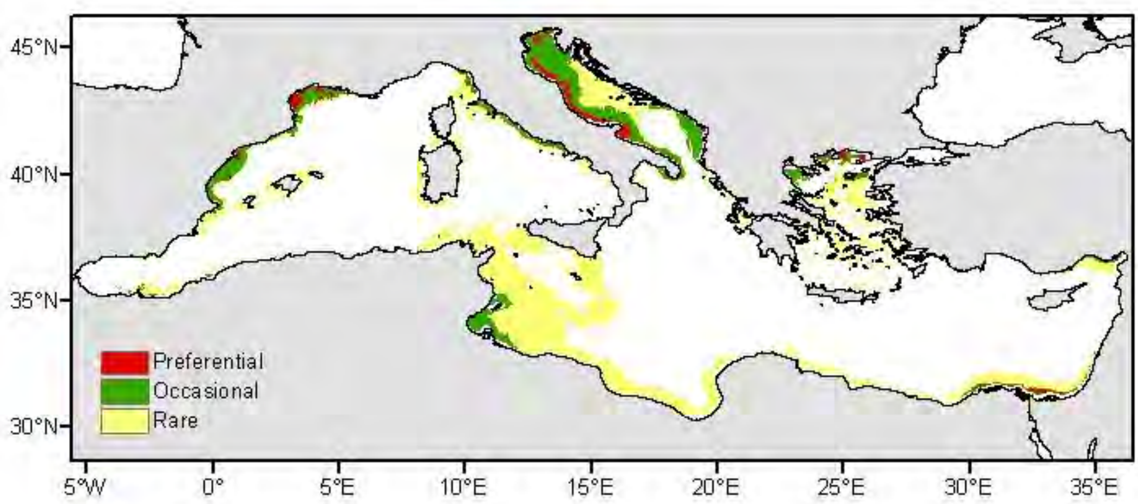

Fig. 2.1.3.2.3.1.5. Persistent habitat map of juvenile mackerel in the Mediterranean Sea for the early summer period 2001–2010 (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html).

In the Western Mediterranean, mackerel potential nursery areas were identified to be in association with the outflow of the Ebro river in the Spanish waters and the Gulf of Lions. In the Adriatic Sea, potential nurseries were located along the coasts of the western part as well as along the Albanian coast. Concerning Eastern Mediterranean, in the Aegean Sea, mackerel potential nursery areas were identified to be in association with the outflow of the Axios river in Thermaikos gulf, the Strymon river in Strymonikos gulf and Netsos river in the eastern part of Thasos Island, as well as in the north eastern part of Samothraki. Mackerel potential nursery areas at the northern coast of Africa were located in the Gulf of Gabes and along the coast of Egypt (See details in the web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

GAMs were also applied concerning the data for juvenile *Scomber scombrus* explaining 35.8%. However, probability maps obtained were not considered reliable, because of the few data available, and the model was not selected for use.

Ecological Characterization (D2.1.3)

Predicted juvenile *scomber scombrus* occurrence (Figs 2.1.3.2.3.1.4, 2.1.3.2.3.1.5) was found to be consistent with the known distribution of this species across the Mediterranean Sea. From literature review, it is known that juveniles *S. scombrus* are present in the Gulf of Gabes (Hajjej *et al.,* 2010), in Ebro river (Sardű *et al.,* 2006) and in Bari (Bottari *et al.,* 2004), which coincide with the present results according to the persistence map of juveniles *S. scombrus*. The areas mentioned above are characterized as preferential and occasional juvenile sites (Fig. 2.1.3.2.3.1.5). Additionally, the adults of the species are abundant in the coast of Tunisia, Egypt and the Turkish Mediterranean coast, according to landings data from GFCM. This could be a hint of potential presence of juvenile mackerel in these areas, where information concerning the juvenile of the species is largely missing.

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between *Scomber scombrus* nursery grounds and fishing restricted areas (FRAs), where purse seine fishing (i.e. gears targeting *Scomber scombrus*) is prohibited, was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 up to 12 months in an annual basis. Purse seine FRAs showed 6.26% overlapping with persistent nurseries and up to 9.42% when occasional nursery grounds are included. These areas are shown in Fig 2.1.3.2.3.1.6. These areas can also be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html).

Fig. 2.1.3.2.3.1.6. *Scomber scombrus* nurseries that are under Fishing Restricted Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

2.1.3.2.4 Scomber colias

2.1.3.2.4.1 Spawning grounds

Modeling Results (D 2.1.1, D 2.1.2)

Maxent is generating a probability distribution over pixels in the grid, starting from the uniform distribution and repeatedly improving the fit to the data. In order to run MAXENT, we selected as background points the absence data from the surveyed area. A randomly selected 25% of the available data was used as test dataset. Given the small sample size MAXENT was run 10 times on both training and test data (using default settings).

The final fitted MAXENT model included as main effects: PAR (Photosynthetically Active Radiation), CHL (sea surface chlorophyll concentration), Depth and SLA (sea level anomaly). PAR was the variable that contributed more to the model (Table 2.1.3.2.4.1.1). The results of this model indicated a higher probability of finding Chub mackerel eggs present at 51 to 57 Einstein m^{-2} day^{-1} PAR, at 0.32 to 0.73 mg m^{-3} CHL, in waters between 40 and 120m, and SLA of 7.5 to 9.5cm (implying the presence of strong downwelling formations) (Fig. 2.1.3.2.4.1.1).

Table 2.1.3.2.4.1.1. MAXENT model selection for eggs of *Scomber colias*: estimates of the relative contribution of each variables.

Variable	Percent contribution
PAR	62.6
CHL	17
Depth	16.1
SLA	4.3

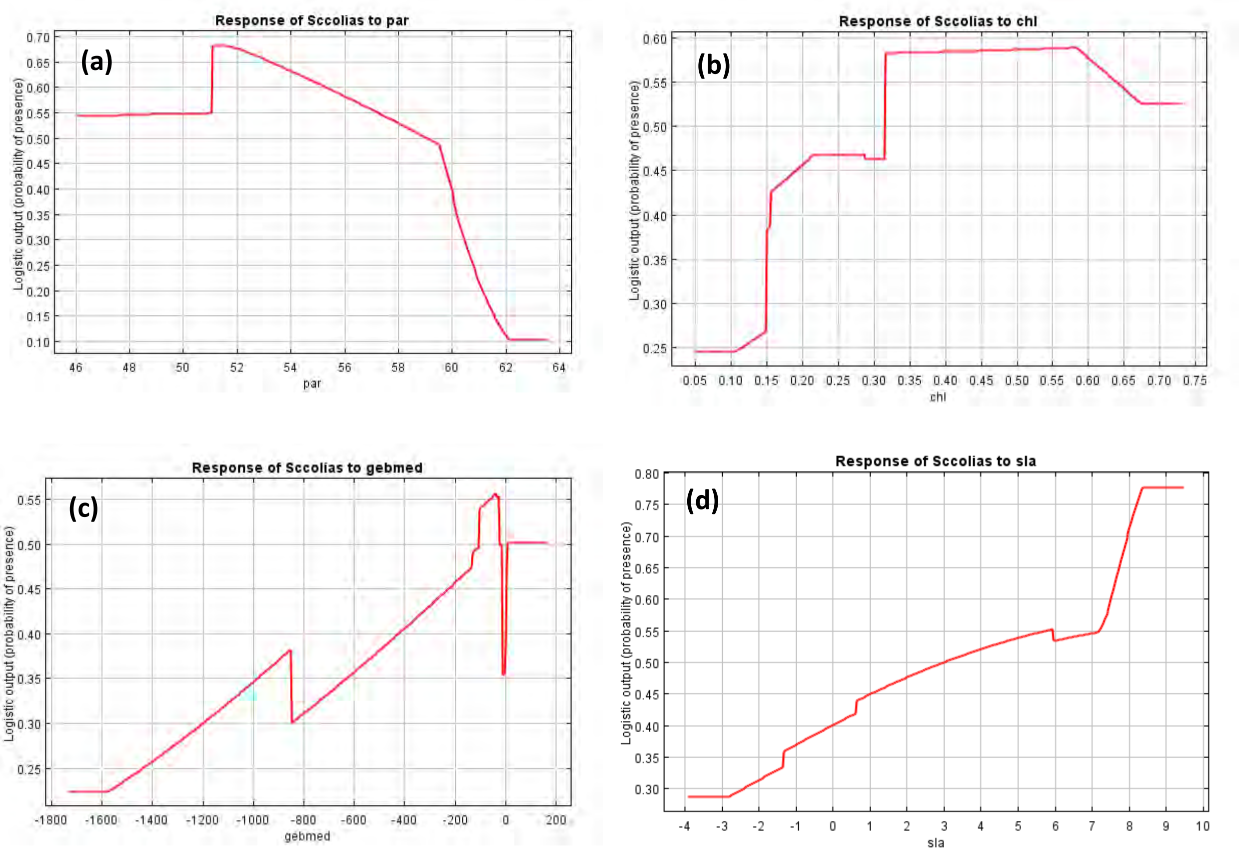

Fig. 2.1.3.2.4.1.1. Coefficients of the Maxent model for chub mackerel eggs in summer: (a) PAR, Photosynthetically Active Radiation (in Einstein m^{-2} day^{-1}); (b) CHL, sea surface chlorophyll concentration (in mg m^{-3}); (c) Depth (in m)and (d) SLA, sea level anomaly (in cm)

The omission rate on test samples shows a good match to the predicted omission rate (straight black line) for test data drawn from the Maxent distribution itself (Fig. 2.1.3.2.4.1.2). The average AUC of the test data (25% of the observations) derived from the replicate runs (10 replicates) is 0.657, and the standard deviation is 0.073, which indicates moderate model performance (Fig. 2.1.3.2.4.1.3). The training dataset gain was estimated at 1.2. The gain expresses how many times higher is the average likelihood of the presence samples compared to a random background pixel. Its low value in the specific model was assigned to the fact that we used as background pixels the absence sampling stations from the survey and the respective environmental data at these sites. The background points often closely located to the presence sampling stations combined with the coarse spatial resolution available for certain environmental predictors (e.g. in CHL is up to 9 km) may assign similar or the same values to both presence and absence pixels. This decreases the possibility of high discrimination between presence samples and background pixels.

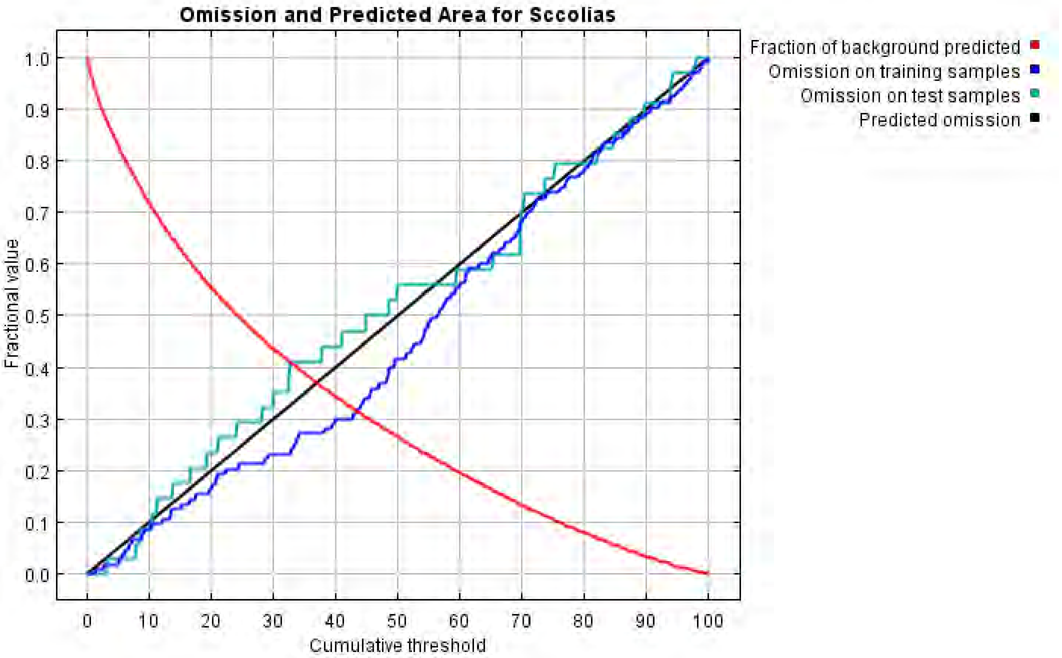

Fig. 2.1.3.2.4.1.2. Omission and predicted area for *Scomber colias* (eggs) Maxent model output.

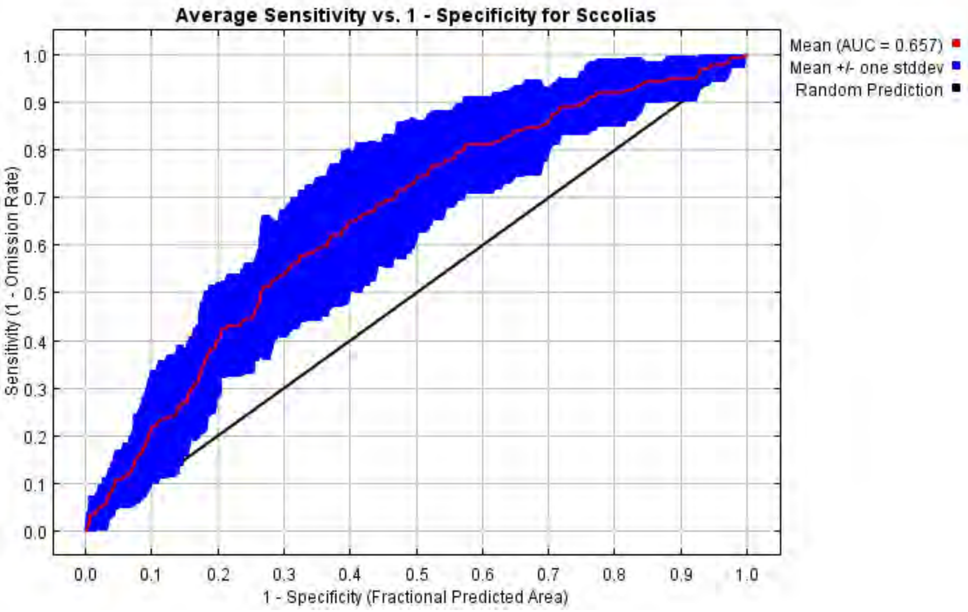

Fig. 2.1.3.2.4.1.3. The receiver operating characteristic (ROC) curve for the test data (25% of the observations) averaged over the replicate runs.

In a subsequent step annual probability maps were obtained (see Annex 2.1.3) and the mean probability map for the summer period was estimated (Fig. 2.1.3.2.4.1.4). Persistence map of chub mackerel spawning grounds is presented in figure 2.1.3.2.4.1.5. At this map three levels are indicated: preferential, occasional and rare habitat areas. Details of the maps can easily be seen in the following link in the web based toolbox (GIS viewer) at http://mareaproject.net/mediseh/viewer/med.html.

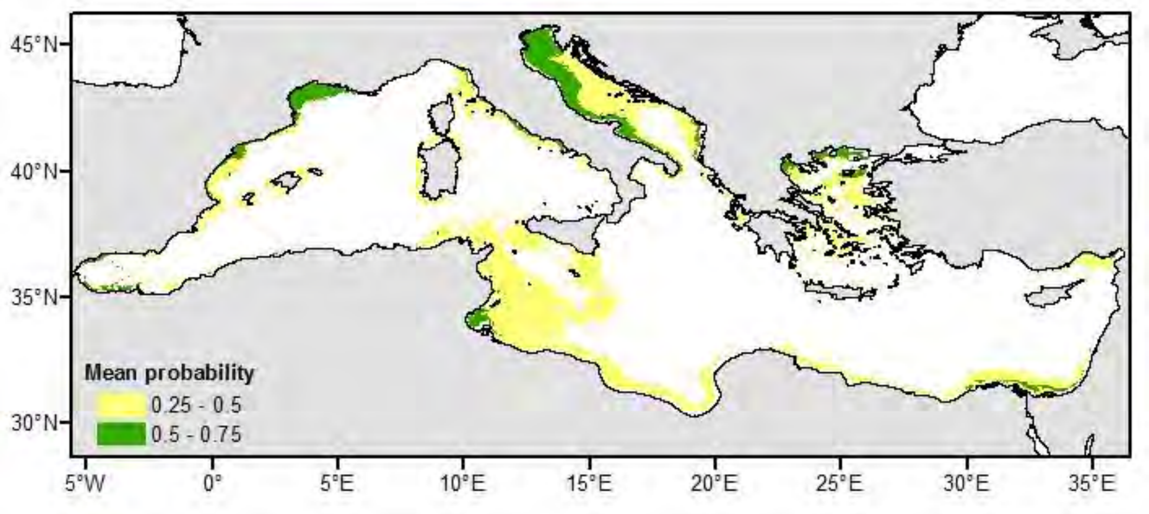

Fig. 2.1.3.2.4.1.4. Mean probability map of chub mackerel eggs in the Mediterranean Sea for the summer period 2006, 2008 and 2010 (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html).

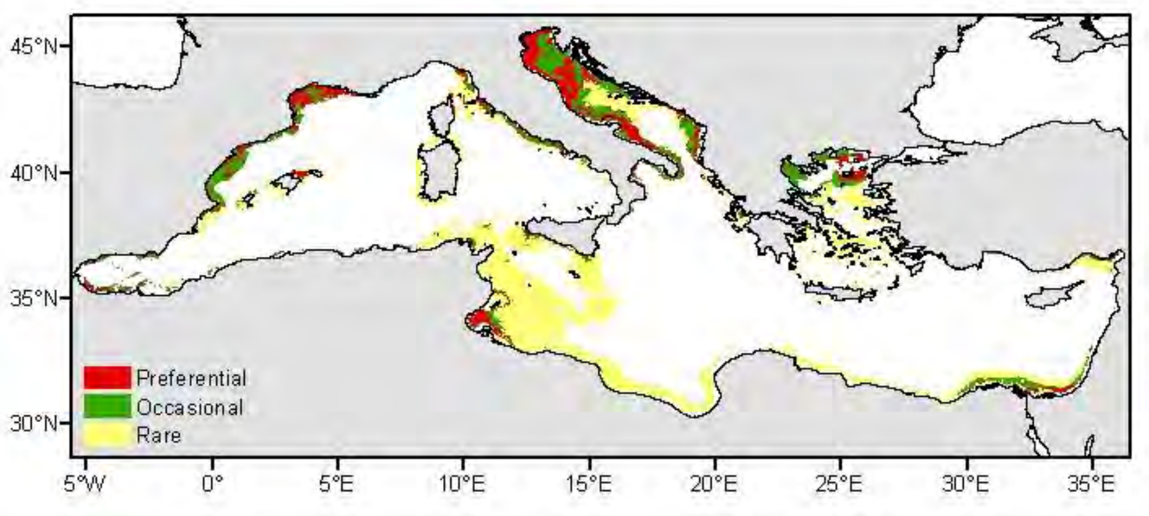

Fig. 2.1.3.2.4.1.5. Persistent habitat map of chub mackerel eggs in the Mediterranean Sea for the summer period 2006, 2008 and 2010 (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html).

In the Western Mediterranean, chub mackerel potential spawning areas were located at the Catalan coast as well as in the Balearic Islands plateau and in the Gulf of Lions. The persistence map indicated that suitable areas cover also the western coast of the Italian peninsula. In the Adriatic Sea, potential nurseries were located in the inner part of the continental shelf in the coastal part of the basin, extending south along the coasts of the western part as well as along the Montenegro and Albanian coast. Concerning Eastern Mediterranean, in the Aegean Sea, suitable areas were located in the Thracian Sea as well as around Limnos Island. Chub mackerel potential spawning areas at the northern coast of Africa were located in the Gulf of Gabes as well as along the coast of Egypt and Lebanon.

Ecological Characterization (D2.1.3)

Predicted *scomber colias* eggs' occurrence (Figs 2.1.3.2.4.1.4, 2.1.3.2.4.1.5) was found to be consistent with the known distribution of this species across the Mediterranean Sea. The work of Somarakis *et al.* (2002) indicated high larvae concentrations at the offshore waters of the Samothraki plateau and Thermaikos gulf. Other studies indicated as spawning grounds the Thracian Sea, the Srymonikos gulf (Isari *et al.,* 2008; Somarakis *et al.,* 2011a and the area around Limnos Island (Isari *et al.,* 2008). Concerning western Mediterranean, ichthyoplankton surveys in the Spanish waters during the early summer period 1992 indicated areas with high larvae concentrations at the Catalan coast (Olivar and Sabates, 1997). The areas mentioned above coincide with the present results according to the persistence map of *S. colias* eggs, representing preferential or occasional spawning site (Fig. 2.1.3.2.4.1.5).

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between *Scomber colias* spawning grounds and fishing restricted areas (FRAs), where purse seine fishing (i.e. gears targeting *Scomber colias*) is prohibited, was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 -12 months in an annual basis. Purse seine FRAs showed 4.14% overlapping with persistent spawning and up to 7.97% when occasional spawning grounds are included. These areas are shown in Fig 2.1.3.2.4.1.6. These areas can also be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html).

Fig. 2.1.3.2.4.1.6. *Scomber colias* spawning grounds that are under Fishing Restricted Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

2.1.3.2.4.2 Nurseries grounds

Modeling Results (D 2.1.1, D 2.1.2)

Maxent is generating a probability distribution over pixels in the grid, starting from the uniform distribution and repeatedly improving the fit to the data. In order to run MAXENT, we selected as background points the absence data from the surveyed area. A randomly selected 25% of the available data was used as test dataset. Given the small sample size MAXENT was run 10 times on both training and test data (using default settings).

The final fitted MAXENT model included as main effects: CHL (sea surface chlorophyll concentration), SLA (sea level anomaly), Depth and SST (sea surface temperature). CHL was the variable that contributed more to the model (Table 2.1.3.2.4.2.1). The results of this model indicated a higher probability of finding juvenile Chub mackerel present at 0.2 to 3.8 mg m^{-3} CHL, at -5 to 2 and 10 to 14 cm SLA, in waters 25 to 70m depth and SST of 19 to 23 and 26.5 to 28^{o}C (Fig. 2.1.3.2.4.2.1).

Table 2.1.3.2.4.2.1. MAXENT model selection for juvenile *Scomber colias*: estimates of relative contributions of the variables to the MAXENT model.

Variable	**Percent contribution**
CHL	51.1
SLA	23.6
Depth	19.4
SST	5.8

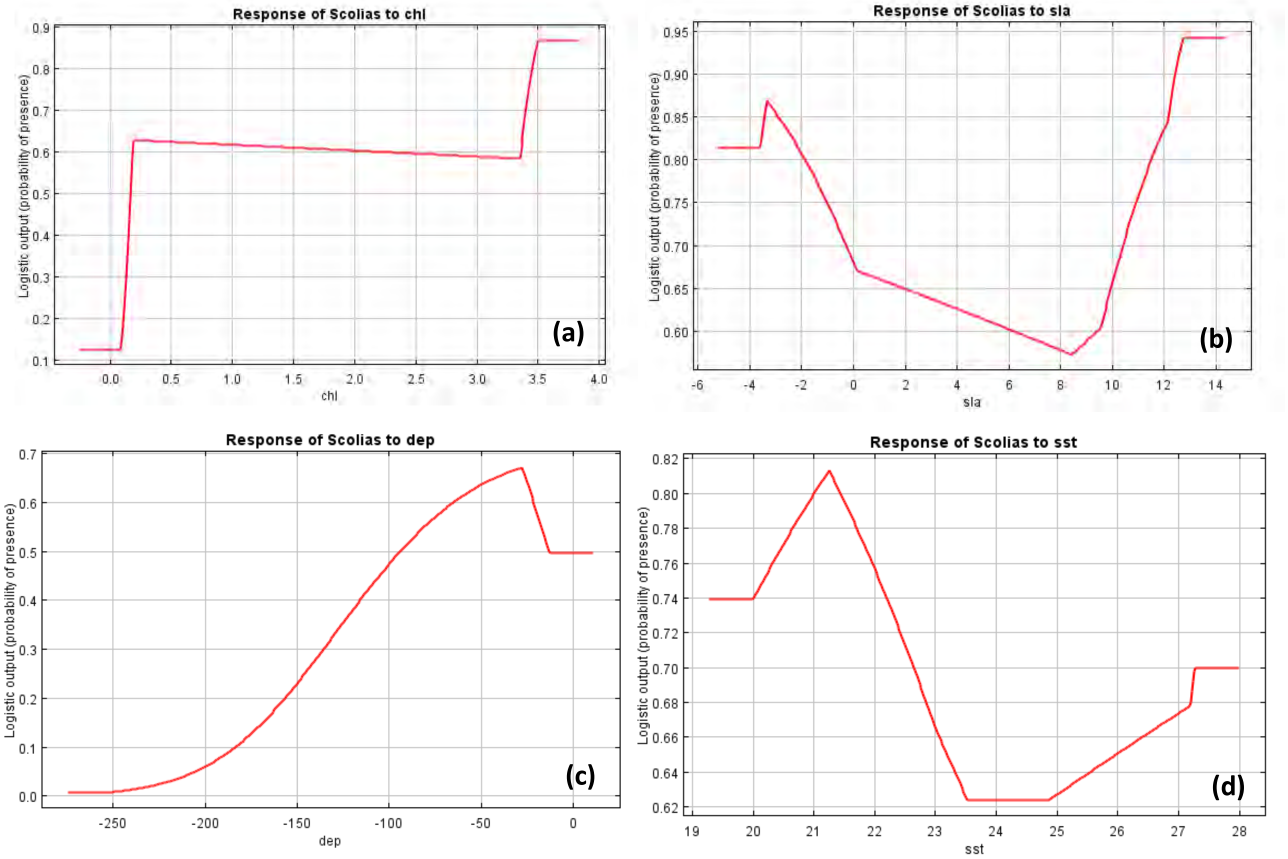

Fig. 2.1.3.2.4.2.1. Coefficients of the Maxent model for juvenile chub mackerel: (a) CHL, sea surface chlorophyll concentration (in mg m^{-3}); (b) SLA, sea level anomaly (in cm), (c) Depth (in m); and (d) SST, sea surface temperature (in ^{o}C).

The omission rate on test samples shows a good match to the predicted omission rate (straight black line) for test data drawn from the Maxent distribution itself (Fig. 2.1.3.2.4.2.2). The average AUC of the test data (25% of the observations) derived from the replicate runs (10 replicates) is 0.683, and the standard deviation is 0.108, which indicates moderate model performance (Fig. 2.1.3.2.4.2.3). The training dataset gain was estimated at 1.3. The gain expresses how many times higher is the average likelihood of the presence samples compared to a random background pixel. Its low value in the specific model was assigned to the fact that we used as background pixels the absence sampling stations from the survey and the respective environmental data at these sites. The background points often closely located to the presence sampling stations combined with the coarse spatial resolution available for certain environmental predictors (e.g. in CHL is up to 9 km) may assign similar or the same values to both presence and absence pixels. This decreases the possibility of high discrimination between presence samples and background pixels.

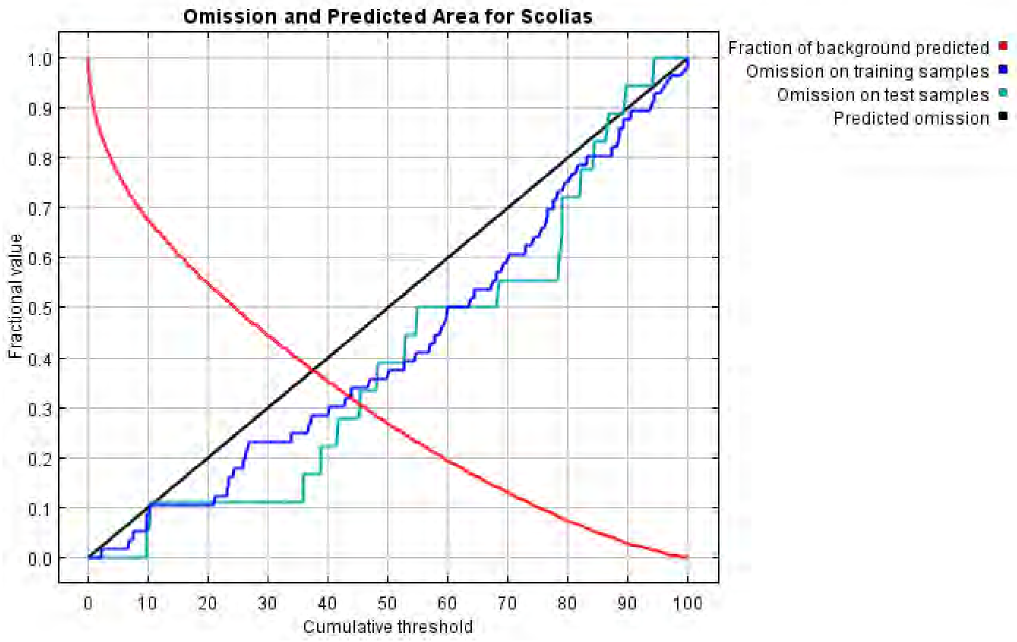

Fig. 2.1.3.2.4.2.2. Omission and predicted area for juvenile *Scomber colias* Maxent model output.

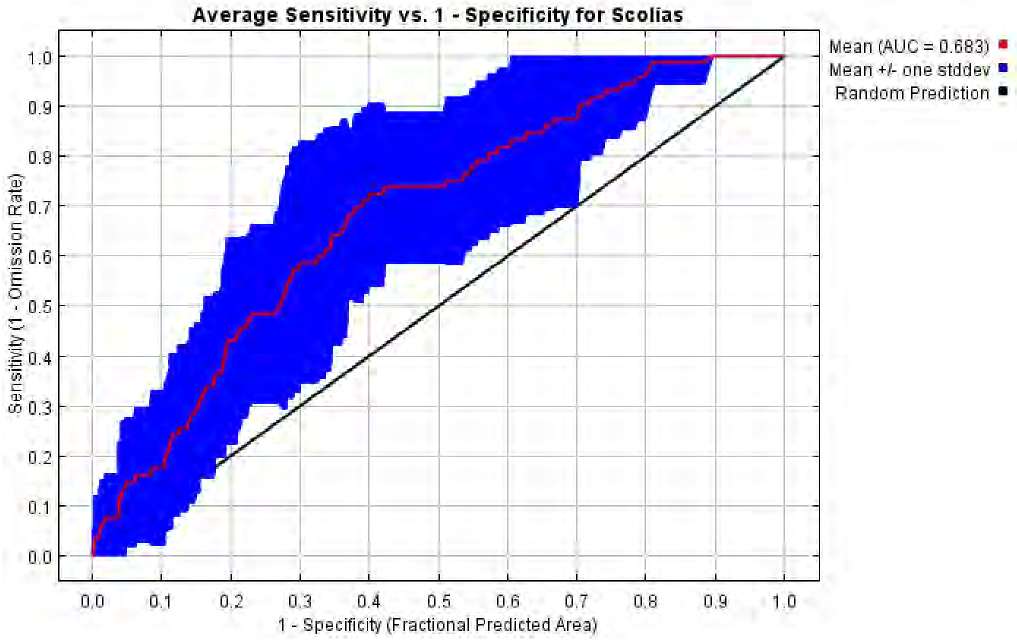

Fig. 2.1.3.2.4.2.3. The receiver operating characteristic (ROC) curve for the test data (25% of the observations) averaged over the replicate runs.

In a subsequent step annual probability maps were obtained (see Annex 2.1.3). Based on these maps the mean probability map was estimated (Fig. 2.1.3.2.4.2.4). Persistence map of chub mackerel nursery grounds is presented in Fig. 2.1.3.2.4.2.5. At this map three levels are indicated: preferential, occasional and rare habitat areas. Details of the maps can easily be seen in the following link in the web based toolbox (GIS viewer) at http://mareaproject.net/mediseh/viewer/med.html.

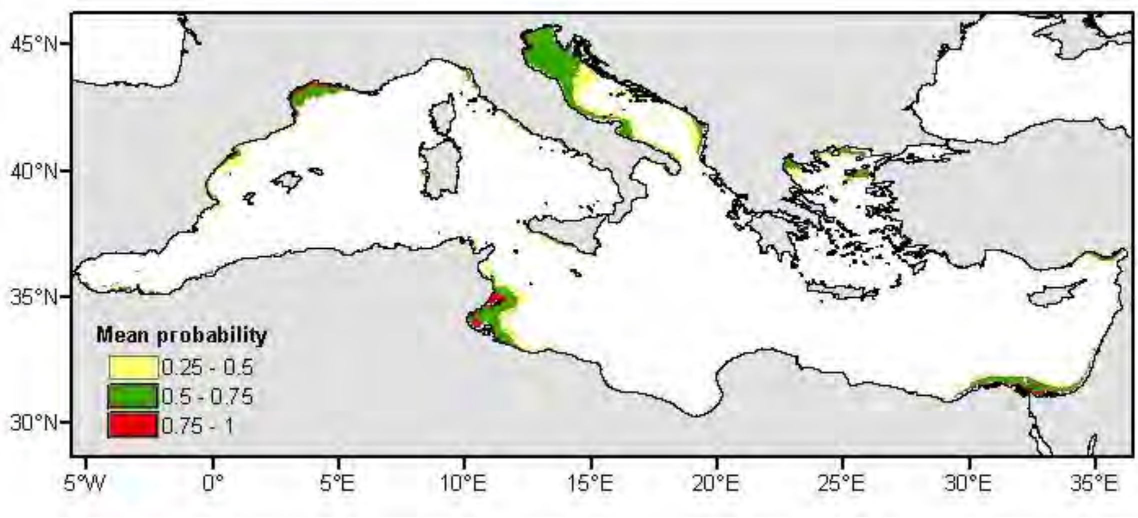

Fig. 2.1.3.2.4.2.4. Mean probability map of juvenile chub mackerel in the Mediterranean Sea for the period 2001–2010 (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html).

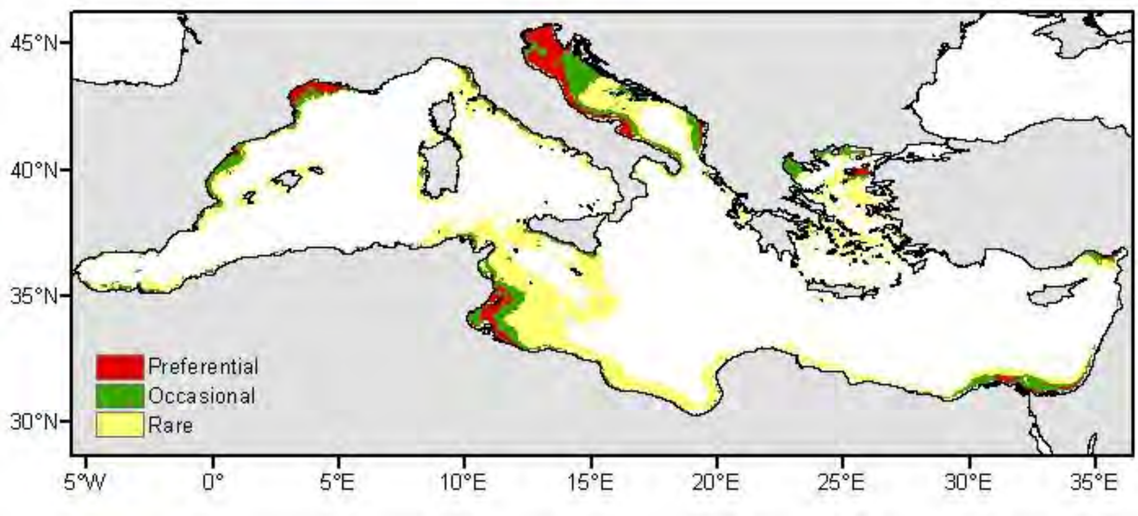

Fig. 2.1.3.2.4.2.5. Persistent habitat map of juvenile chub mackerel in the Mediterranean Sea for the period 2001–2010 (See also web based GIS viewer, http://mareaproject.net/mediseh/viewer/med.html).

In the Western Mediterranean, chub mackerel potential nursery areas were identified to be in association with the outflow of the Ebro River in the Spanish waters, the Arno River in the Ligurian Sea and the Gulf of Lions. The persistence map indicated that suitable areas cover also the western coast of the Italian peninsula. In the Adriatic Sea, potential nurseries were located in the inner part of the continental shelf in the coastal part of the basin, extending south along the coasts of the western part as well as along the Albanian coast. Concerning Eastern Mediterranean, in the Aegean Sea, suitable areas were identified to be in association with the outflow of Nestos River in the Thracian Sea, in Evoikos gulf, at the area among Limnos, Tenedos and Imbros Island, between Chios and the Turkish Mediterranean coast as well as between Samos and the Turkish Mediterranean. Chub mackerel potential nursery areas at the northern coast of Africa were located in the Gulf of Gabes as well as along the coast of Egypt, Israel and Lebanon.

GAMs were also applied concerning the data for juvenile *Scomber colias* explaining 13.6%. However, probability maps obtained were not considered reliable, because of the few data available and the model was not selected for use.

Ecological Characterization (D2.1.3)

Predicted juvenile *Scomber colias* occurrence (Figs 2.1.3.2.4.2.4, 2.1.3.2.4.2.5) was found to be consistent with the known distribution of this species across the Mediterranean Sea. From literature review, it is known that juveniles *Scomber colias* are present in Lebanon (Bariche *et al.,* 2007) and in Izmir (Sever *et al.,* 2006), which coincide with the present results according to the persistence map of juveniles *S. colias*. The areas mentioned above are characterized as occasional juvenile sites (Fig. 2.1.3.2.4.2.5). In Tunisia waters these areas coincide with known distribution grounds in the early 00's (MedSudMed, 2004)

Additionally, the adults of the species are abundant in the coast of Tunisia, Egypt and the Turkish Mediterranean coast, according to official reported landings data in GFCM (FAO 2010). This could be a hint of potential presence of juvenile chub mackerel in these areas, where information concerning the juvenile of the species is largely missing.

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between *Scomber colias* nursery grounds and fishing restricted areas (FRAs), where purse seine fishing (i.e. gears targeting *Scomber colias*) is prohibited, was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 up to 12 months in an annual basis. Purse seine FRAs showed 6.21% overlapping with persistent nurseries and up to 11.88% when occasional nursery grounds are included. These areas are shown in Fig 2.1.3.2.4.2.6. These areas can also be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html).

Fig. 2.1.3.2.4.2.6. *Scomber colias* nurseries that are under Fishing Restricted Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

2.1.3.2.5 Trachurus trachurus

2.1.3.2.5.1 Nurseries grounds

Modeling Results (D 2.1.1, D 2.1.2)

The final selected GAM was based on pooled *Trachurus trachurus* juveniles presence/absence data from MEDITS surveys in GSAs 7,8,10,11,15,16,17,18,22,23 (summer 2000 to 2008) and included as main effects: SST and interactive effect of depth (cubic root transformed) and CHLA (log transformed). SST is the variable initially entered the model, explaining most of the total variation (Table 2.1.3.2.5.1.1). Plots of the best fitting smooths indicate a higher probability of finding *Trachurus trachurus* juveniles present at SST values

17-22°C and greater than 26 °C as well as waters 20-200 m depth when co-occur with CHL-a values at 0.22 to 12.18 mg/lt (Fig. 2.1.3.2.5.1.1).

Areas and years not included in the GAM estimation (GSAs 1, 6, 5, 9, 20) were considered for model validation. Results are shown in Table 2.1.3.2.5.1.2. The selected models showed good to very good prediction ability as the estimated AUC, sensitivity and specificity values were on average 0.78-0.84.

Table 2.1.3.2.5.1.1 GAM model selection for *Trachurus trachurus* nurseries: analysis of deviance for GAM covariates and their interactions of the final models fitted.

Parameter	**Res. Df**	**Res. Deviance**	**Deviance explained %**	**P-value**
s(CHLA, DEpth)+s(SST)	6785.04	5970.44	35.5%	<<0.000

Table 2.1.3.2.5.1.2 Mean values of sensitivity and specificity accuracy measures ± standard error (sterr) for two threshold criteria: MDT (maximize the specificity-sensitivity sum) and prevalence values. The estimated area under the ROC curve (AUC) for each model is also indicated.

Year	**Area**	**AUC**	MDT Sensitivity	MDT Specificity	Prevalence Sensitivity	Prevalence Specificity
2000-2010	GSA 1	0.82	0.77	0.81	0.73	0.81
2000-2010	GSA 5	0.78	0.76	0.71	0.54	0.85
2000-2010	GSA 6	0.84	0.77	0.78	0.48	0.88
2000-2010	GSA 9	0.87	0.97	0.65	0.89	0.73
2000-2008	GSA 20	0.79	0.86	0.59	0.88	0.56

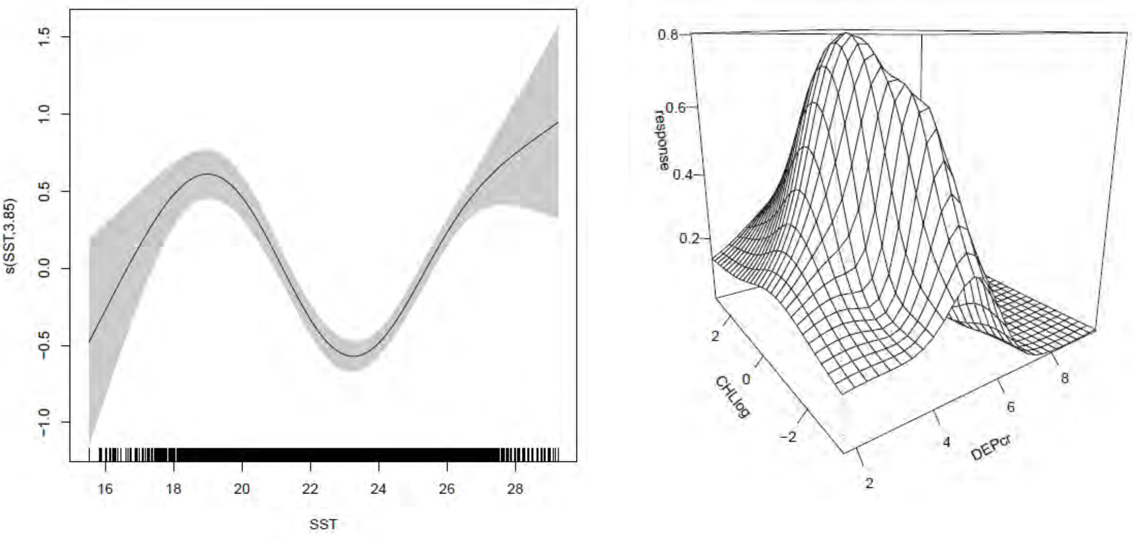

Fig. 2.1.3.2.5.1.1. Coefficients of the Generalized Additive Models (GAMs) for *Trachurus trachurus* nurseries grounds CHLA: log transformed Surface chlorophyll concentration (in mg m^{-3}) SST: Sea Surface Temperature (°C), Depth: Cube root transformed Bottom Depth (in m). The interaction plots are also shown.

In a subsequent step annual probability maps were obtained (see Annex 2.1.3). Based on these maps the mean probability map for *Trachurus trachurus* nurseries were estimated (Fig. 2.1.3.2.5.1.2.) as well as habitat suitability map (hereafter called persistence maps) of *Trachurus trachurus* nurseries (Fig. 2.1.3.2.5.1.3). In each map three levels are indicated: preferential, occational and rare habitat areas.

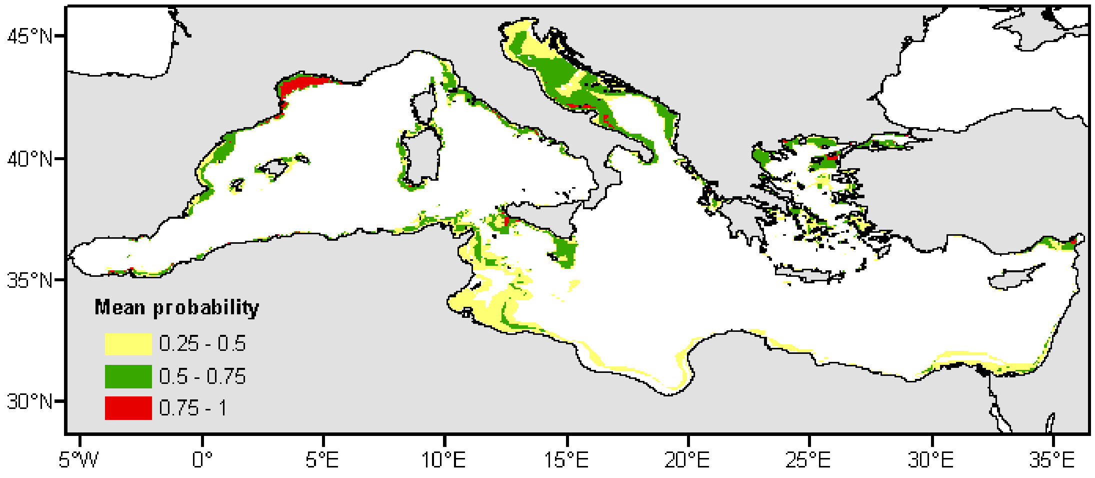

Figure 2.1.3.2.5.1.2. Mean probability maps of *Trachurus trachurus* nurseries in the Mediterranean Sea for the period 2000-2010 during summer **(See also web based GIS viewer** http://mareaproject.net/mediseh/viewer/med.html**).**

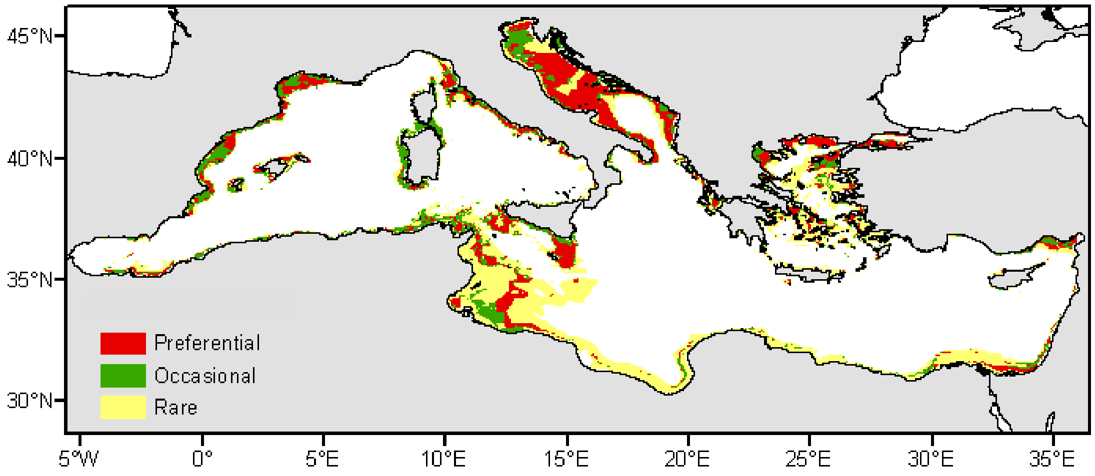

Figure 2.1.3.2.5.1.3. Persistent habitat maps of *Trachurus trachurus* nurseries in the Mediterranean Sea for the period 2000-2010 during summer **(See also web based GIS viewer** http://mareaproject.net/mediseh/viewer/med.html**).**

In the western Mediterranean areas suitable for *Trachurus trachurus* nurseries were consistently identified in the northern part of the Catalan Sea, surroundings of the Ebro River Delta and the Balearees plateau, the Gulf of Lions and the coastal waters of Tyrrhenian Sea (Figs. **2.1.3.2.5.1.2**, **2.1.3.2.5.1.3**). In the Strait of Sicily suitable nurseries are indicated in the Malta plateau and the northwestern part. In the Adriatic Sea where the species is known to be widely distributed (Alegria Hernandez, 1983; 1984), potential nurseries were indicated in the central area of the basin, covering consistently the coastal waters of both the western and the eastern part. In the eastern part of the Mediterranean areas suitable for nurseries were identified in the inshore waters of Thracian Sea and also inside closed gulfs like Saronikos, South Evoikos Gulf (Central Aegean) and Patraikos gulf (Ionian Sea). Landings information collected at Saronikos Gulf at Central Aegean Sea in the middle of the ‘80s also confirm the occurrence of nursery areas (Tsangridis and Filippousis, 1991). Moreover areas were indicated in the western part of Aegean Sea along the Turkish coastal waters. Suitable nurseries were shown near the Nile Delta and in the offshore waters of Tunisia (Figs. **2.1.3.2.5.1.2**, **2.1.3.2.5.1.3**).

Ecological Characterization (D2.1.3)

Suitable nurseries for *Trachurus trachurus* generally distribute on the continental platform and occasionally close to the shelf break in certain areas (e.g. Gulf of Lions, Thracian Sea, central Adriatic Sea and Tunisian waters. Specifically, based on model results as suitable nurseries for *Trachurus trachurus* were indicated areas presenting SST values 17-22^{o}C or greater than 26 ^{o}C as well as coastal waters from 20-200 m deep when co-occurring with medium to highly productive waters (CHL values at 0.22 to 12.18 mg/lt).

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between *Trachurus trachurus* nursery grounds and fishing restricted areas (FRAs), where purse seine fishing, pelagic trawl and bottom trawl (i.e. gears targeting *Trachurus trachurus*) are prohibited, was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 up to 12 months in an annual basis. Purse seines FRAs showed 5.19% overlapping with persistent nurseries and up to 12.13% when occasional nursery grounds are included. Bottom trawls FRAs showed 7.13 % overlapping with persistent nurseries and up to 20.38% when occasional nursery grounds were included. These areas are shown in Figs 2.1.3.2.5.1.4- 2.1.3.2.5.1.5. Pelagic trawls restrictions showed 19.62 % overlapping with persistent nurseries and up to 41.59% when occasional nursery grounds were included. These areas can also be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html).

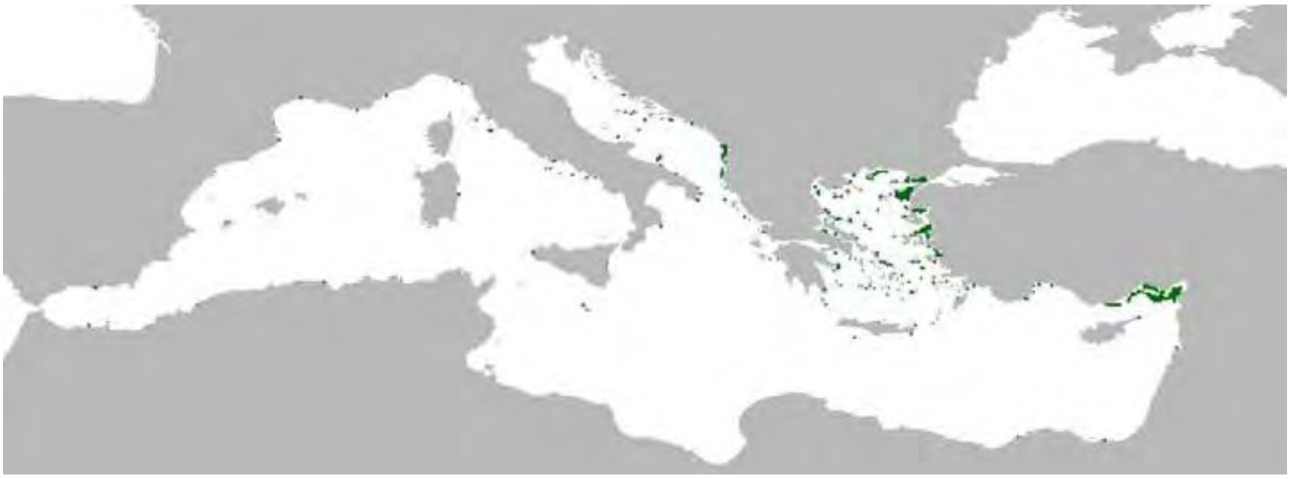

Fig. 2.1.3.2.5.1.4. *Trachurus trachurus* nurseries that are under Fishing Restricted Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

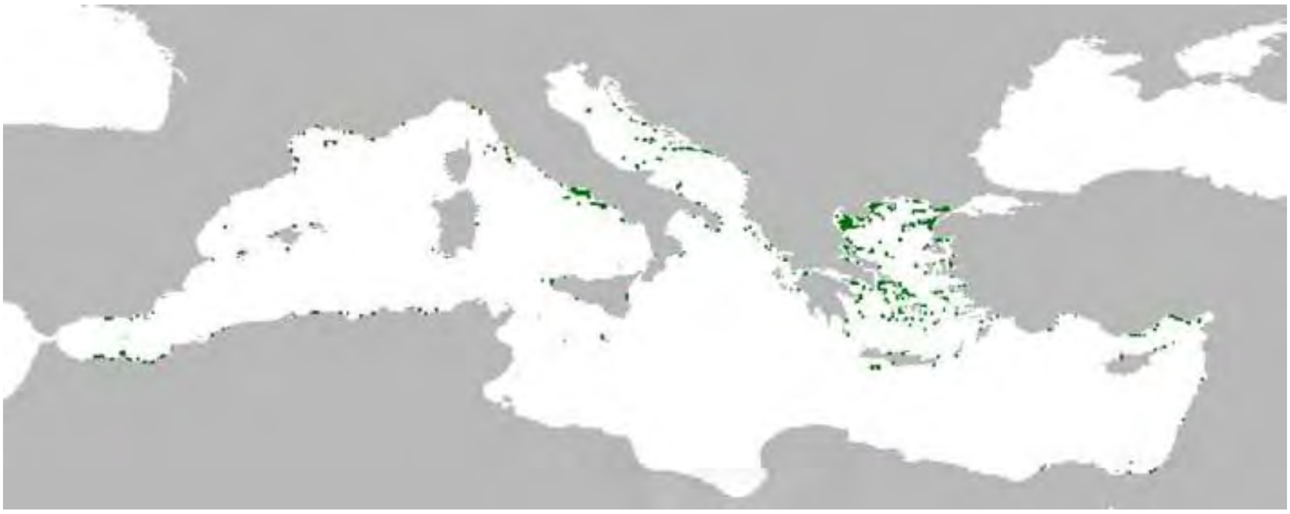

Fig. 2.1.3.2.5.1.5. *Trachurus trachurus* nurseries that are under Fishing Restricted Areas where bottom trawl is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

2.1.3.2.6 Trachurus mediterraneus

2.1.3.2.6.1 Spawning grounds

Modeling Results (D 2.1.1, D 2.1.2)

A) Bottom trawl surveys

The final selected GAM was based on pooled *Trachurus mediterraneus* spawners presence/absence data from MEDITS surveys in GSAs 7,8,10,11,18,20,22,23 (summer 2000 to 2008) and included as main effects: SST, depth (cubic root transformed) and SLA. Depth is the variable initially entered the model, explaining most of the total variation (Table 2.1.3.2.6.1.A.1). Plots of the best fitting smooths indicate a higher probability of finding *Trachurus mediterraneus* spawners present at SST values <22^{o}C as well as waters 20-200 m depth when co-occur with SLA at >5 cm(Fig. 2.1.3.2.6.1.A.1).

Areas and years not included in the GAM estimation (GSAs 1, 6, 5, 17) were considered for model validation. Results are shown in Table 2.1.3.2.6.1.A.2. The selected models showed good to very good prediction ability as the estimated AUC, sensitivity and specificity values were on average 0.74-0.84.

Table 2.1.3.2.6.1.A.1 GAM model selection for *Trachurus mediterraneus* spawners: analysis of deviance for GAM covariates of the final model fitted.

Model	Res. Df	Res. Deviance	Deviance explained %	AIC	P-value
s(Depth)+s(SLA) + s(SST)	4230.01	3127.62	27	3145.59	<<0.000

Table 2.1.3.2.6.1.A.2 Mean values of sensitivity and specificity accuracy measures ± standard error (sterr) for two threshold criteria: MDT (maximize the specificity-sensitivity sum) and prevalence values. The estimated area under the ROC curve (AUC) for each model is also indicated.

Year	**Area**	**AUC**	MDT Sensitivity	MDT Specificity	Prevalence Sensitivity	Prevalence Specificity
2000-2010	GSA 1,5,6	0.84	0.547	0.869	0.926	0.637
2000-2010	GSA 17	0.74	0.723	0.682	1	0.05

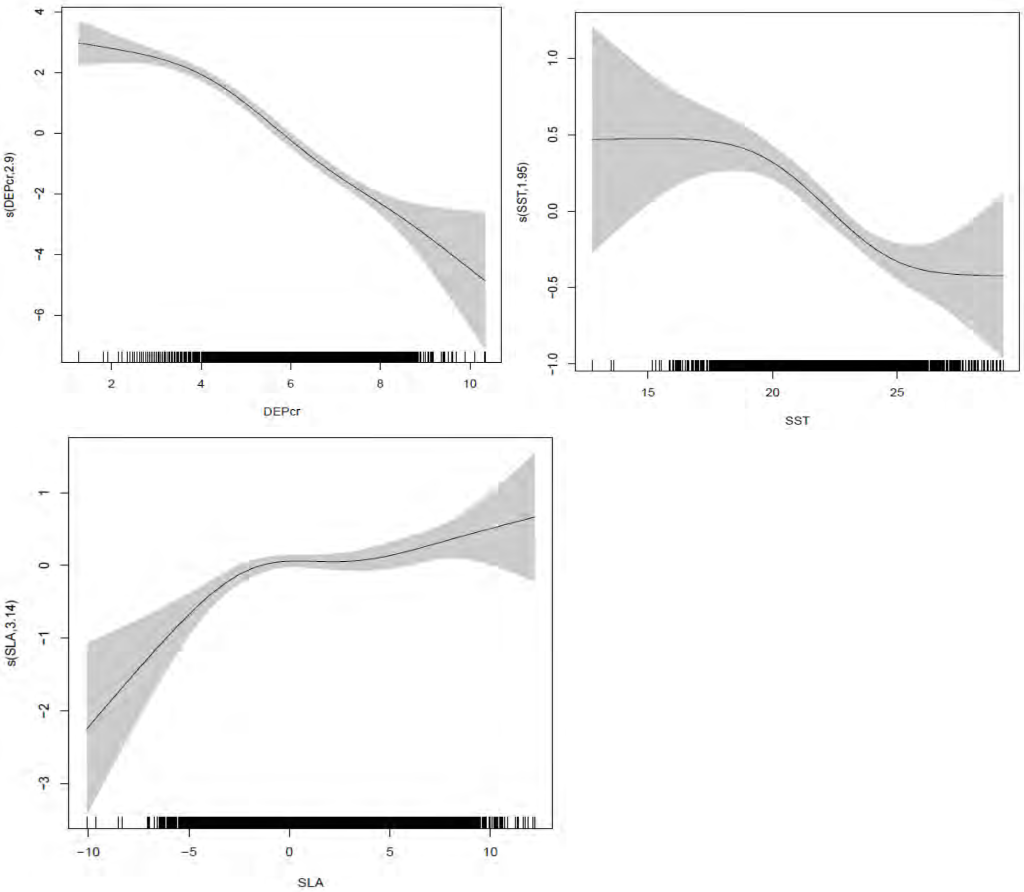

Fig. 2.1.3.2.6.1.A.1. Coefficients of the Generalized Additive Models (GAMs) for *Trachurus mediterraneus* spawning grounds SST: Sea Surface Temperature (^{o}C), SLA: Sea Level Anomaly (in cm), Depth: Cube root transformed Bottom Depth (in m).

In a subsequent step annual probability maps were obtained (see Annex 2.1.3). Baesd on these maps the mean probability map for *Trachurus mediterraneus* spawners were estimated (Fig. 2.1.3.2.6.1.A.2**.**) as well as habitat suitability map (hereafter called persistence maps) of *Trachurus mediterraneus* spawning grounds (Fig. 2.1.3.2.6.1.A.2**.**). In each map three levels are indicated: preferential, occational and rare habitat areas.

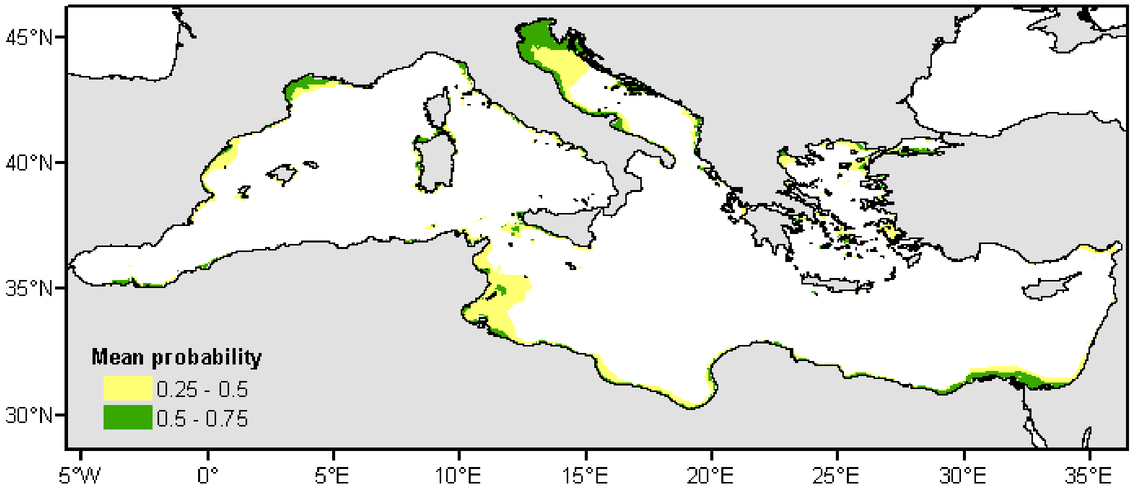

Fig. 2.1.3.2.6.1.A.2. Mean probability maps of *Trachurus mediterraneus* spawning grounds in the Mediterranean Sea for the period 2000-2010 during summer **(See also web based GIS viewer** http://mareaproject.net/mediseh/viewer/med.html**).**

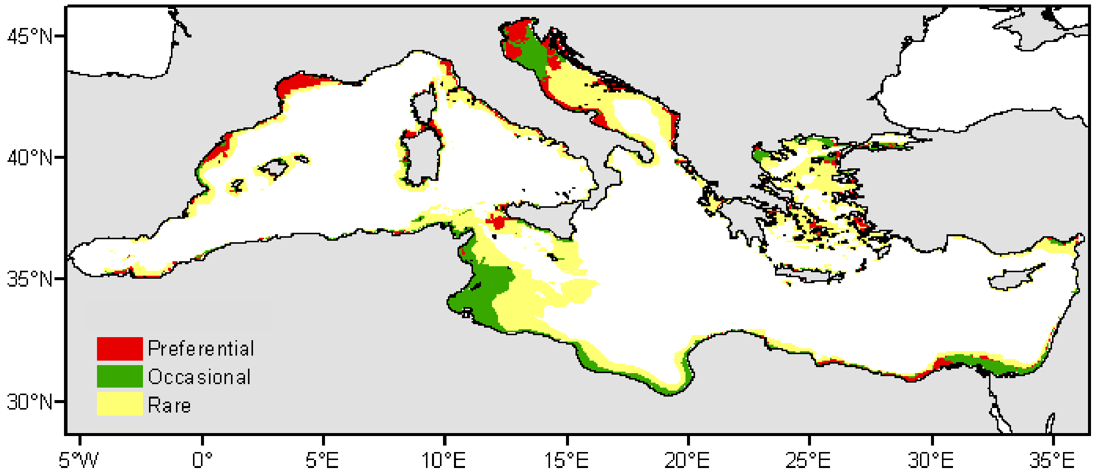

Fig. 2.1.3.2.6.1.A.3. Persistent habitat maps of *Trachurus mediterraneus* spawning grounds in the Mediterranean Sea for the period 2000-2010 during summer **(See also web based GIS viewer** http://mareaproject.net/mediseh/viewer/med.html**).**

In the western Mediterranean areas suitable for *Trachurus mediterraneus* spawning grounds were consistently identified in the northern part of the Catalan Sea, the Gulf of Lions and the coastal waters of Ligurian Sea (Figs. 2.1.3.2.6.1.A.2**.**, 2.1.3.2.6.1.A.3**.**). In the Strait of Sicily suitable spawning grounds are limited in the northwestern part. In the Adriatic Sea potential spawning grounds were indicated in the northern part of the basin and in the coastal waters of the central-southern part. Limited spawning grounds were identified in the north western part of the Dalmatian islands. In the eastern part of the Mediterranean areas persistent spawning grounds were identified in the inshore waters of Saronikos and Thermaikos gulf as well as in the gulf of the eastern Aegean Sea along the Turkish coast (See details in the web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

B) Ichthyoplankton surveys

Maxent is generating a probability distribution over pixels in the grid, starting from the uniform distribution and repeatedly improving the fit to the data. In order to run MAXENT, we selected as background points the absence data from the surveyed area. A randomly selected 25% of the available data was used as test dataset. Given the small sample size MAXENT was run 5 times on both training and test data (using default settings).

The final fitted MAXENT model included as main effects: Sea Level Anomaly (SLA), depth, Chl-a, Photosynthetic Active Radiation (PAR) and SST. CHL was the variable found most important in the training dataset followed by depth and SLA. Depth was the most important variable concerning the test dataset.

Model predictions were evaluated based on the threshold independent Receiver Operator Characteristic (ROC) was employed which yields the Area Under Curve (AUC) as an indicator of model performance (Hanley and McNeil, 1982) that are commonly applied to species distribution models (Hirzel and Guisan, 2002; Phillips *et al.,* 2006).

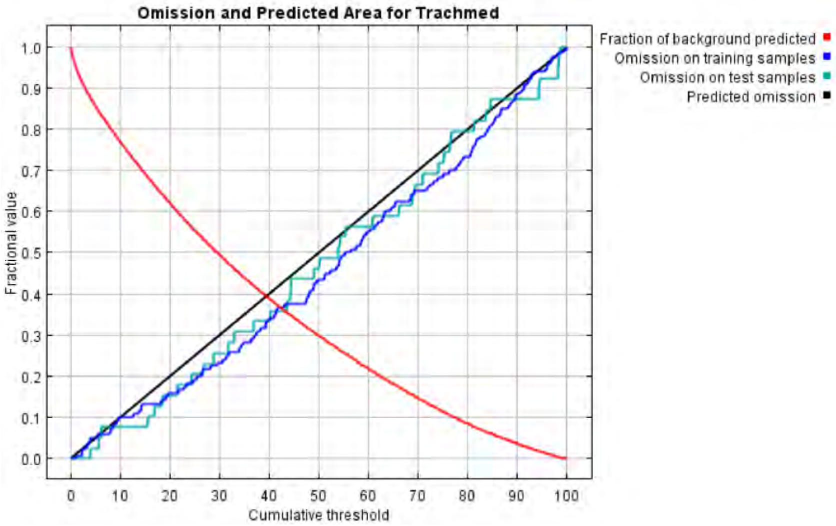

Fig. 2.1.3.2.6.1.B.1. Omission error and predicted area for Trachurus mediterraneus (larvae) Maxent model output.

The omission on test samples shows a good match to the predicted omission rate (straight black line) for the omission rate for test data drawn from the Maxent distribution itself (**Fig. 2.1.3.2.6.1.B.1.**). The AUC criterion showed moderate model fit being equal to 0.68. The training dataset gain was estimated at 1.5. The gain expresses how many times higher is the average likelihood of the presence samples compared to a random background pixel. Its low value in the specific model was assigned to the fact that we used as background pixels the absence sampling stations from the survey and the respective environmental data at these sites. Thus the background points were often closely located to the presence sampling stations. This along with the coarse spatial resolution available for certain environmental predictors (e.g. in Chl is up to 9 km) similar or the same values for certain predictors can be assigned to both presence and absence pixels. This decreases the possibility of high discrimination between presence samples and background pixels.

In a subsequent step annual probability maps were obtained (see Annex 2.1.3). Based on these maps the mean probability map for *Trachurus mediterraneus* spawners were estimated (Fig. 2.1.3.2.6.1.B.2**.**) as well as habitat suitability map (hereafter called persistence maps) of *Trachurus mediterraneus* spawning grounds (Fig. 2.1.3.2.6.1.B.3**.**). In each map three levels are indicated: preferential, occational and rare habitat areas.

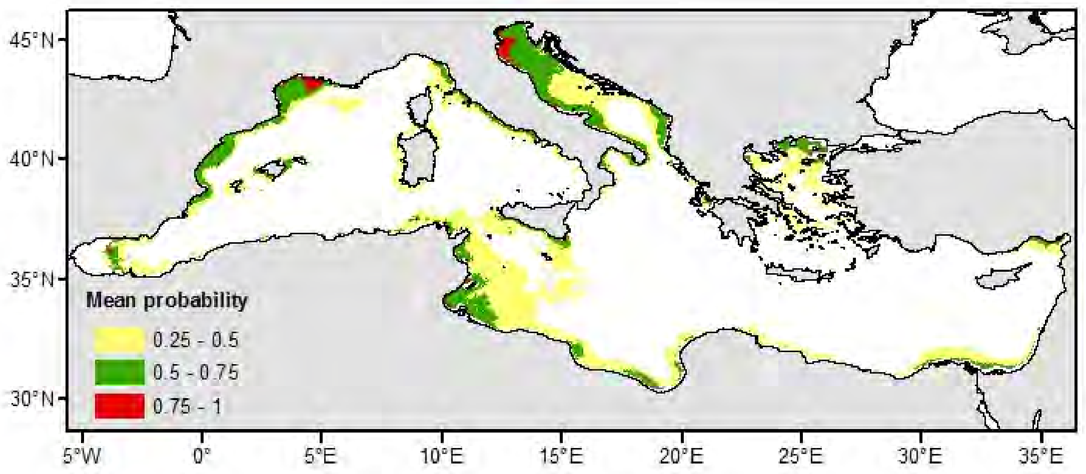

Fig. 2.1.3.2.6.1.B.2. Mean probability maps of *Trachurus mediterraneus* spawning grounds (based on MAXENT results and larvae data) in the Mediterranean Sea for the period 2000-2010 during summer.

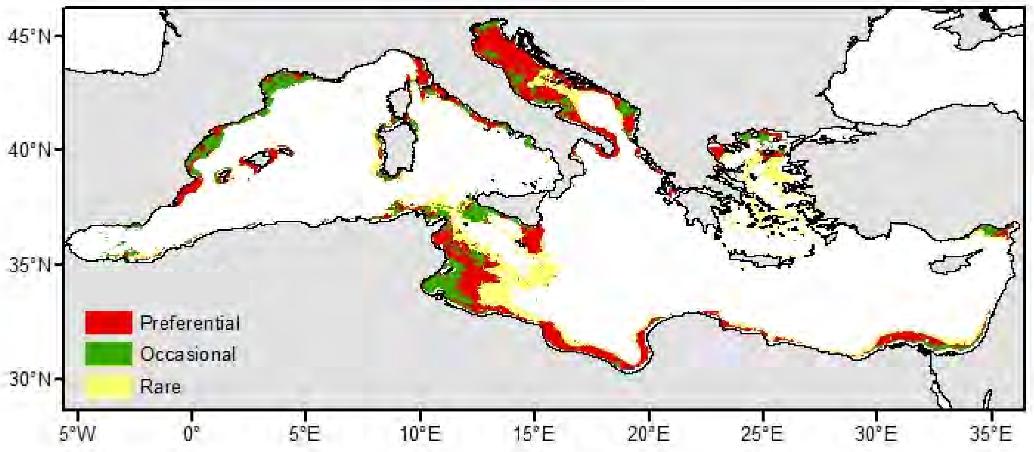

Fig. 2.1.3.2.6.1.B.3. Persistent habitat maps of *Trachurus mediterraneus* spawning grounds (based on MAXENT results and larvae data) in the Mediterranean Sea for the period 2000-2010 during summer.

Potential spawning grounds as estimated from larvae data generally match the potential spawning grounds estimated based on spawners (MEDITS data) although the former consist comparably more extended areas. This is explainable in terms of larvae dispersal: Early larvae development can last several days during which they can be advected away from original spawning sites (e.g. Ospina-Alvarez *et al.,* 2011).

Finally the Consortium experts decided to select as more suitable model for management advice and include in the web based GIS viewer only the GAM model for spawners (MEDITS data). This model was based on a higher number of samples covering extended areas of the north part of the Mediterranean Sea opposed to the MAXENT model which was based on larvae data limited in the Eastern Mediterranean (Aegean Sea) and exhibited moderate model performance.

Ecological Characterization (D2.1.3)

Pesristent areas indicated as suitable spawning grounds for *Trachurus mediterraneus* were identified in areas over the continental shelf presenting SST values <22^{o}C during summer, co-occurring with downwelling phenomena (SLA values at 5 cm). However the occasional areas (where spawning grounds indicate high probability of occurring in some years but not in others) are more extensive, covering the more productive waters over the continental shelf (e.g. Thracian Sea in North Aegean, the north part of the Adriatic Sea or the Ebro area in the Spanish Mediterranean waters).

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between *Trachurus mediterraneus* spawning grounds and fishing restricted areas (FRAs), where purse seine fishing, pelagic trawl and bottom trawl (i.e. gears targeting *Trachurus mediterraneus*) are prohibited, was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 up to 12 months in an annual basis. Purse seines showed 9.14% overlapping with persistent spawning and up to 14.27% when occasional spawning grounds are included. Bottom trawls FRAs showed 18.21 % overlapping with persistent spawning and up to 30.83% when occasional spawning grounds were included. These areas are shown in Figs 2.1.3.2.6.1.4 - 2.1.3.2.6.1.5. Pelagic trawls restrictions showed 18.76 % overlapping with persistent spawning and up to 30.74% when occasional spawning grounds were included. These areas can also be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html).

Fig. 2.1.3.2.6.1.4. *Trachurus mediterraneus* spawning areas that are under Fishing Restricted Areas where purse seine fishing is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

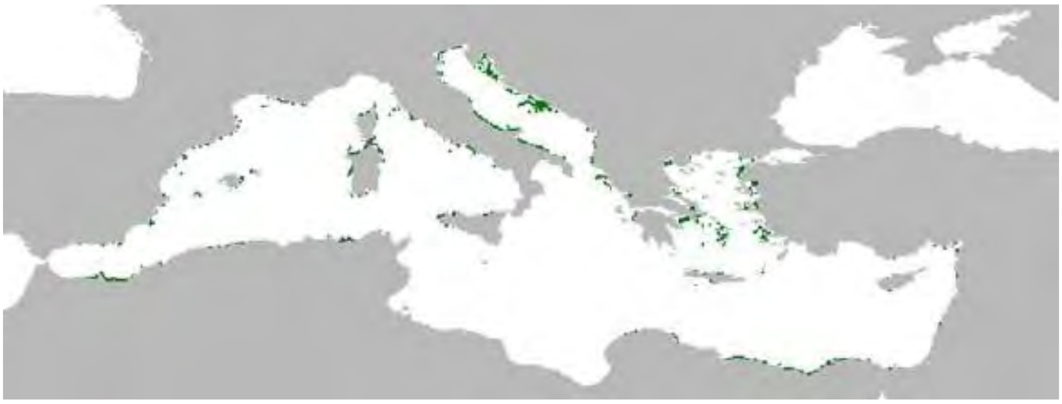

Fig. 2.1.3.2.6.1.5. *Trachurus mediterraneus* spawning areas that are under Fishing Restricted Areas where bottom trawl is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

2.1.3.2.6.2 Nurseries grounds

Modeling Results (D 2.1.1, D 2.1.2)

The final selected GAM was based on pooled *Trachurus mediterraneus* juveniles' presence/absence data from acoustic surveys in GSAs 1 and 6 (mid November-mid December 2003 to 2009) and included as main effects: depth and CHL (log transformed) as well as the interactive effect of SST with SLA (Table 2.1.3.2.6.2.1). The model explained a 31.3% of the total variance. The model shows that juvenile Mediterranean horse mackerel are found between 20 and 90 m depth with a preference for depth ranges between about 30 and 65 m depth. Furthermore, the higher probability of presence of juvenile Mediterranean horse mackerel was found at CHL between 0.47 and 2.23 mg m^{-3}. Upwelling areas combined with low SST, i.e. SLA between -2.5 and 0 cm and SST between 14 and 16.5ºC, were as well preferred at the same time than moderate downwelling areas with higher temperatures, i.e. SLA between 0 and 5 cm and SST between 16.5 and 18.5ºC (Fig. 2.1.3.2.6.2.1). All the AUC values of the years included in the model are above 0.80, while the AUC values for the year 2003 and 2009 that are not included in the model and are used only for validation purposes are0.78 and 0.76, respectively (Table 2.1.3.2.6.2.2).

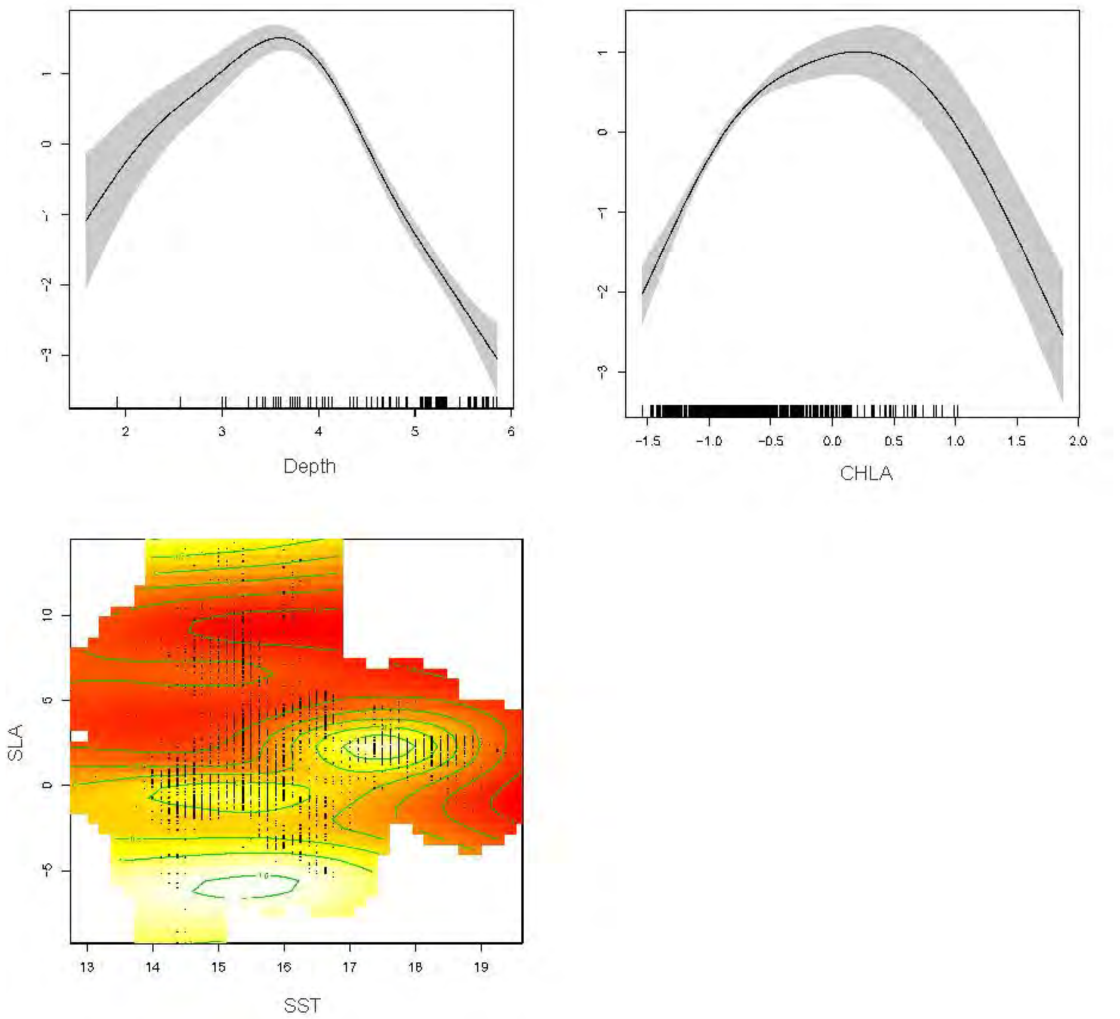

Fig. 2.1.3.2.6.2.1. Coefficients of the Generalized Additive Models (GAMs) *Trachurus mediterraneus* nursery grounds in Late autumn (mid November – mid December) CHL: log transformed Surface chlorophyll concentration (in mg m^{-3}) SST: Sea Surface Temperature (^{o}C), SLA: Sea Level Anomaly (in cm), Depth: Cube root transformed Bottom Depth (in m). The interaction plots are also shown.

Table 2.1.3.2.6.2.1. GAM model selection for *Trachurus mediterraneus* nursery grounds: analysis of deviance for GAM covariates and their interactions of the final models fitted.

Period	Model	Res. Df	Res. Deviance	Deviance explained %	AIC	P-value
Nov-Dec	Spanish Mediterranean model					
	s(Depth)+s(CHLA)+s(SLA, SST)	4767	4562	31.3	4614	<<0.000

Table 2.1.3.2.6.2.2. Mean values of sensitivity and specificity for two threshold criteria: MDT (maximize the specificity-sensitivity sum) and prevalence values. The estimated area under the ROC curve (AUC) for each model is also indicated. , Years used only for validation purposes are in bold.

Year	Area	AUC	MDT Sensitivity	MDT Specificity	Prevalence Sensitivity	Prevalence Specificity
2003	**N. and S. Spanish Medit.**	**0.78**	**0.83**	**0.62**	**0.76**	**0.66**
2004	N. and S. Spanish Medit.	0.82	0.76	0.74	0.77	0.72
2005	N. and S. Spanish Medit.	0.86	0.85	0.72	0.78	0.77
2006	N. and S. Spanish Medit.	0.89	0.80	0.84	0.83	0.80
2007	N. and S. Spanish Medit.	0.84	0.83	0.76	0.78	0.80
2008	N. and S. Spanish Medit.	0.82	0.85	0.67	0.86	0.67
2009	**N. and S. Spanish Medit.**	**0.76**	**0.82**	**0.61**	**0.51**	**0.78**

In a subsequent step annual probability maps were obtained (see Annex 2.1.3). Based on these maps the mean probability map for early winter nursery grounds were estimated (Fig. 2.1.3.2.6.2.2) as well as persistence map of juvenile Mediterranean horse mackerel (Fig. 2.1.3.2.6.2.3). In each map three levels are indicated: preferential, occational and rare habitat areas.

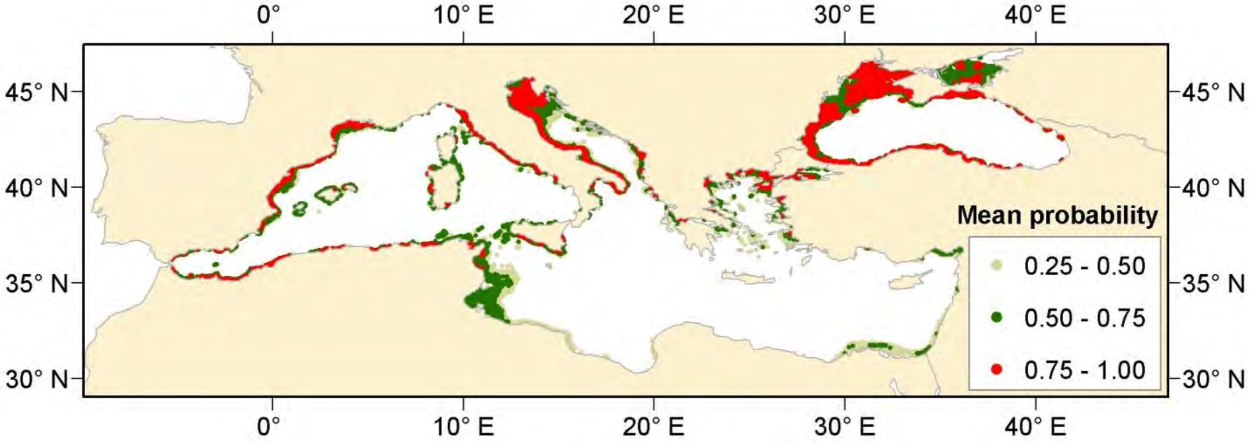

Fig. 2.1.3.2.6.2.2. Mean probability maps of juvenile *Trachurus mediterraneus* habitat in the Mediterranean Sea for the period 2003-2009 during early winter **(See also web based GIS viewer** http://mareaproject.net/mediseh/viewer/med.html**).**

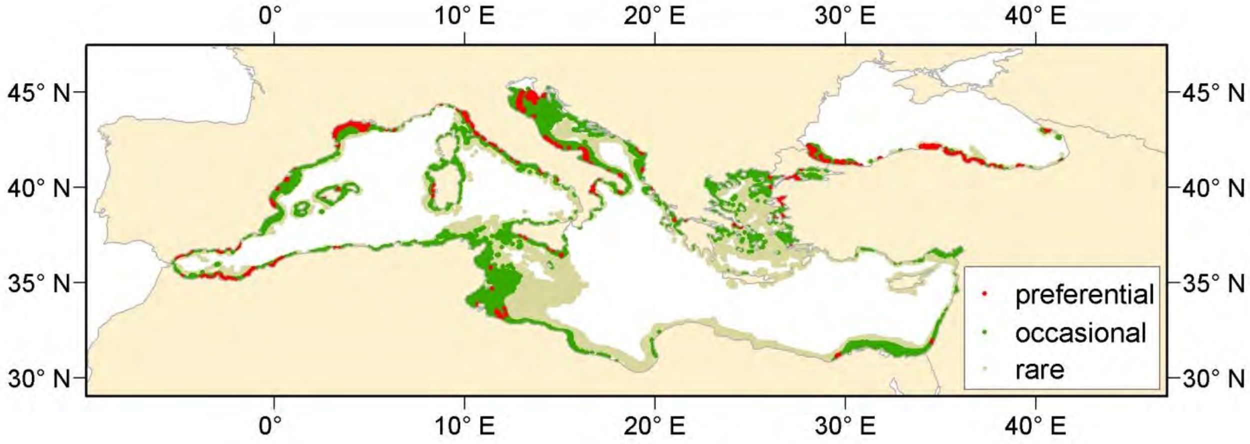

Fig. 2.1.3.2.6.2.3. Persistent habitat maps of juvenile *Trachurus mediterraneus* habitat in the Mediterranean Sea for the period 2003-2009 during early winter (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

Maps showed that the largest areas of juvenile Mediterranean horse mackerel are predicted throughout the Mediterranean coastal areas with the higher probabilities being found in the Adriatic, North-Western Mediterranean and Morocco and Argelian coasts (Fig. 2.1.3.2.6.2.2).

Preferential habitat areas for *Trachurus mediterraneus* juveniles are located at the coastal waters of North Adriatic Sea, Gulf of Lions and Alboran Sea (both Northern and Southern areas). More extended were the occational areas covering related mainly to continental shelf areas (e.g. Gulf of Gabes, Adriatic Sea, Spanish waters (see Fig 2.1.3.2.6.2.3).

Ecological Characterization (D2.1.3)

Pesristent areas indicated as suitable nurseries for *Trachurus mediterraneus* were identified in shallow waters areas between about 30 and 65 m depth when associated to productive waters (0.47 and 2.23 mg m^{-3}), moderate upwelling and SST between 14 and 16.5ºC. However, the occasional areas (where nurseries indicate high probability of occurring in some years but not in others) are more extensive, covering the more productive waters over the continental shelf (e.g. Thracian Sea in North Aegean as well as the gulfs in Central Aegean Sea, the north part of the Adriatic Sea, the Catalan Sea and the Ebro Riarea in the Spanish Mediterranean waters).

Spatial overlapping with fishing restricted areas and Marine Protected Areas (D2.1.4)

The spatial overlapping between *Trachurus mediterraneus* nurseries and fishing restricted areas (FRAs), where purse seine fishing, pelagic trawl and bottom trawl (i.e. gears targeting *Trachurus mediterraneus*) are prohibited, was estimated by means of GIS techniques. It should be noted that FRAs refer to areas where fishing restrictions apply from 2 up to 12 months in an annual basis. Purse seines showed 8.82% overlapping with persistent nurseries and up to 17.36% when occasional nursery grounds are included. Concerning bottom trawls 24.13 % overlapping was estimated with persistent nurseries and up to 42.33% when occasional nurseries were included. Pelagic trawls restrictions showed 16.14% overlapping with persistent nurseries and up to 36.24% when occasional nursery grounds were included. These areas are shown in Fig 2.1.3.2.6.2.4. These areas can also be seen in detail in the web based GIS viewer at the following link http://mareaproject.net/mediseh/viewer/med.html).

Fig. 2.1.3.2.6.2.4. *Trachurus mediterraneus* nursery areas that are under Fishing Restricted Areas where pelagic trawl is prohibited (See also web based GIS viewer http://mareaproject.net/mediseh/viewer/med.html).

Overall comments/Summarizing results

Our objective and challenge was to identify potential persistent juvenile and spawning grounds based on habitat modeling for the main commercial small pelagic species (*Engraulis encrasicolus, Sardina pilchardus, Trachurus mediterraneus, Trachurus trachurus, Scomber colias, Scomber scombrus)* within the Mediterranean basin. The Mediterranean Sea has been characterized as a miniature ocean and although generally considered as oligotrophic, it is highly heterogeneous in terms of hydrography, bathymetry and productivity. It comprises different kinds of ecosystems including areas with strong upwelling like the Alboran Sea and the Sicily Channel; closed basins with shallow waters and high productivity like the Adriatic Sea; coastal areas that are under the influence of strong river outflow with subsequent nutritional forcing and human impact like the North-Western Mediterranean and less productive areas like the Aegean Sea, characterized by peculiar topography with many semi-closed basins under Black Sea Water influence. Thus to a large degree suitable areas for spawning and juvenile grounds of migratory, short lived species like small pelagic are linked to environmental variability.

Potential habitat maps for *Engraulis encrasicolus, Sardina pilchardus, Trachurus mediterraneus, Trachurus trachurus, Scomber colias, Scomber scombrus* concerning spawning and nurseries grounds based on the analysis of available surveys data (i.e. acoustic, ichthyoplankton, pelagic and bottom trawl) and the application of modeling techniques are probably the most accurate presently available at their spatial scale for the Mediterranean Sea.

Suitable spawning grounds determination for anchovy was based on ichthyoplanklton surveys data. A consistent preference for 40 - 160 m bathymetric range and more productive waters was indicated. In the western Mediterranean, persistent suitable spawning areas were located in the Gulf of Lions and off the Catalan coast, the Alboran Sea and to a lesser extent the Italian coasts of the Ligurian and Tyrrhenian Seas. In the Adriatic Sea persistent areas with higher probability of anchovy spawning were consistently indicated in the northern and the western part of the basin as well as around the coastal waters of the mid-Dalmatian islands in the eastern part. In the Strait of Sicily persistent spawning grounds were indicated along the coastal waters of Sicily, being more extended in the west and east part. In the Aegean Sea, besides the northern part and the coastal areas within gulfs that are known spawning grounds for anchovy, persistent areas were also identified in the coastal areas of Asia Minor, along the Turkish coasts. Going south, persistent spawning grounds for anchovy were also identified in the Gulf of Gabes in Tunisia, the coasts of Egypt and the northeastern corner of the Levantine Basin.

In the Mediterranean Sea anchovy spawns from spring to autumn with a peak in June/ July thus late autumn and winter are periods with high percenatges of juveniles in the population. However, available acoustic surveys during this period are limited and the majority was carried out in the Spanish Mediterranean waters. Our analysis showed that anchovy juvenile habitats were located in high productivity waters within the continental shelf. These habitats were more extended in late autumn (i.e., up to 160 m depth) compared to later in season (15-90 m depth). Bathymetry and SST along with productivity were the variables that largely determined anchovy juvenile habitat. A selection for shallower/more coastal waters as season progresses from autumn to winter was denoted. Potential juvenile habitats presented high interannual variability implying the vulnerability of potential nurseries to changing environmental conditions. Most persistent juvenile grounds were identified in the Western Mediterranean in association with the outflow of the Rhone river in the Gulf of Lions and the Ebro river southwards in the Spanish waters. In the Adriatic Sea, persistent potential nurseries were located in the inner part of the continental shelf in the coastal part of the basin. They were closely associated with the Po river outflow area, also extending southwards along the coasts of the western and the eastern part of the Adriatic Sea. Suitable areas in the Strait of Sicily were also located in coastal waters being wider in the north and south part where the continental shelf is wider. Potential juvenile grounds are also indicated along the North Africa coast in association to productive areas like the Gulf of Gabes in Tunisia and the Nile Delta region. Areas are also indicated in the coastal waters of the North Alboran Sea and the western part of the Italian Peninsula (i.e., the Ligurian and the Tyrrhenian Sea) but representing suitable habitat for anchovy only occasionally depending on the interannual variability of environmental conditions.

Sardines are known to spawn in the Mediterranean Sea mainly from October to April. Therefore, during the early summer, the sardine population is a mixture of juveniles and adults, dominated by the young of the year. Locations presenting high variability as sardine juvenile grounds were the coastal waters of the North Alboran Sea, the Sicily Strait, the western part of the Italian Peninsula (i.e. the Ligurian and the Tyrrhenian Sea and the area around the island of Sardinia), the Cretan Shelf in Greek seas and areas along the coastline of the Levantine. These areas seem to represent suitable positions for sardine juveniles occasionally, largely depending on the annual variability of environmental conditions. The most persistent sardine juvenile grounds were located in the coastal waters of the north western part of the Adriatic and around the coastal waters of the mid-Dalmatian islands in the eastern part. In Spanish waters, persistent juvenile grounds are located in the Catalan Sea as well as near the mouth of the Ebro River. Similarly, in the south part of the basin along the North African coast where information on small pelagic nursery grounds is generally lacking, persistent areas are indicated in the coastal waters of Morocco and Algeria, the gulf of Gabes in Tunisia and the Nile Delta area.

Persistent potential spawning grounds for sardine have been identified in the Catalan Sea, the Baleares plateau, the coastal waters of the Thyrrenian and Ligurian Sea, the gulfs in both sides of Aegean Sea. Locations presenting high variability, characterized as occasional spawning grounds were the western part of the Adriatic Seas, the Thracian plateau in Aegean Sea and most part of the Gulf of Lions. In the Africa coast persistent grounds occur in the Gulf of Gaben, along the Libyan coast and the Nile Delta area.

For certain species revised information showed almost complete lack of knowledge for both nurseries and spawning grounds e.g. Trachurus spp., Scomber ssp. We managed to solve this issue by using for *Trachurus spp*. MEDITS Trawl survey information along with acoustic surveys and we largely improved our knowledge. For *Scomber colias*, *Scomber scombrus*, available information covered limited areas and thus models constructed were evaluated as a very good source of initial information for these species but of course data from more areas are needed to make more robust estimations.

Atlantic horse mackerel (*Trachurus trachurus*) presents wide persistent juvenile grounds covering most of the middle Adriatic Sea, the Thracian Sea (northern Aegean Sea), the outer part of the shelf in Catalan Sea and in the Gulf of Lions, the coastal waters of the Thyrrhenian Sea. Persistent areas in the Strait of Sicily were located in coastal waters being wider in the north and south part where the continental shelf is wider.

Mediterranean horse mackerel (*Trachurus mediterraneus*) persistent juvenile grounds are limited to the inner part of the Gulf of Lions and the Catalan Sea, the northeast part of the Adriatic Sea and the east part of Thracian Sea (northern Aegean Sea). On the other hand locations presenting high variability, characterized as occasional spawning grounds are much extended underlying the high dependence of the species with environmental conditions. When it comes to the spawning grounds where analysis was based on MEDITS trawl survey data the persistent spawning areas are are more extended covering most of the Gulf of Lions, the coastal waters of the Catalan Sea, the northwestern part of the Adriatic Sea and the coastal part of the central western Adriatic. The majority of persistent spawning grounds seem to occur in the eastern part of the Aegean Sea.

Concerning mackerel (*Scomber scombrus*) persistent juvenile grounds were much narrower in extent compared to anchovy and sardine. Persistent areas were identified in Thracian Sea (northern Aegean Sea), in the coastal waters of the western part of the Adriatic Sea as well as in limited coastal locations of the Catalan Sea and the Gulf of Lions. The picture for chub mackerel (*Scomber colias*) persistent juvenile grounds is different. Extended areas are indicated in the western part of the Adriatic Sea, the inner part of the Gulf of Lions, areas in the north part of the Catalan Sea, the east part of Thracian Sea and the coastal waters of the Gulf of Gabes in Tunisia. The spawning persistent areas of chub mackerel although still in the same geographic location were much wider in extent.

Overlapping with Fishing Restricted Areas (i.e. where prohibition applies from 2 up to 12 months per year) for the three main gears (i.e. purse seine, pelagic trawl and to a lesser degree bottom trawl) targeting these species showed that anchovy nursery areas are subjected to a degree of protection up to 17.68% for purse seines and up to 45% for pelagic trawls. For sardine these percentages are up to 31.37% for purse seines, 52.27% pelagic trawl and 47% for bottom trawl. For Mediterranean horse mackerel the percentages range from 17.36 % for purse seines up to 42.3% for bottom trawls. Similarly, for Atlantic horse mackerel percentages are les varying between 12.13% for purse seine up to 41.5% for pelagic trawls. By all means the degree of protection varies across the Mediterranean depending on the GSA as well as between the western and the eastern part. Since these species are often part of the same mixed fishery, areas where persistent spawning/nurseries overlap for more than one species can consist a part of the Marine Spatial Planning Strategy and critical for spatial prioritization.

Difficulties encountered and remedial actions

Suitable surveys (i.e. at a temporal resolution that matches spawning/recruitment time) to study spawning/nursery grounds of the target species were available only in certain areas. Thus in order to get information for the whole Mediterranean, we applied habitat suitability modeling using environmental information. This approach also allowed us to use information from different surveys carried out at different seasons in limited areas and still obtain an idea on habitat distribution for the whole basin. Moreover, we applied a presence absence approach that overcomes the problem of not fully comparable abundances between acoustic surveys as well as the catchability of the bottom and pelagic trawl for species that perfom vertical diel migrations like small pelagic.

Habitat modeling techniques based on environmental data are very effective in filling the gaps in available survey data, but it cannot be taken for granted that their predictions are correct over huge unknown areas. The best way to improve habitat distribution models is to add information from additional areas, especially from the North African countries and Turkey. This would allow the validation of existing models or the development new improved ones.

Gaps in knowledge and future actions

Models' output concerning *Scomber colias* and *Scomber scombrus* due to limited data available should be considered only as preliminary and indicative. Additional occurrence data from suitable surveys (e.g. acoustic surveys) and additional areas are needed in order to estimate more accurate models.

Besides additional survey, habitat suitability models also need suitable information concerning predictor variables. The latter must be available over the whole domain to be modelled, correlated to the habitat distribution, and possibly linked to it by causal relationships at an appropriate spatial scale. Unfortunately, very few, if any, predictor variables have all these properties.

Although no model can fully overcome these problems and some uncertainty is be accepted, the models we developed are state-of-the-art and as accurate as possible. Therefore, we are confident that their results will be useful to support environmental management policies at Mediterranean basin scale.

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Task 2.2 Mapping of nursery and spawning grounds of demersal fish

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2.2.1 Objectives

The protection of the so-called essential fish habitat (EFH: those habitats where fish concentrate for recruitment, spawning or feeding) from the negative impacts of human activities, including fishing, is one of the requirements of the Ecosystem Approach to Fisheries (EAF). It is recognised within the latest European Common Fishery Policy that in order to maintain the integrity, structure and functioning of ecosystems, safeguarding of fish nursery areas is advisable. In this context, the Council Regulation of the European Community (EC reg. no. 1967/2006) provides some guidelines for the implementation of the EAF in the Mediterranean, with particular attention devoted to the protection of nursery areas. The regulation has the potential to yield important conservation benefits and it is based on 2 assumptions: (1) juvenile fish are particularly vulnerable to fine mesh trawl fishery (Caddy 1993), especially when they concentrate in nursery areas, and (2) a reduction in fishing mortality of immature fish represents a fundamental prerequisite for sustainable fisheries (Beverton and Holt 1957). At the same time when fish aggregate in the spawning areas are particularly exposed to fishing. This can result into abrupt reduction in the spawning biomass and reproductive success of stock units as already demonstrated for many commercial stocks. The implementation of management measures aimed at reducing the impact of fishing on juveniles, spawners and their habitats requires the spatial identification of areas where recruitment and spawning took place. This information is also crucial to investigate the spatial structure of populations (e.g. identification of stock boundaries).

The approach adopted inTask 2.2. for the identification of nurseries and spawning areas is based on the use of density measures to identify “density hot spots” (i.e. areas where density is significantly higher) of recruits and spawners. To this aim we have used the MEDITS trawl survey data set from 1994 to 2010, which is the longest time series of standardized survey data covering European GSAs in the North Mediterranean. To evaluate the importance that each annual density hot spot play for the population we have used measures of temporal persistence of the areas.

Our approach is based on the assumption that the average contribution to the adult population can be expected to be higher for nurseries with higher juvenile density and higher spatio-temporal stability. In fact, maintenance of a population depends on successful recruitment of young fish to nursery areas and from nursery areas back to the parent population (Hinckley et al. 2001). The location of nursery areas is therefore an integral component of the adaptation of marine fish life cycles to their environments. The same rationale used for nurseries applies for spawning areas, where we can expect a higher contribution to the annual recruitment from more denser and temporal stable areas.

In this context, the stability of a density hot-spot of fish juveniles or spawners in a given area can be assumed to be an indirect evidence of the importance of that area for the recruitment/spawning success of the population. Furthermore, the temporal persistence of the characteristics of an area is a fundamental prerequisite for its inclusion in a conservation network, as commonly considered in terrestrial ecosystems (Early et al. 2008).

We propose a 3-step approach to identify and classify nursery/spawning areas for conservation purposes of target species. In particular, we (1) estimated the distribution of juvenile densities using different modeling approaches, depending on the species and area, and MEDITS trawl survey data, (2) identified density hot-spots in a standardized way and (3) produced measures of persistence of each identified hot spot.

It is however important to remark that the identification of areas was based on MEDITS time series (1994-2010). This implies that we have identified areas of aggregation of recruits/spawners and measured their temporal stability during late spring-early summer, i.e. the period of the year when the MEDITS survey is carried out. For species with long spawning/recruitment periods (e.g. hake, deep-sea pink shrimp, etc.) it would be therefore necessary to further investigate the seasonal stability of the identified areas as well as the occurrence of additional areas in other periods of the year.

2.2.2 Milestones and deliverables

The main objective of Task 2.2 was the identification and mapping of nursery areas and spawning grounds of certain demersal species within the Mediterranean basin as base for future implementation of spatial measure of fishing effort control.

To achieve this general objective the following 5 milestones have been addressed:

- Milestone 2.2.1. Review and collect trawl survey data and geo-referenced information about the distribution of nurseries and spawning grounds of target species (i.e., *Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris, Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrhosa*) on a temporal and spatial scale and to organise this information in a common geodatabase.
- Milestone 2.2.2. Analyze all available data from surveys concerning the target species in order to define recruits and spawners in a standardised way;
- Milestone 2.2.3. Apply spatial analysis techniques to construct density distribution maps of recruits and spawners of target species.
- Milestone 2.2.4. Identify nurseries and spawning grounds of target species, based on density and temporal persistence measures. Environmental and survey data will be used to characterize these areas from an environmental and ecological (e.g. species composition) point of view.
- Milestone 2.2.5. Report on the gaps in knowledge and in adequate survey data for the identification of spawning and nursery grounds

Activities developed to address Milestones 2.2.1-2.2.5 were basically aimed at achieving 3 main deliverables (table 2.1).

Table 2.1. Deliverables list for task 2.2

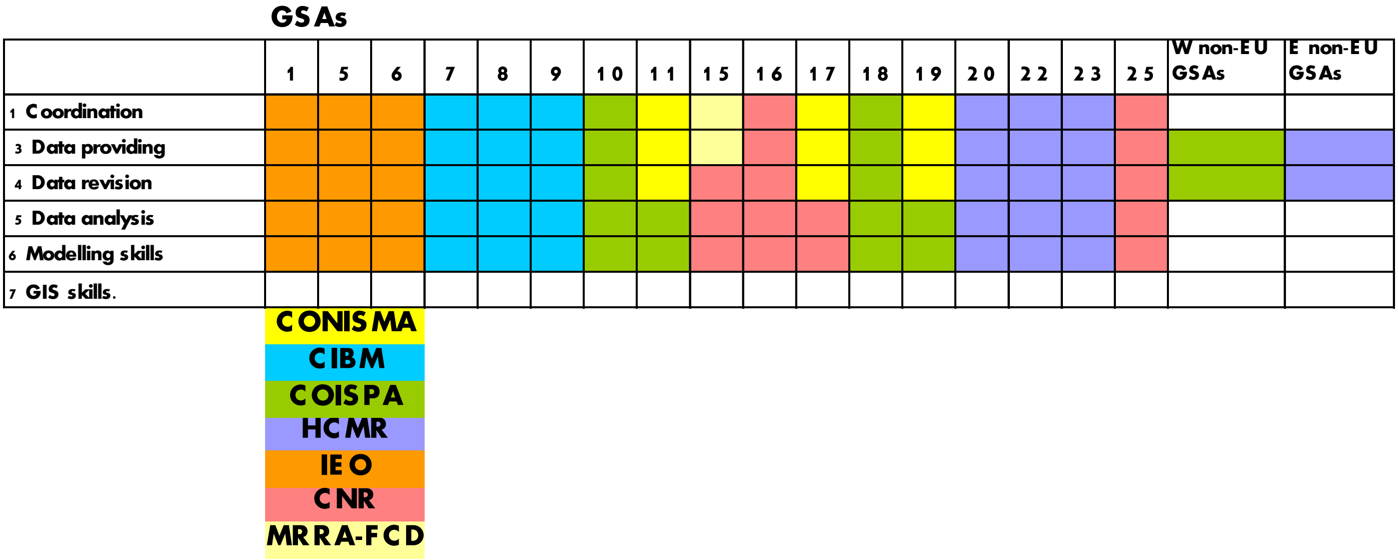
Deliverable No	Deliverable title	WP No.	Delivery month
D2.2.1	Annual distribution maps of nursery and spawning grounds of target species indicating density hot spots areas	2	16
D2.2.2	Maps indicating an index of persistency for density hot	2	16

	spots nursery and spawning grounds		
D2.2.3	Ecological characterization of the indicated nursery and spawning grounds	2	16

2.2.3 Role of participants

Task 2.2. has involved 7 participants each with specific responsibilities for the collection and analysis of data in Mediterranean GSAs as showed in table 2.2

Table 2.2. Subdivion of work among participants in task 2.2.



	GSAs																	
	1	5	6	7	8	9	10	11	15	16	17	18	19	20	22	23	25	W non-EU GSAs
1 Coordination	🟧	🟧	🟧	🟦	🟦	🟦	🟩	🟨	🟡	🟥	🟨	🟩	🟨	🟪	🟪	🟪	🟥	
3 Data providing	🟧	🟧	🟧	🟦	🟦	🟦	🟩	🟨	🟡	🟥	🟨	🟩	🟨	🟪	🟪	🟪	🟥	🟩
4 Data revision	🟧	🟧	🟧	🟦	🟦	🟦	🟩	🟨	🟥	🟥	🟨	🟩	🟨	🟪	🟪	🟪	🟥	🟩
5 Data analysis	🟧	🟧	🟧	🟦	🟦	🟦	🟩	🟩	🟥	🟥	🟥	🟩	🟩	🟪	🟪	🟪	🟥	
6 Modelling skills	🟧	🟧	🟧	🟦	🟦	🟦	🟩	🟩	🟥	🟥	🟥	🟩	🟩	🟪	🟪	🟪	🟥	
7 GIS skills.																		

	E non-EU GSAs
1 Coordination	
3 Data providing	🟪
4 Data revision	🟪
5 Data analysis	
6 Modelling skills	
7 GIS skills.	

🟨 CONISMA
🟦 CIBM
🟩 COISPA
🟪 HCMR
🟧 IEO
🟥 CNR
🟡 MRRA-FCD

2.2.4 Progress achieved

2.2.4.1 Methodological framework for the identification of nurseries and spawning grounds

Given the substantial lack of knowledge on population structure of the target species and the geographical boundaries of stocks in the Mediterranean it was agreed to carry out the analyses separately for each GSA or certain combinations of adjacent GSAs (e.g. GSA 15-16; GSAs 22-23; GSAs 1-6). This was decided considering that the GSA is currently the spatial unit at which both the data collection (EU-DCF) and the assessments are carried out.

The objective to identify nurseries and spawning grounds in each EU GSAs has therefore implied the development of different sets of models for each combination of species/life stage/GSAs. The dataset used for the analysis was the MEDITS (MEDIterranean Trawl Survey) time series for the period 1994-2010. In GSA 5 (Balearic Islands), GSAs 15-16 (North Strait of Sicily) and 17 (central-North Adriatic) a shorter time series was used. In GSA 17 MEDITS begun in Croatian and Slovenian waters only in 2002 and therefore the survey for the years 1994-2001 was carried out only in the Italian side. Similarly, Malta (GSA 15) entered in the MEDITS project only in 2001. In GSA 5 MEDITS surveys started in 2007. To obtain a global picture of nursery/spawning areas distribution in the whole area covered by the GSAs it was agreed to exclude the years where only a part of the GSAs was covered.

In order to improve the standardization of the analyses among different areas it was agreed to develop a common analytical framework based on the following 5 main steps:

1. Identification of recruits and spawners;
2. Calculation of density indices for recruits and spawners;
3. Modeling of spatial distribution and identification of density hot spots;
4. Estimates of temporal persistence of the identified hot-spots;
5. Environmental characterization of the main nursery and spawning grounds.

Identification of recruits and spawners (M 2.2.2)

Recruits

The functional definition of recruits for demersal species adopted in task 2.2 was the following: «*recruits are those specimens that have settled on the bottom, becoming available to the fishing gear in well-defined habitats at the end of their larval – pelagic stage and which remain in these habitats before dispersing or migrating*». Identification of the recruits component inside the populations of target species was therefore based on this concept which has implied to select the first modal component within the MEDITS length frequency distributions (LFDs) corresponding to the first year of life (i.e. age group 0) or to a younger age for short living species as for example deep water pink shrimp. We have assumed that, in absence of specific studies on the recruitment dynamics (es. Bartolino et al., 2008), the first modal component includes specimens recently settled on the bottom presumably sharing similar habitat preferences.

Spawners

The identification of spawners from MEDITS trawl survey data should be reasonably based on the estimation of density indices of specimens with ripe gonads or in an advanced maturing stage. However, this procedure for some of the target species has faced some difficulties during the data compilation phase due to the following reasons:

- -spawning peaks and MEDITS trawl survey timing did not match for certain species, determining a scarce catch of mature/spawning specimens (e.g. hake);
- -low catchability of spawners with the MEDITS gear since their spatial distribution expanded also on untrawable areas (e.g. hake, striped red mulled, red Pandora);
- very low abundance of species due to ecological reasons (e.g. red shrimps in Adriatic Sea, Norway lobster in Levantine Sea) or as result of overexploitation (e.g thornback ray in several areas);
- change in the maturity scales adopted by the MEDITS project has reduced the possibility to standardize the identification of the mature stage across the years. For example the protocol of maturity staging adopted in MEDITS from 1994 to 2006 for crustaceans used 2 maturity stages (immature and mature), with code 2 denoting a mixture of maturing, mature and resting individuals. Since 2007, a more detailed maturity scale was adopted, introducing the stage of recovering (2b), maturing (2c), mature (2d) and spent (2e) individuals. A similar problem of standardization occurs for also for cephalopods and elasmobranchs. In addition, only females were staged for the whole time series.

Considering all these aspects, for *Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Nephrops norvegicus, Parapenaeus longirostris, Galeus melastomus, Raja clavata, Illex coindetti, Eledone* *cirrhosa* it was agreed to resctrict modeling to the adult females fraction of the populations using the length-at-maturity calculated from MEDITS or landing data (DCF) as threshold length. In these cases the identified areas can be regarded as aggregation areas of adults. For *Mullus barbatus, Mullus surmuletus, Pagellus erythrinus*, which have their spawning peak during the MEDITS survey period, models were based either on mature female specimens or on the adults' fraction. In both cases spatial analysis led to the identification of spawning grounds. In GSAs 1, 5 and 6 mature females of *Aristaemorpha foliacea*, *Illex coindetti* and *Eledone cirrhosa* were used instead of length-at-first maturity.

Calculation of density indices for recruits and spawners

Prior to the use for indices calculation, MEDITS data have been checked for errors and inconsistencies by using the R routine RoME which is devoted to perform multiple checks on TA, TB and TC MEDITS files.

An ad-hoc automatized R routine (R_RSI MEDISEH-ver2.2)was developed to identify annual threshold sizes of recruits, following the method used by Fiorentino *et al.* (2003), and calculate density indices (n km^{-2}) by year both for recruits and spawners, MEDITS station, GSA and species.

The routine is made up by 4 main modules (Fig. 2.2.1, see Facchini et al., 2012 for more details):

1. Data transformation from MEDITS database to MEDISEH meta-database;
2. Threshold computation sub-divided into LFDs standardization and threshold computation;
3. Selection of recruits and/or spawners from MEDISEH meta-database;
4. Abundance indices computation by haul.

The module 2 of the routine applies the Bhattacharya's method for separation of modal components (Bhattacharya, 1967; Sparre e Venema, 1998) and the estimation of maturity ogive using Generalized Linear Models. In addition, the calculation of standardized length-frequency distribution (SLFD) is performed using stratified mean standardization formulas (Souplet, 1996).

Similarly the routine allows the calculation of standardized abundance indices of spawners or adults based on maturity stages or a threshold length of maturity (e.g. L_{50}).

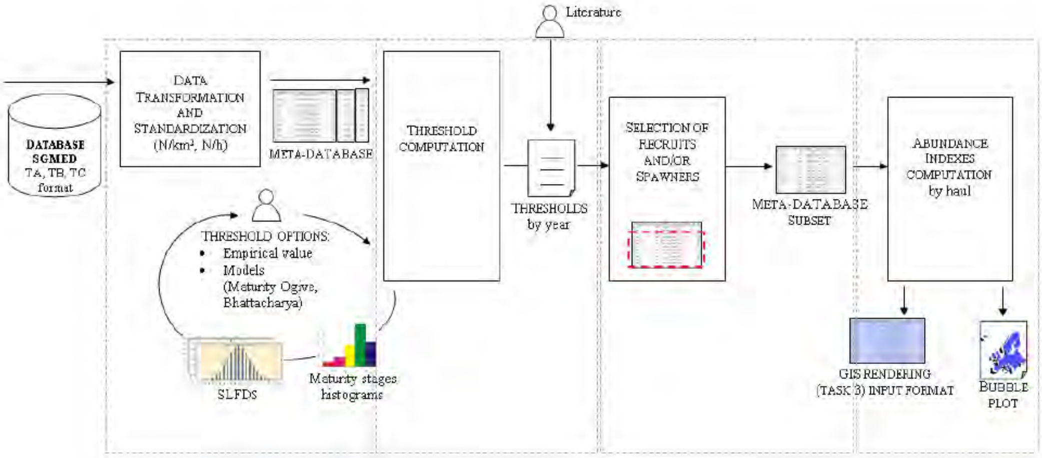


Fig. 2.2.1. Routine for the calculation of abundance index of recruits and spawners adopted in task 2.2. (from Facchini et al., 2012)

Modeling of spatial distribution and identification of density hot spots (M 2.2.3, D 2.2.1)

During the third Mediseh meeting held in Rome (26-28 September 2012) participants of task 2.2. agreed to adopt a general common framework for data modeling allowing for flexibility in the choice of the modeling approach. From the results of preliminary modeling trials carried out on target species in several areas, it was clearly recognized the impossibility to identify a unique modeling approach/methodology suitable for all species/stages/areas.

The amount of data (i.e. positive hauls), the environmental characteristics of the areas, the availability of appropriate covariates were all factors changing significantly across species and areas, in turn reducing the possibility to standardize consistently the methods applied.

The agreed common framework has implied the need to adopt regression approaches (e.g. GAM, GAMM, applications for zero inflated data sets such as COZIGAM and ZIGAM) as the main methods for modeling the spatial distribution of the target species. Classical geostatistical approaches, such as kriging, eventually in a simplified Bayesian framework (e.g. INLA approach) have been adopted as an alternative approach in the case of failure of regression methods or in combination with them. For all the species/life stage/GSAs combination it was agreed to produce bubble plots of the observed MEDITS density values in order to facilitate abundance comparison across areas.

To facilitate the work of participants the following R scripts have been implemented and made available on the MAREA ftp server:

- COZIGAM: to apply constrained and unconstrained Zero-Inflated Generalized Additive Models with Model Selection Criterion.
- Presence/Absence GAMs: to apply spatial analysis GAM to presence/absence data relating fish spatial distribution with environmental data:
- MixGAM: to apply spatial analysis using the Mixed GAMs approach;
- GAM with kriging: to incorporate the spatial component into GAM model for target species;
- R_MEFH_MEDISEH: to spatial modeling and nursery/spawning grounds identification in GSA 10, 11, 18, 19 using GAM, or kriging or GAM with kriging.

The participants agreed on the necessity to use as much as possible a single common method for the identification of the density hot-spots of spawners and recruits. The Getis' Gi with a radius of 2.5-5.0 km, was the selected method among the spatially local methods of hot spot identification. As an alternative method it was agreed to use the 45° tangent method over the cumulative curve of predicted values (Bartolino et al., 2011). R-scripts were implemented and made available to the participants on the respective folder of the MAREA ftp server.

Estimates of temporal persistence of the identified hot-spots (D 2.2.2)

For each cell in the study area, we calculated an Index of Persistence (Ii), measuring the relative temporal persistence of the cell *i* as a density hot-spot which can be assumed as an annual nursery (Fiorentino et al. 2003, Colloca et al., 2009). The temporal persistence as nursery of a given cell can range from 0 if the cell was never classified as a density hot spot to 100 if that cell wasclassified as hot spot in all the survey years.

For mapping purposes we classified the temporal persistence in 5 classes (0.05-20, 21-40, 41-60, 61-80, 81-100).

Environmental characterization of the main nursery and spawning grounds (D 2.2.3)

As required by Deliverable 2.2.3 the core of the most persistent nursery and spawning/adult aggregation areas were described according to the main information available concerning their environmental characteristics (e.g. depth range, type of sediments, biocenosis and occurrence of peculiar hydrographic conditions). The description was limited to the information available on literature without any further exploration of MEDITS or other source of data. Results of this deliverable are included at the end of each section describing results obtained for each target species.

2.2.4.2 Summary of the results and progresses achieved

The spatial identification of nurseries and spawning grounds of target species has required a huge modeling effort. A total of 157 different combination of species/life stages/GSA (Table 2.4.1) were analysed for a total of more than 1500 annual models. Despite such a big analytical effort no reliable models were built in GSAs 8 (Corsica) and 25 (Cyprus). In these two GSAs the number of positive hauls, combined with a generally low number of specimens caught and a sampling design with scattered hauls has not allowed assessing consistently the spatial distribution of recruits and spawners.

In the other GSAs identification of nursery and spawning areas was possible only upon a sufficient number of positive hauls and specimens available through the MEDITS time series.

In addition to the initial target species list in the MEDISEH proposal, we have added also *Solea solea* in GSA 17.

As showed in Table 2.4.1 the spatial coverage of modeling for some species/life stage was very good for the most abundant life stages such as European hake recruits, spawners of red mullet and blackmouth catshark, recruits and spawners of deep-sea pink shrimp, horned octopus, broadtail shortfin squid. For these species the work done has allowed for the first time in Mediterranean to obtain a large scale picture of the distribution of the most important areas for recruits and spawners in the north part of the Mediterranean.

The main causes of lack of models for other target species/life stage are summarized below:

- *Spawners of* ***Merluccius merluccius***: the mismatch between MEDITS survey period (late spring-early summer) and the main spawning period (winter-spring) of the species resulted into low catch of big hake during MEDITS in most GSAs;
- Recruits of ***Mullus barbatus, M. surmuletus, Pagellus erythrinus***: the mismatch between MEDITS survey period (late spring-early summer) and recruitment period. The striped red mullet was generally poorly caught during MEDITS except than in GSAs 5, 11, 16 and 22-23. The low number of positive hauls for recruits and spawners was also the main reason behind lack of modeling for common Pandora.
- Recruits and spawners of ***Raja clavata***: low MEDITS catch (i.e. few specimens per annual survey) in almost all GSAs except GSA 11, 15-16 and 22-23.
- Recruits and spawners of ***Galeus melastomus***: the species was sporadically caught in few hauls in the Adriatic Sea (GSA 17). In GSA 7 only recruits were caught during MEDITS
- Recruits and spawners of ***Aristeus antennatus*** and ***Aristaemorpha foliacea***. Both species are almost absent in central-North Adriatic Sea (GSA 17). *A. antennatus* was sporadically caught during MEDITS in the Eastern basin (GSAs 20, 22, 23, 25) and recruitment take place on deep bottom of the middle slope beyond the depth interval sampled during MEDITS. *A. foliacea* was rarely caught during MEDITS in the N-W Mediterranean (GSA 1, 5, 6 7). In GSA 9 the smallest specimens caught were age 1+ according to the growth parameters adopted.
- Recruits and spawners of ***Parapenaeus longirostris:*** very low MEDITS catches in NW Mediterranean (GSA 5-6, 7).
- Recruits of ***Nephrops norvegicus***: very low MEDITS catches of juveniles in several GSAs due to their behaviour during the first yer of life.
- Recruits and spawners of ***Eledone cirrhosa:*** low MEDITS catches in the Strait of Sicily (GSAs 15-16) and Ionian Sea (GSA 20)
- Recruits of ***Illex coindetii***: catches often limited to few hauls in several GSAs

It is important to note that modeling was based on data from a single seasonal survey, the MEDITS, carried out in May-July. Identified areas therefore correspond to nurseries and aggregation areas of spawners/adults during this specific period of the year. Supplementary nurseries/spawning grounds could be used in other seasons by those species displaying long recruitment/spawning periods, such as hake, deep-sea pink shrimp, broadtail shortfin squid and others. The seasonal stability of the identified areas was investigated for these species based on the approach followed for hake recruits in GSA 9 (Colloca et al., 2009), as the basis to understand their relevance for the productivity of investigated species. As explained in section 2.2.4, except for *Mullus barbatus, M. surmuletus and P. erythrinus*, it was not generally possible to model the distribution of mature specimens to identify spawning grounds. For most of the species modeling was based on adults' specimens, returning their predicted spatial distributions across time.

Table 2.2.3. Species/ life stages modelled in each GSA

Species		GSA													
		1-6	5	7	8	9	10	11	15-16	17	18	19	20	22-23	25
MERLMER	Rec	🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
	Spaw		🟩	🟩				🟩		🟩		🟩			
MULLBAR	Rec									🟦	🟦				
	Spaw	🟩	🟩	🟩		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
MULLSUR	Rec														
	Spaw		🟩					🟩	🟩					🟩	
PAGEERY	Rec						🟦	🟦		🟦	🟦				
	Spaw			🟩			🟩	🟩	🟩	🟩	🟩		🟩	🟩	
RAJACLA	Rec							🟦	🟦						
	Spaw							🟩	🟩						
GALUMEL	Rec		🟦	🟦		🟦	🟦	🟦	🟦		🟦	🟦			
	Spaw	🟩				🟩	🟩	🟩	🟩		🟩	🟩	🟩	🟩	
SOLEVUL	Rec									🟦					
	Spaw									🟩					
ARISFOL	Rec						🟦	🟦	🟦		🟦	🟦			
	Spaw						🟩	🟩	🟩		🟩	🟩		🟩	
ARITANT	Rec														
	Spaw	🟩					🟩	🟩	🟩		🟩	🟩			
PAPELON	Rec	🟦				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
	Spaw	🟩				🟩	🟩		🟩	🟩	🟩	🟩	🟩	🟩	
NEPHNOR	Rec							🟦	🟦	🟦		🟦			
	Spaw	🟩		🟩		🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩	
ELEDCIR	Rec			🟦		🟦	🟦	🟦		🟦	🟦	🟦		🟦	
	Spaw	🟩				🟩	🟩	🟩		🟩	🟩	🟩		🟩	
ILLECOI	Rec	🟦				🟦	🟦	🟦	🟦		🟦	🟦	🟦	🟦	
	Spaw	🟩	🟩	🟩		🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩	

2.2.5 Results per Species/Life Stage/GSA

2.2.5.1 Merluccius merluccius

2.2.5.1.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

In GSA 05, there are not published maps available on the spatial distribution of their recruits and spawners concerning the entire area. The only information on this matter is related to the bathymetric distribution of recruits. Maximum abundance of *M. merluccius* recruits (<18 cm) has been detected around 250 m depth and post-recruits (18-22 cm) have been mainly found at 150 m depth, while the bathymetric range of adults (>22 cm) is wider, being mostly distributed on the upper slope (Hidalgo et al., 2008a).

Some evidences concerning the influence of the environment on the spatio-temporal dynamics of this species in the Balearic Islands have been demonstrated. Along with other species inhabiting the continental shelf, the stock of *M. merluccius* shifted from a past period (before 1980s) of under-exploitation to a recent period (after 1980s) of over-exploitation. Short spatial differences between northern and southern the Balearic Islands have been detected in the population dynamics, biology and condition of some deep water species, *M. merluccius* among them (Cartes et al., 2008a, 2009; Guijarro et al., 2008, 2009, 2012; Hidalgo et al., 2008a, 2008b, 2009a). These differences are likely to be related to the distinct environmental conditions (hydrodynamics, water masses, geomorphology, sediment characteristics and trophic resources) and fishing impact among these areas (Cartes et al., 2008b; López-Jurado et al., 2008; Moranta et al., 2008), located at the Balearic and Algerian sub-basins, respectively. Some spatial differences have been detected in the recruitment dynamics of *M. merluccius* (Hidalgo et al., 2008a), with a main pulse of recruits occurring early at the north than the south part of the Archipelago.

In GSA 6 juveniles range from 12 and 14 cm TL in spring (Recasens et al., 1998) with two peaks in spring-summer and late summer-winter (Orsi-Relini et al., 1986, Voliani et al., 1991; Recasens et al., 1998; Gõni et al., 2004). Well-defined nursery areas were identified along the Catalan coast between 68 and 168 m depth, but the density in well-defined nursery areas was not different from the density in occasional nursery areas. Some sediment variables (i.e. redox potential and organic matter contents) were statistically different in nursery areas and in occasional nursery areas, indicating that juvenile hake recruit on bottoms where food resources are enhanced (Maynou et al., 2003).

In GSA 9 migration from nurseries located on the shelf break (120-250 m) takes place when juveniles attained a critical size between 13 and 15.5 cm TL .Recruitment take place all year round with main peaks in spring-summer and late summer-winter. In the Gulf of Lions (GSA 7) the highest abundance of the 0-group was observed in June, while it was less abundant in November and almost absent in February. In GSA 9 it was demonstrated an influence of sea-surface temperatures coupled with water circulation on recruitment strength.

In GSA10 the more significant aggregations of European hake juveniles, identified in previous studies (Lembo et al., 1998; 2000a), were generally localized during late spring-early summer season in the northern part of the GSA, i.e. in the Napoli and Gaeta Gulfs within 100-200 m depth. During autumn season other areas were also stably located in shelf break-upper slope, off Cape Licosa and Cape Suvero, along the Calabrian coasts, west to Cape Orlando and off the Castellammare Gulf, along the northern Sicily coasts. Recruitment size in previous studies ranged between 12.6 and 16.2 cm TL.

In GSA11 the more persistent areas of recruits , in previous studies (Murenu et al., 2010), were located in the western side of the island, offshore Carloforte and Oristano at depth from 200 to 300 m. Recruitment size ranged between 13 and 15.5 cm TL.

In the Strait of Sicily (GSA 15+16), hake recruitment takes place all year round and the species is considered fully recruited to trawl grounds at 100 mm TL. Two areas of high spatio-temporal persistence (i.e. nursery areas) are known. They are located on the eastern side of Adventure Bank and Malta Bank respectively and show a core of maximum stability between 100 and 250 m depth.

In GSA 17 the recruitment of young individuals has two different maxima; the peaks are in spring and autumn.

The main concentrations of hake juveniles in GSA18 were found in the Gulf of Manfredonia and off Gargano Promontory, at 100-200 m depth (Lembo et al., 2000a). Other less relevant nuclei were also identified in the Otranto Channel. Recruitment follows a quasi continuous pattern with main peaks in spring and autumn. Recruitment size ranged between 10 and 15.3 cm TL.

In the North-Western Ionian Sea (GSA19) recruits of hake were found throughout the year mostly on the shelf and shelf break-upper slope. The sizes of recruitment estimated in the framework of previous studies ranged between 11 and 17 cm TL. The main nursery areas were detected on the shelf between Otranto and Santa Maria di Leuca, around the Amendolara Bank, in the Gulf of Squillace and offshore Siracusa. The more persistent nursery area was previously identified between Otranto and Santa Maria di Leuca (Carlucci et al., 2009).

In GSA 22-23 the available information suggests that recruits of hake are present all year around, with smaller juveniles (40-110 mm TL) generally observed during spring and early summer, whereas larger ones (100-160 mm TL) are abundant mainly in autumn, at depths ranging between 100-200 m. No information is available for hake recruits for GSA 20.

In GSA 25 the recruitment of young individuals it is observed in spring-summer in a depth of 150-400 m. Size at first sexual maturity was estimated between 20 and 30 cm of total length for females with smaller sizes for males.

Spawning

The reproductive biology of this species is fairly known. In GSA 5, although mature specimens of *M. merluccius* can be found all year round, its main reproductive period has been situated in autumn-winter (Reñones et al., 1995b) and its length of first maturity has been estimated at 32.7 cm (Oliver, 1993). The recruitment of this species starts in February, with a mode at around 11 cm (5-6 months of life), and it can be followed through spring and early summer, with a peak in April (Hidalgo et al., 2008a, b, 2009a).

In GSAs 6 higher spawning activity occurs from August to December, with peaks in September and December (Recasens et al., 2008). The length at first maturity (L50) was 35.8 cm for female (Recasens et al., 2008). Migration from nurseries to fishing grounds take place massively in autumn (12-14 cm LT) and in spring (Gil de Sola, 1999; Orsi Relini et al., 2002).

In GSA9 females in advanced maturity stages, spawning and post-spawning are present all year round. Spawning is concentrated from January to May, with two peaks in February and May. The presence of hake spawners seems to be reduced in the northern Ligurian Sea. Length at first maturity of females range between 31 to 37 cm LT. In the Gulf of Lions (GSA 7) the species seems to achieve maturity at larger length, about 40 cm TL.

In GSA10 a proxy of size at first maturity for females was estimated in the SAMED project (AA.VV. 2002) that indicates an average length of about 30 cm. According to the data obtained in the DCF of 2008, the proportion of mature females by length class in the period 2006-2008 gave an estimate of Lm50% of about 33 cm (±0.27 cm), a value similar to those of 2003-2005 (L50%=32.9±0.8; MR=6.4±0.9) and of 2010 (L50%= 33.58±0.41; MR= 2.34±0.42) as estimated by means of GLMs.

In GSA11 the reproductive period of the species is long, with two peaks of activity that falls in winter and summer.

In GSA18 a proxy of size at first maturity for females was estimated in the SAMED project that indicates an average length of about 29 cm. According to the data obtained from DCR in 2008, the proportion of mature by length class (period 2006-2008) gave an estimate of L50% of about 33.5 cm (±0.17 cm; MR=3.3±0.16) a value similar to that of DCF 2010 (L50%=33.4±0.15; MR=3.8±0.16) and of DCF in 2010 (L50%= 33.1±0.19; MR=2.8 ±0.16) as estimated by means of GLMs.

Adult specimens of hake were mainly collected on the slope in GSA19. The smallest mature female and male were 315 and 165 mm TL, respectively. L50%=31.5 was taken as size at first maturity for females. No persistent spawning areas were detected for hake in the basin.

An extended spawning period is hypothesized for hake in the Strait of Sicily (GSA 15+16) with two peaks in December-February and June. Estimates for females' length at first maturity (Lm50%) range between 310 and 370 mm TL.

In the GSA 17 size at first sexual maturity was estimated between 23 and 33 cm of total length for females and between 20 and 28 cm for males (Vrgoč et al., 2004). In the northern Adriatic Sea (GSA 17) European hake spawns throughout the year but with different intensities; two spawning peaks fall in winter and summer (Vrgoč et al., 2004).

In GSAs 20, 22 and 23 females in advanced maturity stages, are present all year round and there are indications for the existence of two spawning peaks: in winter and in late spring. Length at first maturity (L50) of females ranges from 30 to 43 cm while males generally attain maturity at smaller sizes (26 to 36 cm). In GSA 25 European hake spawns throughout the year, presenting different intensities.

2.2.5.1.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.1.1 and 2.2.5.1.2 list the frequency of positive hauls and the number of hake specimens caught during MEDITS in each GSA. Recruitment and maturity size are indicated in Table 2.2.5.1.3.

GSA 1, 5, 6

The proportion of positive hauls is similar in the three Spanish GSAs, varying from 0.62 to 0.70 in the GSA05 and from 0.63 to 0.77 in the GSA 01 and 06. The amount of specimens is highly variable ranging from 783 to 2897 in the GSA05 and from 2297 to 20502 in the GSA 01 and 06.

Following the protocol developed in the R_RSI_MEDISEH script, we applied the Bhattacharya's method to extract the first modal component of the length-frequency distribution of *M. merluccius*, on a yearly basis. The mean length of the first modal component plus the standard deviation was applied as a threshold value of total length. This threshold and the swept area of each haul were used to calculate the standardized abundance index of recruits (n/km^2). Differences in the length frequencies between GSAs were observed, thus Bhattacharya's method was applied separately in each GSA.

The spawning fractions of females were extracted by means of the length at first maturity (L50 or length at which 50% of the individuals are mature) and the maturity ogive (L25-75). For this purpose, data on monthly biological samplings of commercial catches, obtained within the Data Collection Framework, were used to identify the spawning periods of each species, from monthly average of the Gonadosomatic Index (GSI) and the percentage of maturing or mature individuals. Only data compiled during these spawning periods was used to calculate L50, from the logistic curve: PL= e(a+b*L)/(1+e(a+b*L)), where PL is the proportion of mature individuals for a given size class L. Logistic curves were fitted by maximizing the log-likelihood function, using Solver in EXCEL (Tokai, 1997).

GSAs 7, 8, 9

In GSA7 the species has been caught almost in all the hauls with a frequency of positive hauls ranging from 0.84 to 0.98. The number of specimens caught per year ranged from 1500 to 3847 (as concerns 1996 no data were available for this species in the database). In GSA8 the occurrence of the species varied from a frequency of 0.48 in 1994 to 0.86 in 2000. The number of specimens caught per year was low: from 66 in 1997 to 200 in 2006. In 1996 and 2002, the database did not contain data for this species. *M. merluccius* has been caught frequently in GSA9 with a frequency of positive hauls between 0.74 in 1994 and 0.86 in 1999. The catches were very abundant, ranging between 11625 specimens in 1994 to 77176 specimens in 1998. In 2010 only 5592 specimens were caught.

In GSA 7, recruits have been identified using the Bhatthacharya approach; the mean size of the first modal component ranged from 85 to 135 mm TL (plus 2* standard deviation). In GSA 8 and in GSA9 a fixed cutoff size of 140 mm has been used to identify recruits, according to previous studies (Bartolino et al., 2008a)

In GSAs 7, 8 and 9, spawners have been identified using the female cutoff size of 350 mm TL, according to the available previous knowledge on the size at first maturity of the species.

GSAs 10, 11, 18, 19

In GSAs 10, 11, 18 and 19 data were available from 1994 to 2010.

The frequency of positive hauls for *M. merluccius* in GSA10 was rather high, ranging between 0.59 (MEDITS 2002) and 0.77 (MEDITS 2008), with an overall catch fluctuating from a minimum of 1937 (MEDITS 2001) and a maximum of 12641 (MEDITS 2005) sampled specimens.

The frequency of positive hauls for *M. merluccius* in GSA11 was rather high, ranging ranges between 0.62 (MEDITS 2002) and 0.82 (MEDITS 2010), with an overall catch fluctuating from a minimum of 1548 (MEDITS 1998) and a maximum of 3073 (MEDITS 1996) sampled specimens.

The frequency of positive hauls for *M. merluccius* in GSA18 was very high, ranging ranges between 0.86 (MEDITS 1995, 1999 and 2001) and 0.96 (MEDITS 2005, 2006 and 2009), with an overall catch fluctuating from a minimum of 1619 (MEDITS 1999) and a maximum of 4629 (MEDITS 2008) sampled specimens.

The frequency of positive hauls in the North-Western Ionian Sea (GSA19) ranges between 0.46 and 0.71 with an overall catch fluctuating from a minimum and a maximum of 564 (MEDITS 1997) and 5858 (MEDITS 2004) sampled specimens, respectively.

In GSAs 10, 11, 18 and 19 the recruits have been identified annually according to ability of the survey to intercept the phenomenon. In GSAs 10 and 18 the threshold to separate the recruits has been estimated as the mean length of the first modal component plus 2* standard deviation using the Bhattacharya's method and the R_RSI MEDISEH routine, specifically developed for the Mediseh project. In GSA11 and GSA19 the threshold size was calculated as the mean length of the first modal component + 1 or 2sd depending on the amplitude of the first modal component estimated each year.

To identify the adults or potential spawners, an average of the parameters of the maturity ogive among the years from the MEDITS survey and/or from biological samplings of DCR and DCF has been used in GSAs 10 and 18, selecting those better fitting to the model. In GSA19 spawners were identified using the empirical value of 31.2 cm TL estimated for the species using both MEDITS and GRUND time series, while in GSA 11 MEDITS data were used with the approach of maturity stage estimation.

GSAs 15-16

M.merluccius was quite abundant and widely distributed in GSA 15+16, being 0.8 the mean frequency of positive hauls in the period 2003-2010. The total number of specimens caught each year varied between 4413 and 13884. In GSA 15+16, a pronounced recruitment signal was observed in the LFDs time series. The cutoff size of recruits was estimated using the Bhattacharya method (mean length of the first modal component + 1sd). It ranged from 120 to 135 mm TL over the years.

The spawners were identified considering the number of females showing a maturity stage "3" (measured length between 195 and 810 mm TL) according to MEDITS maturity scale. They were observed in the 13-24% of the hauls, albeit in low numbers.

GSA 17

In GSA 17 MEDITS data are available for the period 2002-2010. The period 1994-2001 has been excluded from the analyses because data of the eastern side of the basin were not available. European hake is abundant with more than 80% of positive hauls (Table 2.5.1.1) and an average of more than 7,000 specimens collected each year (Table 2.5.1.2), the species is suitable for modeling both for recruits and spawners. In accordance to the other GSAs the approach employed to detect the recruits was the Bhattacharya, which identified threshold sizes comprised between 10.2 and 13.8 cm of total length. The threshold length (L50 = 28 cm) to detect the spawners was derived from Vrgoč et al., 2004.

GSAs 20, 22, 23

The data for hake used in the present work were obtained from the MEDITS survey. The available data for hake that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 and in GSAs 22_23 the proportion of positive hauls for hake was >70% with fluctuating catches in each GSA. Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates following the aforementioned approaches, threshold values were established based on literature information and expert knowledge.

GSA 25

In GSA 25 MEDITS data are available for the period 2005-2010. Although European hake occurred usually in 30-40% of the hauls, the number of specimens was quite scarce with an average of less than 30 individuals collected per year. In GSA 25 the recruits and spawners of European hake have been identified with a knife edge threshold sizem at 10 cm and 30 cm respectively, as applied for the GSAs 22-23, based on expert knowledge and literature information.

Table 2.2.5.1.1. Frequency of positive MEDITS hauls (n of positive hauls/n. of total hauls) for hake by GSA and year

	GSA													
YEAR	5	7	8	9	10	11	17	18	19	20	25	1_6	15_16	22_23
1994		0.84	0.48	0.74	0.64	0.74		0.89	0.57			0.69		
1995		0.93	0.64	0.78	0.67	0.69		0.86	0.58			0.66		
1996				0.78	0.62	0.77		0.89	0.57			0.70		0.76
1997		0.92	0.62	0.84	0.64	0.71		0.89	0.61			0.65		0.88
1998		0.97	0.61	0.80	0.64	0.72		0.89	0.57	0.84		0.73		0.95
1999		0.95	0.70	0.86	0.61	0.76		0.86	0.49	0.69		0.63		0.92
2000		0.97	0.86	0.76	0.73	0.79		0.89	0.47	0.75		0.67		0.84
2001		0.95	0.82	0.82	0.66	0.77		0.86	0.59	0.94		0.72		0.86
2002		0.98		0.76	0.59	0.62	0.87	0.92	0.46			0.77		
2003		0.96	0.61	0.79	0.76	0.78	0.91	0.91	0.61	0.91		0.73	0.80	0.90
2004		0.96	0.64	0.81	0.66	0.76	0.90	0.89	0.54	0.81		0.67	0.87	0.88
2005		0.95	0.65	0.78	0.73	0.71	0.86	0.96	0.67	0.88	0.40	0.71	0.80	0.85
2006		0.90	0.83	0.83	0.76	0.72	0.91	0.96	0.71	0.88	0.32	0.68	0.82	0.90
2007	0.62	0.93	0.85	0.78	0.64	0.73	0.90	0.91	0.54		0.44	0.69	0.80	

2008	0.66	0.92	0.80	0.81	0.77	0.78	0.93	0.90	0.71	0.91	0.19	0.75	0.76	0.93
2009	0.62	0.95	0.82	0.79	0.69	0.74	0.84	0.96	0.71		0.33	0.74	0.76	
2010	0.70	0.90	0.59	0.78	0.70	0.82	0.84	0.94	0.59		0.41	0.77	0.81	

Table 2.2.5.1.2. Number of specimens of hake caught by GSA and year

	GSA												
YEAR	5	7	8	9	10	11	17	18	19	20	25	1_6	15_16	22_23
1994		3847	144	11810	3434	2933		1772	2143			3361		
1995		2144	190	29382	6375	2174		3351	1343			2297		
1996				19776	3335	3073		4253	1489			4981		6362
1997		1500	66	36079	6066	2219		2962	564			6339		4368
1998		2654	167	77176	2706	1548		2170	1266	443		6335		4280
1999		1928	107	49314	4726	2755		1619	972	432		8111		7301
2000		1903	119	19663	4492	2564		2736	698	1155		16263		5220
2001		1635	138	14713	1937	2572		1992	735	791		7244		3957
2002		1819		46069	3070	1911	9412	3176	1412			14496		
2003		1799	120	24683	6550	2668	7020	1753	836	2091		11858	4985	5208
2004		2336	85	34421	3728	2187	8802	2954	5858	2876		18365	4679	8025
2005		1573	143	13235	12641	2682	17447	7149	4081	4900	33	16531	13884	6395
2006		1590	200	11625	6626	2531	10166	2734	2235	2053	20	20502	10392	14275
2007	2113	1511	141	14576	9094	1977	8753	2387	1994		37	5221	12286	
2008	783	2196	213	33917	8397	1733	10006	4629	5096	2186	23	9131	9717	16144
2009	2897	2074	105	13432	8810	2036	3077	3234	1696		42	7046	10467	
2010	1962	1005	104	5592	4987	2479	3163	2942	618		28	5900	4413	

Table 2.2.5.1.3. Recruitment and spawning size identification for modeling purposes

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (TL mm)**	**Data source**	**Method used**	**Mean maturity length (TL mm) /Maturity stage**
05	2007-2010	MEDITS	Batthacharya	87	DCF	Fixed threshold length (L50)	314
01	1994-2010	MEDITS	Batthacharya	97	DCF	Fixed threshold length (L50)	323
06	1994-2010	MEDITS	Batthacharya	90	DCF	Fixed threshold length (L50)	323
7	1994-2010	DCF/MEDITS	Batthacharya	100	DCF/MEDITS	Fixed threshold length (L50)	350
8	1994-2010	DCF/MEDITS	Fixed threshold length	140	DCF/MEDITS	Fixed threshold length (L50)	350
9	1994-2010	Bartolino et al., 2008	Fixed threshold length	140	DCF/MEDITS	Fixed threshold length (L50)	350

		Recruits			Spawners		
10	1994-2010	MEDITS	Bhattacharya	129	Biological sampling	Maturity ogive	332
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya	130	MEDITS	MS maturity stages estimation	350
15+16	2003-2010	MEDITS	Batthacharia	127 (annual threshold:120-135)	MEDITS	Maturity stage "3"	410 (annual mean:382-512
17	2002-2010	MEDITS	Bhattacharya	125	Vrgoc et al., 2004	Fixed threshold length (L50)	280
18	1994-2010	MEDITS	Bhattacharya	145	Biological sampling	Maturity ogive	333
19	1994-2010	MEDITS	Bhattacharya	132	MEDITS and GRUND	Fixed threshold length (L50)	312
20	1998-2008	MEDITS	Batthacharya	100	MEDITS	Fixed threshold length (L50)	300
22_23	1996-2008	MEDITS	Batthacharya	100	MEDITS	Fixed threshold length (L50)	300
25	2005-2010	GSAs 22-23	Fixed threshold length	100	GSAs 22-23	Knife-edge	300

Mapping of density and identification of hot spot areas

A detailed description of models used to map distributions and identify hot spots is provided in Annex 2. In this chapter the modeling approach (e.g. method for mapping, covariates, etc.) is summarized. Table 2.2.5.1.4. summarizes the models developed to map hake recruits and spawners distribution in Mediterranean GSAs using MEDITS indices.

GSAs 1-6

Recruits and adult aggregations were modeled using two GAM models, one for presence/absence data a second one for standardized abundances restricted to presence data only. The final presence/absence model for recruits in GSAs 1-6 included bottom depth and the interaction between longitude and latitude, whereas the abundance restricted to presence samples model included depth, the interaction between longitude and latitude, and year as factors. Each model explained 47 and 36% of the total variance, respectively. Recruits are found between 100 and 250 m depth and preferentially at about 150-200 m. The final models of presence/absence and abundance of adult aggregations in GSAs 1-6, restricted to presence samples, included depth and year as factors, which explained 4 and 40% of the total variance, respectively. Clear oscillations in the mean annual abundance occurred during the study period, although the highest values predominate during the last years. The abundance of adult aggregations is very low compared to to recruits (9 and 979 individuals/Km^2 for the period 2007-10, respectively for spawners that represent only 0.9% of recruits).

GSA 5

In GSA 5 adult aggregations and recruits were modeled using GAM. Two models were conducted independently, one for presence/absence data, and another for standardized abundances restricted to presence data only. The final models for recruits included depth and year as factors (Table 2.2.5.1.4.), the presence/absence and abundance explained 59 and 42% of the total variance, respectively. The final model for spawners in GSA 5 included depth and year as factors, which explained 39 and 20% of the total variance, respectively. The predictions did not show any distinct areas presenting higher abundance of spawners. In fact, they are found around almost all the study area, but restricted to the bathymetric range 100-350 m and preferentially at about 200 m. High variability was observed in the mean annual values estimated during the study period, being minimum and maximum in 2009 and 2010. In any case, this abundance of spawners is very low in comparison to the recruits of this species (14 and 141 individuals/Km^2 for the whole period 2007-10, respectively, spawners represent 10% of recruits). This is in agreement with the population figures, estimated from Virtual Population Analysis within the framework of the GFCM stock assessment working groups (GFCM, 2011): For the period 1980-2010, the average recruitment and spawning stock are, respectively, 3.5 and 0.1 millions in terms of abundance (spawners only represent only 2.8% of the recruited population), and 91.2 and 39.7 tons in terms of biomass.

GSAs 7, 8, 9

In GSA 7 it was possible to map hot spot areas for both recruits and spawners. In GSA8 the abundance of recruits and spawners was very scarce and the low numbers did not allow the application of any modeling approaches to identify hot spot areas. Recruits were very abundant in GSA9 allowing the implementation of reliable annual models. On the other hand, the very scarce presence of spawners prevented the identification of their aggregation areas. Due to data limitation we could only produce bubble plots for recruits and spawners in GSA8 and spawners in GSA 9.

A generalized additive model (GAM) was used to model hake recruits in GSAs 7 and 9 adding a spatial term with a spherical or exponential covariance function depending on the year. The covariates used in the GAM models were sampling year (GSA 9), geographical coordinates (GSA 7 and 9), distance from the shore (GSA 9), bottom stepness (GSA 9) and depth (GSA 7). Spawners in GSA 7 were modelled using GAM with year and geographical coordinates as covariates. As for recruits, a spatial term with a spherical or exponential covariance function depending on the year was included in the model.

The density hot spots both in GSA 7 and 9 were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km.

GSAs 10, 11, 18, 19

In the GSAs 10-11-18-19 annual abundance values were predicted by mean of a ZIGAM model (Gaussian + Binomial GAM) with the depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging was applied on raw abundance values. In the kriging approach the model fitting was validated using cross-validation (Bleines et al., 2000). For modelling, the R MEFH MEDISEH routine 2.0 (Martiradonna et al., 2012) was used. Modeling of recruits was accomplished for almost all the years and GSAs. The only successful covariate among those tested was depth. Data on spawners allowed the analysis only in GSA11, as in the other areas, the occurrence of this life stage was scant. Hot spots were identified using the Getis and Ord G statistic combined with Fisher classification of variance intervals.

GSAs 15, 16

In GSA 15+16, recruits of *M.merluccius* were modelled using a GAM with spatial component and a smooth effect on the covariate “Distance from the coast”. Both the intercept and the spatial component were supposed to change each year. The model goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km.

Despite many attempts to model hake spawners in GSA 15+16, it was not possible to identify any spatial structure in the dataset because the abundance indices were rather low and distributed over a wide bathymetric range.

GSA 17

Modeling approaches employed to identify nursery and spawning grounds of European hake in GSA 17 were the zero-Inflated Generalized Additive Model (Liu and Chan, 2010) and local G statistic (Getis and Ord, 1992), respectively to define the spatial distribution and the hotspots, considered as the place where high values of densities cluster together.

The diagnostics of the ZIGAM model employed for recruits and spawners of European hake in GSA 17 (Table 2.5.1.4) show a better fitting for recruits, although the model results seems appropriate also for the spawners.

GSAs 20, 22, 23

Generalized Additive Models were employed to model the distribution of recruits and spawners of hake in each GSA (GSA 20 and GSA 22_23). The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots.

The period analysed was from 1996-2008 and from 1998-2008 for GSA 20 and GSAs 22_23, respectively. The depth distribution of hake recruits ranged from 40 - 350 m, and from 25 – 580 m in GSA20 and GSAs 22_23, respectively. The depth distribution of hake spawners was found to range between 40 - 750 m and 25 - 760 m in GSA20 and GSAs 22_23, respectively.

Hotspots in GSA20 were not identified in 1998 and 2006 for hake recruits and in 1998 and 2003 for hake spawners due to the inapplicability of the tangent method for these specific year/stage combinations.

Table 2.2.5.1.4. Modeling applied in EU GSAs for mapping hake spawning and nursery grounds. CV= *cross validation index*

Life Stage	**Gsa**	**Depth Range**	**Period**	**Model Type**	**Covariates**	**Explained Variance (%)**	**Goodness of fit (R^2)**
Recruits	05	50-500	2007-2010	Pres./Abs.	Year, depth	59.2	0.68
				Abundance	Year, depth	41.8	
Recruits	01, 06	25-500	1994-2010	Pres./Abs.	(Lon, Lat), depth	46.8	0.62
				Abundance	Year, (Lon, Lat), depth	36.2	
Spawner females	05	50-500	2007-2010	Pres./Abs.	Year, depth	38.8	0.42
				Abundance	Year, depth	20.1	
Spawner females	01, 06	25-820	1994-2010	Pres./Abs.	Year, depth	4.4	0.04
				Abundance	Year, depth	39.9	
Recruits	7		1994-2010	GAM	Lon, Lat, depth	1.038*	0.53
Spawners	7		1994-2010	GAM	Year, (Lon, Lat),	1.035*	0.33
Recruits	9		1994-2010	GAM	Year, (Lon, Lat), distance from the shore, bottom stepness	0.98*	0.52
Recruits	10	10-800	1994-2010	Gaussian GAM	Depth	23.2	0.2
				Binomial GAM	Depth	51.7	0.56
				Ordinary Kriging			
Recruits	11	10-800	1994-2010	Gaussian GAM	Depth	23.4	0.2
				Binomial GAM	Depth	34.1	0.38
				Ordinary Kriging			
Recruits	18	10-800	1996-2010	Gaussian GAM	Depth	20.2	0.18
				Binomial GAM	Depth	47.3	0.53
				Ordinary Kriging (*)			
Recruits	19	10-600	1994-	Gaussian GAM	Depth	27.0	0.20

Life Stage	Gsa	Depth Range	Period	Model Type	Covariates	Explained Variance (%)		Goodness of fit (R^2)	
			2010	Binomial GAM	Depth	40.9		0.38	
				Ordinary Kriging					
Spawners	11	10-800	1994:2003 2007:2010	Ordinary Kriging					
Recruits	15+16	20-700	2003-2010	GAM with spatial component	Year, Distance from the coast			CV=0.994 0.582	
Spawners	17	10-600	2002-10	ZIGAM	Year, Lon, Lat, depth	LR	GAM	LR	GAM
						24.7	20.9	0.28	0.17
Recruits	17	10-600	2002-10	ZIGAM	Year, Lon, Lat, depth	LR	GAM	LR	GAM
						54.9	61.4	0.60	0.60
Spawners	20	40-750	1998-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	66.0		0.53	
Recruits	20	40-350	1999-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	47.7		0.36	
Spawners	22_23	25-760	1996-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	24.6		0.19	
Recruits	22_23	25-580	1996-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	38.1		0.32	

2.2.5.1.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.1.5 summarizes the main environmental features of the most persistent areas identified for hake in European GSAs. Detailed figures can be found in the online GIS viewerat http://mareaproject.net/mediseh/viewer/med.html.

GSAs 1-6, 5

Persistent density hotspots of recruits of *M. merluccius* have been detected in the slope around Menorca and in the north-eastern and southern Mallorca (Fig. 2.2.5.1.1). In the GSAs 01 and 06 nursery hot-spots were found only in the GSA06, between 100 and 250 m depth and preferentially at about 150-200 m.

In GSA 5 recruits are found between 110-380 m and preferentially at about 250 m depth. The largest areas of recruitment are predicted to be located in the north of the Menorca channel, north-west of Menorca, and the south and south-west of Mallorca. In these areas the shelf is wide and gentle (up to 35 km southern Mallorca; Acosta et al., 2002), by contrast to other areas like north-western Mallorca and northern Menorca, where the shelf is very narrow (~3 km). High variability was observed in the mean annual density values estimated during the study period, being the minimum and maximum of distinct orders of magnitude (39 in 2008 and 356 in 2010). This is in agreement with the fact that different oceanographic scenarios around the Balearic Islands, associated with macro and meso-scale climate regimes, can influence the population dynamics of this species, especially for its recruitment (Massutí et al., 2008).

In GSA 6 the largest areas of recruitment and the highest abundances are predicted to be located between the Ebro River delta and Cape Nao. This is an area with a wide continental shelf, frequent up-wellings (Salat, 1996) and an important land runoff, where temporary discharges due to storms may produce intense local enrichment (Estrada, 1996). In fact, this is one of the areas with higher productivity within the general oligotrophy of the Mediterranean. Another important area is also located at the northern part of this GSA06, between Cape Creus and Cape Bagur, in the vicinity of the Gulf of Lions, another productive area, influenced by up-welling and land runoff (Estrada, 1996). Clear oscillations in the mean annual abundance of recruits occurred during the study period, with minimum and maximum values of 192 (in 2007) and 2098 (in 2006) individuals/km^2, respectively. Some differences in the distribution pattern can be observed depending on the annual intensity of recruitment. In years with high level of recruits, their higher abundance is observed not only between the Ebro River delta and Cape Nao, but also further south to Cape Palos and northern to merge with the second important area, between Cape Bagur and Cape Creus. Even in these years of high recruitment indices, the predictions in the GSA 01 indicate that the abundance of recruits is much lower than in the GSA 06.

Regarding spawners, persistent density hot-spots have been detected in the GSA 05 in the slope around Menorca and north-eastern and southern Mallorca, similar to the location of the nursery hotspots but with a higher percentage of persistence. In the GSA 01 and 06 no persistent spawning areas (>80% persistency) were found (Fig. 2.2.5.1.1). Spawners are predicted throughout the continental shelf, in both GSA 01 and 06, and more specifically over bottoms <100 m depth. This is more pronounced in the GSA 06, where the continental shelf is extended, especially in the area of the Ebro River delta.

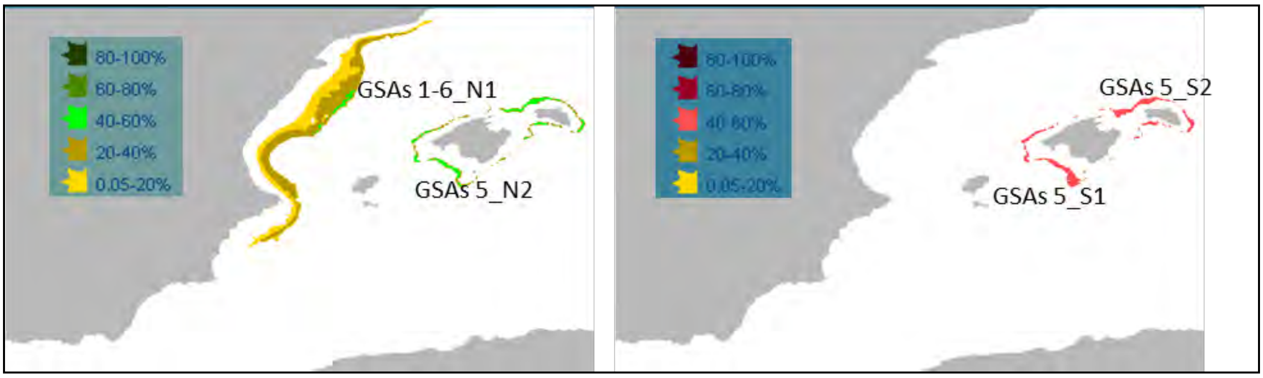


Fig 2.2.5.1.1. Position of persistent nursery (left) and adult aggregation areas (right) in GSA 6

GSA 7

In the Gulf of Lions hake recruits were characterized by low densities; no clear hot spot nursery areas have been identified. They concentrate in the external border of the continental shelf, in the vicinity of the top of the slope canyons where a Fishery Restricted Area has been established in 2009 by the GFCM (STECF, 2009). A hot spot area of spawners have been identified in the eastern part of the Gulf of Lions, from 100 to 200 m depth (Fig. 2.2. 6.1.2).

Juveniles show a patchy distribution with some main density hot spots (i.e. nurseries areas), showing a high spatio-temporal persistence in areas with frontal systems and other oceanographic structures that can enhance larval retention. Recruits were very abundant in GSA9; the collected data well fit with the spatial model, while the very scarce presence of spawners did to allow the identification of hot spot areas.

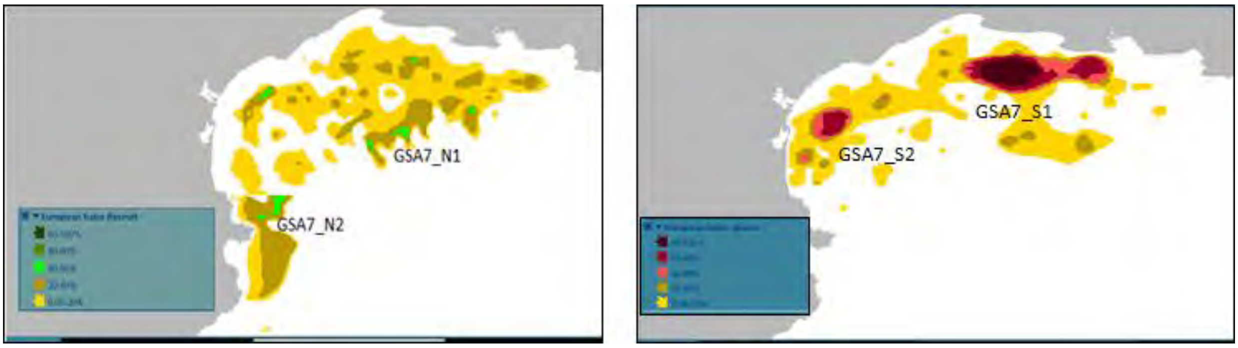


Fig. 2.2.5.1.2. Position of persistent nursery (left) and spawning areas (right) in GSA 7

GSA 9

In GSA9 the nurseries with the largest recruit density were located north (south Ligurian Sea) and south of the Isle of Elba (northern Tyrrhenian Sea), whereas smaller high-density patches occurred along the shelf-break (120 to 250 m depth) in the southern part of the GSA. These areas are often characterized by the abundant presence of the crinoid *Leptometra phalangium* also associated with juveniles of other commercial species, such as *Parapenaeus longirostris, Trisopterus minutus capelanus, Illex coindetii* (Fig. 2.2.5.1.3).

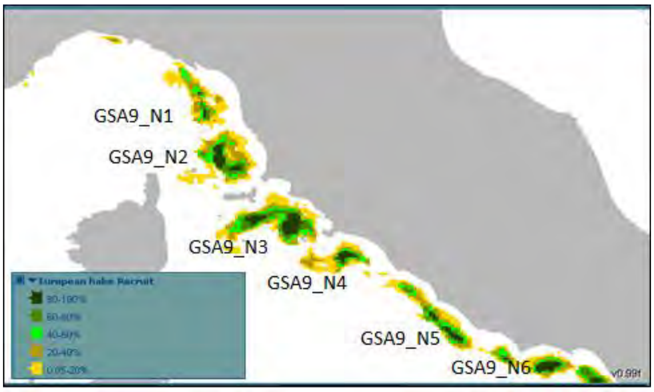


Fig. 2.2.5.1.3. Position of persistent nurseries of hake in GSA 9

GSA 10

The most persistent nurseries of hake in GSA10 were those already observed in previous studies, in the Gaeta, Napoli and to a lesser extent Salerno Gulf, at 100-200 depth. It is remarkable a persistence in a temporal horizon of 17 years (Fig. 2.2.5.1.4). These areas are characterised by muddy bottom and coastal terrigenous muds in the north part of the GSA and by the presence of *Leptometra phalangium* in the southern part (south of Salerno Gulf).

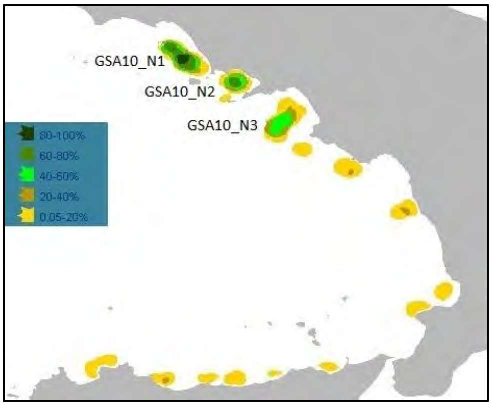


Fig. 2.2.5.1.4. Position of persistent nurseries of hake in GSA 10

GSA 11

In Sardinian seas, zones of high concentration of juveniles are distributed in the range of 100-200 meters although considerable density of recruits was found at greater depths (between 300 m and 400 m). The nursery areas are identified mainly in the south western coasts of Sardinia, and, with a lower level of persistence, also in the northern coast, both characterized by the biocenosis of *Leptometra phalangium* (Fig. 2.2.5.1.5).

The spawning areas (level of persistence of 40-60 %) are distributed along the north western and southern coasts of the island (Fig. 2.2.5.1.5).

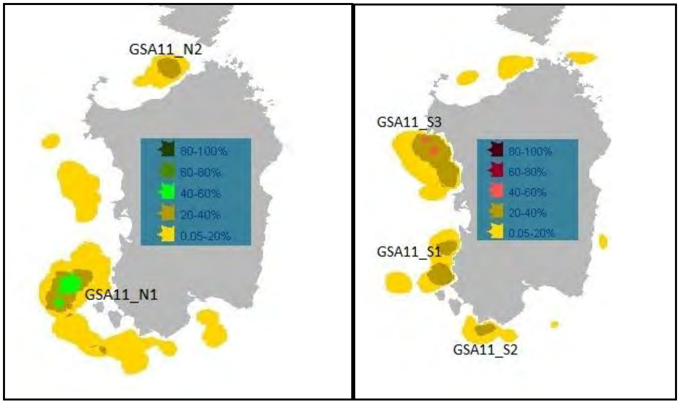


Fig. 2.2.5.1.5. Position of persistent nursery (left) and spawning areas (right) of hake in GSA11.

GSAs 15-16

The highest densities of hake recruits are concentrated on muddy bottoms between 100 and 300 m, showing that the outer shelf corresponds to the preferential depth range for the recruitment processes. The distribution areas are mainly located to the east of the Adventure Bank, along the central southern coast of Sicily, east of Malta Bank at the border of the GSA 15 and just southeast of Malta. According to persistency analysis the largest nursery in the Strait of Sicily (GSA15+16_N1) is located on the eastern side of the Adventure Bank, between the shelf break and the upper slope, and extends till the south central coast of Sicily (Fig. 2.2.5.1.6). As regard the nursery identified east of the Malta Bank (GSA15+16_N3), its core actually lies beyond the border of GSA 15 (area not covered in the present project) as reported in a previous study. Persistent nurseries are all located in areas characterized by permanent upwelling and persistent mesoscale structures such as vortices and fronts which sustain processes of enrichment, concentration and retention, thus providing suitable conditions for recruitment (Fig. 2.2.5.1.6).

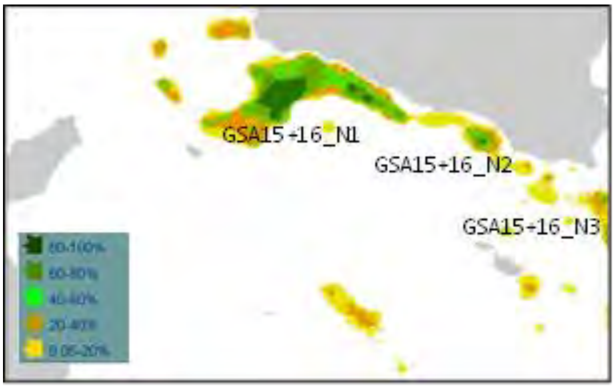


Fig. 2.2.5.1.6. Position of persistent nurseries of hake in GSAs 15-16

GSA 17

The areas of persistency identified for the recruits of European hake in GSA 17 are comprised between 150 and 200 m and located in three areas: the former is southwards the Pomo/Jabuka Pit and parallel to the Italian coast (25 nm from Abruzzo – Apulia Regions; R1), the second is the widest one and is located just eastwards the Pomo/Jabuka Pit area and close to the Croatian Islands (R2) and the third is near the southern limit of GSA17 (R3, Fig. 2.2.5.1.7). In the Pomo Pit muddy-sediments are characterized by oxic conditions in uppermost centimetres. They are due to very low inputs of fresh organic matter and produce low fluxes of all nutrients with the exception of nitrate that flows into the sediment for oxidation processes that take place in first centimetres. Bottom water masses of the Pomo pit are only periodically renewed by the oxygen-rich dense waters formed in the eutrophic coastal regions of the North Adriatic and flowing into the basin (Gramitto and Froglia, 1998). A mesoscale experiment carried out in fall 1988 showed a large gyre in the area which may prevent larval dispersion (Paschini et al., 1993). The area has been reported to be characterized by conspicuous numbers of benthic scavengers (e.g. *Natatolana borealis*) and other crustaceans as *Munida intermedia, Munida rugosa and Nephorps norvegicus* (Gramitto and Froglia, 1998).

The four areas of persistency identified for the spawners of European Hake in GSA 17 are located in the eastern side of the basins and comprised between 50-200 m of depth. S1 is located in the Kvarner Gulf, S2 is located northwards the Pomo/Jabuka Pit, S3 is located between the Islands of Brac and Hvar, S4 is in the Croatian side of the southern limit of GSA 17 (Fig. 2.2.5.1.7). The spawning grounds are characterized by upwelling events, associated to the prevailing NW winds, frequent along the Croatian coast during summer months (Cushman-Roisin et al., 2001). The morphology of the eastern area, where most of the spawning grounds are confined, is replete with islands and headlands, among which the water depths can reach 100 m. Due to complicated geographical features every bay and channel, in general characterized by rocky bottoms, tends to have specific characteristics in terms of sediments, oceanography and biota. In general the eastern side is characterized by the presence of coralligenous communities, maerls beds and sand-muddy biocoenosis.

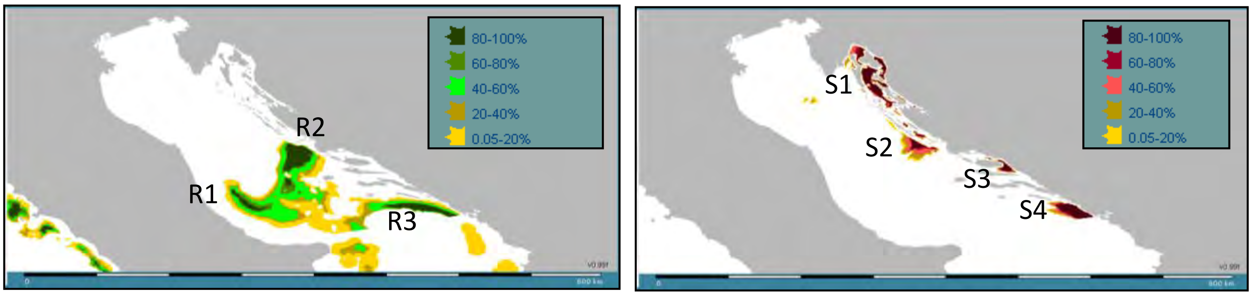


Fig 2.2.5.1.7. Position of persistent nursery (left) and persistent areas of potential spawners (right) in GSA 17

GSA 18

In the GSA18 -South Adriatic the nurseries are mainly localised off-shore Gargano Promontory, a nucleus that is persistent over 17 years, and along the southernmost both east (off-shore Vlora) and west sides of the GSA, mainly between 100 and 200 m depth. (Fig. 2.2.5.1.8). Other nuclei are located in the southern part of the west side, along the border of Otranto Channel and off-shore Dürres. The bottom is muddy characterized by the detritic bottom biocenosis (DL). The direction of the current in the sampling period (spring) is from north to south on the west side and viceversa on the east side.

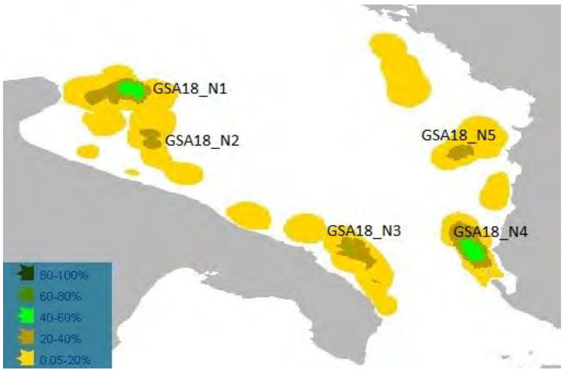


Fig. 2.2.5.1.8. Position of persistent nursery areas of hake in GSA18

GSA 19

In the GSA19 - North-Western Ionian Sea the main nursery areas of *M. merluccius* were generally observed on the shelf grounds distributed between Otranto and Santa Maria di Leuca as well as on the shelf and shelf break-upper slope around the Amendolara Bank and along the coast from Siracusa to Cape Passero. The more persistent nursery areas were distributed on the shelf and shelf break-upper slope around the Amendolara Bank and from Siracusa to Cape Passero (Fig. 2.2.5.1.9).

Fig. 2.2.5.1.9. Position of persistent nursery areas of hake in GSA19

GSAs 20-22-23

Although hake was found throughout the examined depth range (22-800m), our analysis revealed that it is generally more abundant in the 100-450m depth zone. Recruits seem to prefer somehow shallower waters than adults, being more abundant from 100 to 320m and having their major abundance peak around 100m. The density maps revealed that hake is widely distributed over the examined area, but spawners are relatively more abundant in the northern part of the Aegean Sea and in the Korinthiakos gulf in the Ionian (Fig. 2.2.5.1.10).

Several areas of the Aegean and Ionian seas are characterized as hake nursery grounds (Figs. 2.2.5.1.10, 2.2.5.1.11).). Results, however, have shown that the identified nursery grounds are not all of the same importance and that the Saronikos Gulf is by far the most significant one. It seems that the prevailing abiotic and/or biotic factors in Saronikos Gulf, an area of high fishing activity, favour the hake distribution in the area. Certain fishery closures that are locally applied may be also in favour of hake juvenile survival.

In general, the currently observed spatial patterns could be linked to the specific topographic and bathymetric conditions of the examined seas. The Aegean Sea is characterized by a complex bathymetry, the existence of numerous islands and the presence of a narrow continental shelf (with the exception of its north-eastern part). The general large-scale water circulation pattern of the Aegean is anticlockwise. It has been observed that more salinized warmer (eastern Mediterranean of Levantine origin) waters flow northwards in the eastern Aegean, where they are diluted by the inflow of less salinized colder (Black Sea) waters, which flow southwards in the western Aegean. As a consequence, the Dodecanese region (southeastern Aegean) is mainly influenced by the warmer and more saline waters of Levantine origin, whereas the Cyclades area (central Aegean) is influenced by the colder and less saline waters coming from the Black Sea. It is most likely that such temperature/salinity gradients, seriously affect the distribution pattern of the species. However, given that our findings are based on an annual survey, they may have been affected by the timing of the survey; hence they should be considered with caution.

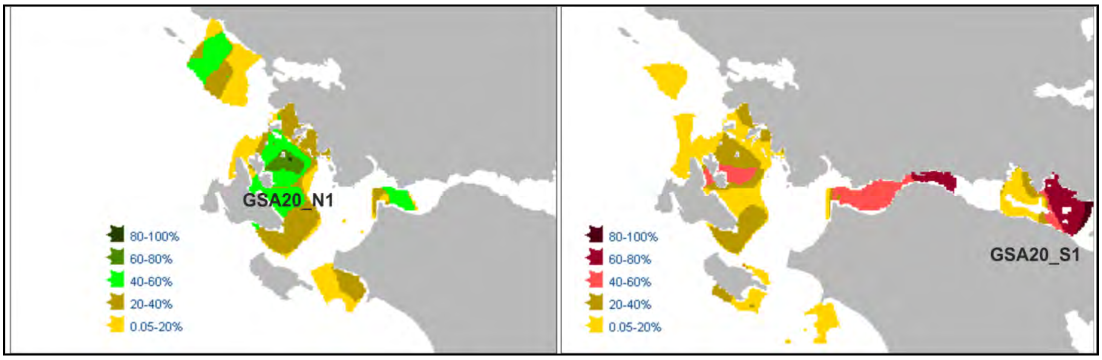


Fig. 2.2.5.1.10. Position of persistent nursery (left) and spawning areas (right) of hake in GSA 20.

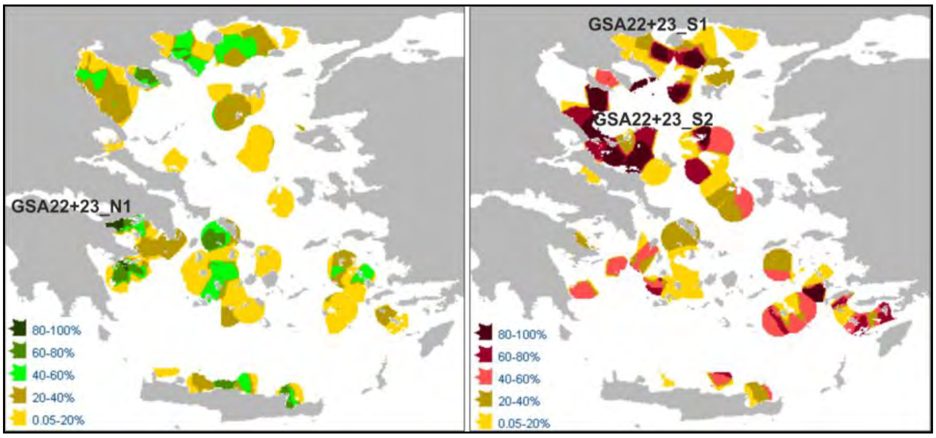


Fig. 2.2.5.1.11. Position of persistent nursery (left) and spawning areas (right) of hake in GSA 22_23.

Table 2.2.5.1.5. Environmental characteristics on nurseries and spawning grounds of European hake.

GSA	Type of area	Code	Depth range (m)	Description
06	nursery	GSAs 01 and 06_N1	200 – 500	Continental-shelf to upper slope. Wide continental shelf and frequent up-welling events.
05	nursery	GSA 05_N1	around 250	Slope around Menorca
05	nursery	GSA 05_N2	around 250	North-Eastern and Southern Mallorca
05	Adults aggregations	GSA 05_S1	around 250	North-Eastern and Southern Mallorca
05	Adults aggregations	GSA 05_S1	around 250	Slope around Menorca
7	nursery	GSA7_N1	90-140	Nursery with low temporal persistence. Shelf-break close to canyon heads.
7	nursery	GSA7_N2	50-120	Nursery with low temporal persistence. Inner shelf between the Lacaze Duthier Canyon and the Cap de Creus Submarine Canyon. Occurrence of mesoscale anticyclones
7	Adults aggregation	GSA7_S1	50-100	Eastern shelf of the Gulf of Lion. Muddy bottoms.
7	spawning	GSA7_S2	50-80	Western shelf of the Gulf of Lion. Muddy bottoms

GSA	Type of area	Code	Depth range (m)	Description
9	nursery	GSA9_N1	130-160	Ligurian Sea, North of Gorgona Island. Detritic bottoms on the shelf break with *Leptometra phalangium*. The area is interested by the flowing Northward of the Eastern Corsican current
9	nursery	GSA9_N2	120-180	South Ligurian Sea. North of Elba Island and East of Capraia Island. Detritic bottoms on the shelf break with Leptometra phalangium and other suspensivors macrozoobenthic species. The area is interested by the flowing Northward of the Eastern Corsican current
9	nursery	GSA9_N3	115-270	North Tyrrhenian Sea. Two main patches across the Tuscany shelf break, between 115-270m and 156-224m (North of the Giglio Island) respectively. Detritic bottoms on the shelf break with Leptometra phalangium. Occurrence of the Tyrrhenian and Levantine currents flowing counterclockwise along the Tuscany slope.
9	nursery	GSA9_N4	115-200	Detritic bottoms on the shelf break with *Leptometra phalangium* between Anzio and Fiumicino
9	nursery	GSA9_N5	110-210	Detritic bottoms on the shelf break with Leptometra phalangium between Gaeta and Capo Circeo.
10	nursery	GSA10_N1	89-119	The northern seabeds of the Ischia Island are characterized from a wide continental shelf. The sandy-muddy bottoms are colonized by coastal terrigenous muds (VTC) biocenosis inhabited from typical species as Alcyonium palmatum, Astropecten spp, Sternaspsis scutata, Bolinus spp etc. The direction of the superficial currents is parallel to the coast from south to north during the sampling period (spring).
10	nursery	GSA10_N2	150-170	The large continental shelf of the Golf of Naples is characterized from muddy bottom and coastal terrigenous muds biocenosis (VTC). The characteristic species are *Alcyonium palmatum*, *Astropecten spp*, *Sternaspsis scutata*. The superficial currents are circular during the sampling period (spring).
10	nursery	GSA10_N3	158-217	The muddy bottoms inside the Golf of Salerno are characterized from coastal terrigenous muds (VTC) and detritic bottom (DL) biocoenosis inhabited from the shallower facies of Leptometra phalangium (along the shelf). The direction of the superficial current in the sampling period (spring) is parallel to the coast from south to north.
11	nursery	GSA11_N1	100-200	Bottoms are characterized by the presence of the biocenosis of the Detrict with an high presence of the crinoid Leptometra phalangium
11	nursery	GSA11_N2	100-200	Bottoms are characterized by the presence of the biocenosis of the Detrict with an high presence of the crinoid *Leptometra phalangium*
11	Adults aggregation	GSA11_S1	100-200	Bottoms are characterized by the presence of the biocenosis of the Detrict with an high presence of the crinoid *Leptometra phalangium*
11	Adults aggregation	GSA11_S2	100-200	Bottoms are characterized by the presence of the biocenosis of the Detrict with an high presence of the crinoid *Leptometra phalangium*
11	Adults	GSA11_S3	100-200	Bottoms are characterized by the presence of the biocenosis of the Detrict with an high presence of the

GSA	Type of area	Code	Depth range (m)	Description
	aggregation			crinoid *Leptometra phalangium*
15+16	nursery	GSA15+16_N1	125-300	Bathyal muds biocenosis with sandy and gravel bottom. The area is characterized by permanent upwelling and by the presence of a large cyclonic vortex, called Adventure Bank Vortex (ABV), a dominant feature linked to the meanders of Atlantic Ionian Stream (AIS) (flowing eastward up to 100 m depth). The mean value of SST observed in late spring-early summer is 21.5 °C.
15+16	nursery	GSA15+16_N2	140-200	Open-sea detritus bottom. The main mesoscale oceanographic feature is a pronounced anticyclonic meander (Maltese Channel Crest-MCC) where the AIS detaches the coast. The mean value of SST observed in late spring-early summer is 22 °C.
15+16	nursery	GSA15+16_N3	140-150	Bathyal muds biocenosis in association with Funiculina quadrangularis. Persistent mesoscale structures in the area are the cyclonic Ionian Shelf Break Vortex (IBV) and the temperature and salinity fronts over the Ionian slope (Ionian Slope Front, ISF) located at the eastern boundary of IBV. The mean value of SST observed in late spring-early summer is 22.8 °C.
17	nursery	GSA17_R1	150-200	- muddy-sediments - water masses periodically renewed - scavengers communities (especially crustaceans)
17	nursery	GSA17_R2	150-200	- upwelling events - rocky and muddy bottoms - presence of coralligenous communities
17	nursery	GSA17_R3	150-200	- muddy-sediments - water masses periodically renewed - scavengers communities (especially crustaceans)
17	Adults aggregation	GSA17_S1	50-100	- upwelling events - rocky bottoms - presence of coralligenous communities
17	Adults aggregation	GSA17_S2	100-200	- upwelling events - rocky and muddy bottoms - presence of coralligenous communities
17	Adults aggregation	GSA17_S3	50-80	- upwelling events - rocky bottoms - presence of coralligenous communities
17	Adults aggregation	GSA17_S4	100-200	- upwelling events - muddy and rocky bottoms
18	nursery	GSA18_N1	108-149	The bottom is muddy characterized by the detritic bottom biocenosis (DL) with pennatulaceans facies (Pteroides spinosus, Pennatula rubra etc.) on the soft bottom and hidroids facies (Funiculina quadrangularis, Lytocarpia myriophyllum) on tanatocenosis of Neopycnodonte cochlear. The direction of the superficial current in the sampling period (spring) is from southern to northern.
18	nursery	GSA18_N2	105-172	The bottom is muddy characterized by the detritic bottom biocenosis (DL) with hidroids facies (Nemertesia antennina, Lytocarpia myriophyllum) on tanatocenosis

GSA	Type of area	Code	Depth range (m)	Description
				of Neopycnodonte cochlear. The direction of the superficial current is from north to south in the sampling period (spring).
18	nursery	GSA18_N3	90-150	The bottom is muddy characterized by coastal terrigenous muds biocenosis (VTC) with facies of A. palmatum on the soft bottom and the detritic bottom biocenosis (DL) with hidroids facies (Funiculina quadrangularis, Lytocarpia myriophyllum Nemertesia antennina) on tanatocenosis of Neopycnodonte cochlear. The direction of the superficial current is from north to south in the sampling period (spring).
18	nursery	GSA18_N4	88-178	The sandy-muddy bottoms are characterized by coastal terrigenous muds (VTC) biocenosis (Alcyonium palmatum, Astropecten spp, Stichopus regalis Pennatula phosphorea etc.) and the detritic bottom biocenosis (DL) inhabited by typical species as Nemertesia antennina, Cidaris cidaris, Tetyiaster subinermis. The direction of the superficial current is from north to south in the sampling period (spring).
18	nursery	GSA18_N5	107-119	The muddy bottoms are characterized by coastal terrigenous muds (VTC) biocenosis inhabited by typical species as Alcyonium palmatum, Stichopus regalis, Pennatula phosphorea, Pteria hyrundo etc. Moreover is not negligible in the presence of tanatocenosis of Neopycnodonte cochlear. The direction of the superficial current is from north to south in the sampling period (spring).
19	nursery	GSA19_N1	23-152	The shelf in the Gulf of Corigliano was characterized by the Amendolara Bank (rising from 200 up to about 20 m below the surface). In particular, this area was characterized by the coarse sand and coastal detritic biocenosis.
19	nursery	GSA19_N2	121-441	The shelf and shelf break-upper slope from Siracusa to Cape Passero was characterized by the terrigenous mud, shelf-edge detritic and bathyal muds biocenosis.
20	nursery	GSA20_N1	200-250	Relatively deep areas between continental Greece and the Ionian Islands complex. Main sediment type: mud
20	Adults aggregation	GSA20_S1	550-650	Deep areas of the Korinthiakos gulf. Enclosed gulf with minor oceanographic interactions with the adjacent areas. Relatively deep waters in the central Aegean (mainly in the Cyclades Island complex). Main sediment type: mud
22_23	nursery	GSA22-23_N1	50-250	Innermost part of the Saronikos gulf. Largely protected from large-scale oceanographic features. Relatively deep waters in the central Aegean (mainly in the Cyclades Island complex). Main sediment type: mud
22_23	Adults aggregation	GSA22-23_S1	200-700	Deep areas of the North Aegean Sea. Largely influenced by the inflow of Black Sea waters from the Dardanelles straits into the AegeanSea. Relatively deep waters in the central Aegean (mainly in the Cyclades Island complex). Main sediment type: mud
22_23	Adults aggregation	GSA22-23_S2	200-700	Deep areas of the northwestern Aegean Sea. Largely influenced by the southward circulation of a branch of the Black Sea water mass entering the AegeanSea from the Dardanelles straits. Relatively deep waters in the

GSA	Type of area	Code	Depth range (m)	Description
				central Aegean (mainly in the Cyclades Island complex). Main sediment type: mud

2.2.5.1.4. Gaps in knowledge

In Western Mediterranean, the results obtained for European hake and adult aggregations should be taken with cautious because of the low number of spawners captured during the MEDITS trawl survey. The observed low catch can be the result of different reasons, including low catchability of big hake with the MEDITS net, mismatch between survey period and spawning peaks, distribution of adults over untrawable areas, as it has been reported in the Gulf of Lions (e.g. Aldebert et al., 1993). A winter-spring survey with trawl and gillnets should be advisable to properly identify areas of spawning aggregation. Furthermore, the seasonal stability of nurseries is still poorly understood and would need to be better investigated.

In Greek seas, given the timing of the MEDITS survey (June), it is likely that the resulted habitat mapping cannot be considered as fully representative of the actual distribution of nurseries and spawning areas. In the Greek Seas, the peak of the reproductive period for hake is well off the time period that the MEDITS survey is taking place, thus results for spawning grounds should be treated with caution. Furthermore, nursery grounds may be inadequately represented as sampling covers only a small part of the recruitment period.
There is a general lack of information on hake biology and distribution in the Levantine Sea and in particular in GSA 25.

2.2.5.2 Mullus barbatus

2.2.5.2.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Annex 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

In GSAs 7, 8, and 9 a massive recruitment occur from mid to the end of summer, on sandy bottoms very close to the shore. Bottom recrutiment is followed by a gradual dispersal toward greater depths. In GSA9 the length at the end of age 1 was estimated at 12-14 cm for males and 15-17 cm for females.

In GSA 10 juveniles of *M. barbatus* are more abundant in the Gaeta Gulf (Campania coasts), off Scalea and Amantea (Calabria coasts) (Spedicato et al., 2007) and off S. Agata di Militello (north Sicily coasts). Recruitment follows a discrete pattern, with a peak in summer, extended to early autumn. Red mullet recruits have an inshore distribution within 50 m depth. Recruitment size ranges between 9.4 cm and 12.7 cm TL.

In the GSA 11, the recruitment starts in July when the first small specimens of about 6 cm TL are caught by the trawl net. It is completed in autumn when the individuals reach a TL of about 9-10 cm. The nursery areas are found at depth less than 50 m, along the coasts of S. Antioco, Carloforte and Bosa Marina.

In the Strait of Sicily (GSAs 15-16) recruitment of red mullet is discrete and occurs in coastal bottoms in late summer–early autumn. The modal length of the 0-group lies in the range 60-80 mm TL. Density hot-spots of recruits are located in shallow coastal waters (up to 70 m) throughout the southern coast of Sicily (GSA

16), whilst they can be observed to the northeast of Malta (GSA 15) close to the border of the 25 nautical mile Fisheries Management Zone at about 100 m depth.

In central-North Adriatic (GSA 17) Juveniles are distributed along the western shallow coastal water (Piccinetti et al., 2012). Indeed recruits aggregate along coast in summer and when they grow up, after two or three months, migrate towards the open sea because of the less extreme conditions in this area during autumn and early winter. Fraction of recruits is small with big difference from year to year; indeed juveniles of *M. barbatus* have the peak of recruitment in late summer-early autumn.

In GSA18 red mullet nurseries were mainly identified off the Gargano promontory and between Molfetta and Monopoli within 50 m depth. Recruitment follows a discrete pattern, with a peak in summer in inshore waters. Size of recruits ranges between 5.4 cm and 11.3 cm TL.

In the GSA19 the reproduction of red mullet occurs from May to August and recruits were mostly found during late summer-autumn on the shelf. The sizes of recruits ranged between 9.6 and 11.6 cm TL. Up to date, no nursery areas were detected for *M. barbatus* in GSA19. However, an area with high density of recruits was frequently detected on the shelf southern Punta Stilo (163525 recruits/km^2 were estimated during autumn 1997). Additional areas were also detected offshore Otranto, Policoro, Cirò and Cape Bruzzano within 200 m.

In GSAs 22-23 recruits of red mullet have been observed mainly in autumn. The appearance of recruits has also been reported as early as July in Saronikos gulf. The depth distribution of recruits of this species ranges according to available sources from 0-100 m in GSAs 22_23.

Spawning

In GSA 1, 5 and 6 the species is found mainly on muddy bottoms between 50-200 m depth (Lombarte *et al.*, 2000). Reproduction period takes place between May and August (Chérif *et al.,* 2007). Length at first maturity was estimated to be at about 11-12 cm for females in the Iberian Peninsula coast.

In GSA7 and 9 spawning occurs in late spring-summer (May – July). In the south part of the GSA9 the larger spawners occur over crinoid beds along the shelf-break at 120-170 m.

The maturity is achieved at the end of the first year: in GSA9 sizes at first maturity of 10-12 cm TL for males and 12-14 cm TL for females have been reported. In the Gulf of Lions the environmental changes (e.g. warming) was interpreted as the main factors driving the long-term increase in landings of small red mullet.

In GSA10 a proxy of size at first maturity for females was estimated in the SAMED project that indicates an average length of about 15 cm. This size is however overestimated. The maturity ogives of females from DCR 2006-2008 biological sampling was: L50% =12 cm ±0.03 cm (MR=1.4±0.05). In 2010 using a GLM approach L50% was 11.84 ± 0.15 and MR= 0.61 ± 0.28.

In GSA11 - Sardinian waters, the reproduction of *M. barbatus* occurs between May and July with some reproductive events also in September. The size at first maturity is about 10.5 for both sexes.

In GSA 15+16 spawning of red mullet takes place in spring-summer with a peak in May. Maturity ogive estimates indicate a L_{50} of 150-160 mm TL for females and 140 mm TL for males. Both in GSA 15 and GSA 16, high density concentrations of spawners are observed on offshore bottoms at 100-150 m depth (Malta Bank and Adventure Bank, respectively).

In the Adriatic Sea (GSA 17), red mullet spawns in late spring and summer (May, June, July) and reach sexual maturity between 10 and 14 cm of total length (Vrgoč et al., 2004). During MEDITS survey spawners dominate the population.

In GSA18 the maturity ogives of females from DCR 2006-2008 biological sampling was: L50% =12.6 cm ±0.04 cm (MR=1.4±0.05). This value was similar to that of DCF in 2009 L50% =11.9 cm ±0.04 cm (MR=1.0±0.05) and 2010: L50%= 12.5 ±0.15 MR= 0.5 ±0.28, using a GLM approach.

In the North-Western Ionian Sea-GSA19 the smallest mature female and male of the red mullet were 9.5 and 9.0 cm TL, respectively. The estimated length at first maturity of females was 11.7 cm TL. Up to date, no spawning areas were detected for *M. barbatus* in GSA19.

In GSAs 22_23 size at maturity shows variation between NW Aegean and N Aegean subareas. NW subarea showed higher L50 values. Red mullets >200mm collected in waters deeper than 100m, but no specimens were collected in depths beyond 200m. Size at maturity shows variation between various areas of the Eastern Mediterranean.

2.2.5.2.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.2.1 and 2.2.5.2.2 list the results of MEDITS survey in terms of frequency of positive hauls and number of specimens caught by year and GSA. Table 2.2.5.2.3 shows recruitment and spawning size identificated for modeling purposes.

GSAs 1, 5, 6

The amount of positive hauls is similar in the three Spanish GSAs, but it depends on the year. It was fairly stable in the GSA05, varied from 0.30 to 0.34 while in the GSA 01 and 06 it varied from 0.28 to 0.51. The amount of specimens is highly variable ranging from 732 to 1578 in the GSA05 and from 395 to 3720 in the GSA 01 and 06.

The spawning fractions of females were extracted based on the length at first maturity (L_{50} or length at which 50% of the individuals are mature) and the maturity ogive (L25-75). For this purpose, data on monthly biological samplings of commercial catches, obtained within the Data Collection Framework, were used to identify the spawning periods of each species, from monthly average of the Gonadosomatic Index (GSI) and the percentage of maturing or mature individuals. Only data compiled during these spawning periods was used to calculate L_{50}, from the logistic curve: PL= e(a+b*L)/(1+e(a+b*L)), where PL is the proportion of mature individuals for a given size class L. Logistic curves were fitted by maximizing the log-likelihood function, using Solver in EXCEL (Tokai, 1997).

GSAs 7, 8, 9

In GSA7 the frequency of positive hauls for red mulled was comprised between 0.27 in 1994 to 0.71 in 2010, with and increasing temporal trend; in GSA8 it was comprised from o.14 to 0.48, without evident temporal trends; in GSA9 the occurrence of this species was substantially stable in the different years, ranging from 0.30 to 0.50. As concerns the specimens caught in GSA7 they ranged from 193 to 989 in the different years; in GSA8 they varied from 68 to 401. In GSA9 *M. barbatus* was notably more abundant: the catches were comprised from 1156 specimens in 1994 to 11988 in 2002.

The MEDITS survey is carried out in a period (spring-beginning of summer) preceding the recruitment of the species, which starts in the second half of summer. For this reason it was impossible to detect recruits in the majority of data analysed. Only for GSA9 in some years (especially in 2002 and 2005) was possible to single out recruits; in these cases Bhatthacharya method was used to select the first size component. The cutoff size resulted in 65mm TL length for all the years.

As concerns spawners, the MEDITS survey period generally overlaps with the maturity period of *M. barbatus*. The maturity stage corresponding to stage 3 of MEDITS maturity scale has been chosen for modeling pursposes.

GSAs 10, 11, 18, 19

The frequency of positive hauls for *M. barbatus* in GSA10 ranges from 0.13 (MEDITS 1994) to 0.37 (MEDITS 2007), with an overall catch fluctuating from a minimum of 377 (MEDITS 2004) and a maximum of 2212 (MEDITS 2002) sampled specimens. The frequency of positive hauls for *M. barbatus* in GSA11 ranges between 0.28 (MEDITS 1997) and 0.51 (MEDITS 2009 and 2010), with an overall catch fluctuating from a minimum of 623 (MEDITS 2000) and a maximum of 1256 (MEDITS 2010) sampled specimens. The frequency of positive hauls for *M. barbatus* in GSA18 ranges between 0.14 (MEDITS 1995) and 0.63 (MEDITS 2008), with an overall catch fluctuating from a minimum of 39 (MEDITS 1995) and a maximum of 5511 (MEDITS 1999) sampled specimens. The number of specimens of *M. barbatus* caught in the GSA19 fluctuated between 188 (MEDITS 1999) and 14468 (MEDITS 2007). Thus, the frequency of positive hauls for the red mullet oscillated between 0.19 and 0.36.

In GSAs 10, 11, 18 and 19 the threshold to separate the recruits has been estimated as the mean length of the first modal component + 2* sd using the Bhattacharya's method and the R_RSI MEDISEH routine, specifically developed for the Mediseh project. To identify the adults or potential spawners, an average of the parameters of the maturity ogive among the years from the MEDITS survey and/or from biological samplings of DCR and DCF has been used in GSAs 10 and 18, selecting those better fitting to the model. The identification of spawners in the GSA11 and GSA19 was carried out using the maturity stage 3.

GSAs 15-16

In GSA 15+16, the percentage of positive hauls varied between 36% and 48% with the exception of a lower value (28%) in 2003. The total number of specimens caught was comprised between 2036 and 7037. A signal of recruitment of *M. barbatus* was detected in two years only (2003 and 2005) in GSA 15+16, hence the juvenile fraction of the species was not analyzed. Spawners of *M.barbatus* in GSA 15+16 were identified by considering all the females with a maturity stage "3" according to the MEDITS maturity scale. The mean size by year resulted comprised between 163 and 175 mm TL.

GSA 17

GSA 17 MEDITS data are available for the period 2002-2010. The period 1994-2001 has been excluded from the analyses because data of the eastern side of the basin were not available. As no recruits were caught in 2009 and 2010 modeling of recruitment area was performed in the period 2002-2008. In GSA 17 based on MEDITS data red mullet seems fairly abundant with more than 50% of positive hauls and an average of more than 5,000 specimens collected each year. In GSA 17 the approach employed to detect the recruits was the Bhattacharya, which identified threshold sizes from 5.7-9.4 cm of total length. The spawners have been detected using the maturity stages collected during the survey.

GSAs 20, 22-23

The data for red mullet in GSAs 20-22-23 used in the present work were obtained from the MEDITS survey. The available data for red mullet that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSAs 22_23 the frequency of positive hauls for red mullet ranged from 30-40%, whereas for GSA20 the frequency was higher (50-63%) (Table 2.5.2.1). Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates based on the aforementioned approaches and thus threshold values were established based on literature information and expert knowledge (Table 2.5.2.3)

GSA 25

In GSA 25 MEDITS data were available for the period 2005-2010. In this area red mullet is fairly abundant with usually more than 40% of positive hauls and an average of more than 900 specimens collected each year. The approach employed to detect the recruits was the Bhattacharya applied only in 2005, which identified threshold size of 7 cm of total length. The spawners have been detected using the maturity stages collected during the survey.

Table 2.2.5.2.1. Frequency of positive MEDITS hauls (n of positive hauls/n. of total hauls) for red mullet by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.29	0.43	0.31	0.13	0.33		0.18	0.22			0.40		
1995		0.29	0.14	0.38	0.26	0.41		0.14	0.23			0.49		
1996				0.43	0.21	0.34		0.23	0.22			0.43		0.33
1997		0.38	0.15	0.39	0.24	0.28		0.21	0.19			0.28		0.36
1998		0.51	0.35	0.41	0.35	0.37		0.22	0.28	0.56		0.44		0.41
1999		0.55	0.48	0.40	0.32	0.41		0.45	0.22	0.63		0.42		0.33
2000		0.43	0.41	0.37	0.27	0.39		0.38	0.24	0.53		0.40		0.39
2001		0.38	0.41	0.50	0.33	0.35		0.44	0.30	0.53		0.33		0.34
2002		0.44		0.43	0.26	0.35	0.66	0.28	0.26			0.39		
2003		0.32	0.43	0.43	0.26	0.46	0.67	0.34	0.31	0.63		0.44	0.28	0.36
2004		0.47	0.41	0.42	0.26	0.37	0.57	0.31	0.31	0.59		0.48	0.39	0.38
2005		0.37	0.39	0.40	0.30	0.49	0.63	0.51	0.27	0.53	0.48	0.40	0.36	0.39
2006		0.39	0.30	0.42	0.30	0.43	0.54	0.38	0.31	0.50	0.20	0.41	0.38	0.34
2007	0.3	0.60	0.30	0.47	0.37	0.42	0.62	0.56	0.36		0.44	0.43	0.40	
2008	0.34	0.51	0.44	0.45	0.26	0.45	0.60	0.63	0.30	0.56	0.52	0.47	0.48	0.30
2009	0.34	0.47	0.36	0.42	0.31	0.51	0.60	0.49	0.34		0.48	0.51	0.41	
2010	0.34	0.71	0.32	0.48	0.33	0.51	0.55	0.42	0.31		0.56	0.45	0.38	

Table 2.2.5.2.2. Number of specimens of red mullet caught by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		193	278	1156	1217	1060		79	717					
1995		537	182	2149	1565	1122		39	2066					
1996		0		2502	1305	656		895	923					1735
1997		431	2	2737	1414	724		354	329					3685
1998		674	401	2946	1890	836		546	820	1760				13453
1999		497	267	3900	1011	1255		5511	188	1224				23105
2000		510	159	3603	1220	623		504	412	499				5599
2001		362	304	4106	1868	880		826	904	1252				7144
2002		354		11988	2212	639	5308	481	1323					
2003		327	298	4717	900	1169	4072	375	777	1489		7037	7037	10325
2004		595	289	2665	377	666	5196	403	1919	1475		2036	2036	4588
2005		386	221	6495	385	1058	4972	2153	1326	641	1225	4036	4036	2835
2006		361	183	1631	527	1073	7461	486	1388	1076	161	2056	2056	3277
2007	1578	989	97	5920	2339	968	4057	1449	14468		1204	6979	6979	
2008	732	649	277	2163	409	842	7041	939	7905	1517	410	4999	4999	7021
2009	677	658	68	1902	1927	1008	5288	1179	990		1264	4345	4345	
2010	419	969	232	1716	398	1256	6457	1253	2872		1153	2890	2890	

Table 2.2.5.2.3. Recruitment and spawning size identification for modeling purposes.

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (TL mm)**	**Data source**	**Method used**	**Mean maturity length (TL mm) /Maturity stage**
05	2003-2004	-	-	-	DCF	Fixed threshold length (L50)	110
01 and 06	2005-2009	-	-	-	DCF	Fixed threshold length (L50)	119
7	1994-2010	No recruits			DCF/MEDITS	Maturity stage "3"	MS = 3
8	1994-2010	No recruits			DCF/MEDITS	Maturity stage "3"	MS = 3
9	1994-2010	MEDITS	Bhattacharya only for 2002 and 2005)	65	DCF/MEDITS	Maturity stage "3"	MS = 3
10	1994-2010	MEDITS	Bhattacharya	81	MEDITS and biological sampling	Maturity ogive	117
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya	60	MEDITS	MS maturity stages estimation	167
15+16	2003-2010				MEDITS	Maturity stage "3"	167 (annual mean:163 -175)
17	2002-2010	MEDITS	Bhattacharya	71		Maturity stage "3"	
18	1994-2010	MEDITS	Bhattacharya	86	MEDITS and biological sampling	Maturity ogive	125
19	2007	MEDITS	Bhattacharya	88	MEDITS	Length at maturity stage 3	3
20	1998-2008	MEDITS	Bhattacharya	70	MEDITS	Fixed threshold length (L50)	110
22_23	1996-2008	MEDITS	Bhattacharya	60	MEDITS	Fixed threshold length (L50)	110
25	2005-2010	MEDITS 2005	Bhattacharya	70		Maturity stage "3"	

Mapping of density and identification of hot spot areas

A detailed description of models used to map distributions and identify hot spots is provided in Annex 2. In this paragraph the modeling approach (method for mapping, covariates, etc.) is summarized. A summary of the spatial model implemented for mapping recruits and adults/spawners of red mullet is provided in Table 2.2.5.2.4. For details on the maps ypu can check the link at http://mareaproject.net/mediseh/viewer/med.html.

GSA 1-6, 5

Spawners were modeled using GAMs. Two models were conducted independently, one for presence/absence data, and another for standardized abundances restricted to presence data only. The recruits of this species were not modeled due to the mismatch between the sampling period and the time of the year the recruits are able to be found (spawning occurs in summer, after the survey).

The final presence/absence model for spawners in GSA 5 included depth and the interaction between longitude and latitude, whereas the final abundance was restricted to presence samples model included year and depth as factors, these models explaining 50 and 29% of the total variance, respectively. Spawners' abundance showed a decreasing trend in relation to depth up to 200 m, with higher values at the shallowest samples, while the presence/absence model showed a maximum at 100-150 m depth.

In GSA 1-6 the final presence/absence model for spawners included depth and the interaction between longitude and latitude, whereas the abundance restricted to presence samples model included depth, the interaction between longitude and latitude and year as factors. Each model explained 32 and 28% of the total variance, respectively. The spawners showed a decreasing trend in relation to depth up to 350 m, with higher values at the shallowest samples. Two periods can be distinguished in the mean annual abundance, the first from 1994 to 2005 shows frequent oscillations without a clear trend, whereas the second between 2006 and 2010 shows clearly higher values, which appear to be more stable.

GSAs 7, 8, 9

Since MEDITS is carried out before the recruitment season no modeling of recruitment distribution was developed. Spawning grounds were modelled both in GSA 7and 9. In GSA 8 the low number of positive and scattered hauls returned inconsistent models also when using geostatistical approaches and no identification of spawning grounds was allowed.

In GSA 7 and 9 spawners were mapped using a GAM with spatial component, fixed intercept, year effect and a smooth effect on the covariate distance from the shore (GSA 7) and bottom stepness (GSA 9). The whole MEDITS time series was used (1994-2010). The covariance functions were both exponential and spherical depending on the year.

GSA 10, 11, 18, 19

In GSA10-11-18-19 annual abundance values were predicted by means of ZIGAM modeling (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging only was applied on raw abundance values. In the kriging approach the model fitting was validated using cross-validation. For modelling, the R MEFH MEDISEH routine 2.0 (Martiradonna et al., 2012) was used. The recruitment has been identified annually according to ability of the survey to intercept the phenomenon, especially considering that recruitment occurs at a season different from that of MEDITS sampling. Thus recruits could be only detected in those years when the survey time was slightly delayed. Modeling using other environmental covariates (e.g. bottom slope and distance from the shore) was not successful.

GSAs 15-16

In GSA 15+16, red mullet spawners were modeled using a GAM with spatial component and a smooth effect on covariates Latitude and Distance from the coast. Both the intercept and the spatial component were supposed to change each year. The model goodness-of fit was measured by the cross-validation index

(CV) and the correlation index (R2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km.

GSA 17

Modeling approaches employed to identify nursery and spawning grounds of red mullet in GSA 17 were respectively the zero-Inflated Generalized Additive Model (Liu and Chan, 2010) and Ordinary Kriging. COZIGAM-ZIGAM approach did not find any suitable model to describe the spatial distribution of spawners and, hence, Ordinary Kriging was chosen because it produces a spatial distribution simply basing on the location of sampled stations. In both cases local G statistic (Getis and Ord, 1992) was employed to identify the hot spots, considered as the place where high values of densities cluster together. The covariates employed to identify the spatial patterns of recruits of red mullet were year (as factor), latitude, longitude and depth. The diagnostics of the ZIGAM model employed for recruits of red mullet hake in GSA 17 (table 2.5.2.4) show an acceptable fitting.

GSAs 20, 22-23

Generalized Additive Models were employed to model the distribution of spawners of red mullet in GSA 20 and GSA 22_23. The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots. Only spawners of the species were modelled, as the data of recruits were insufficient. The period analyzed was from 1996-2008 and from 1998-2008 for GSA 20 and GSAs 22_23, respectively. The depth distribution of red mullet spawners ranged from 35 - 350 m, and from 25 – 380 m in GSA20 and GSAs 22_23, respectively

GSA 25

In GSA 25, attempts of modeling have been undertaken for recruits and spawners of red mullet, but as is possible to observe in Suppl 2.2.2, both GAMs and geostatistical approaches could not provide any appropriate results. The relatively high distance of the hauls carried out did not allow the implementation of any reasonable model (no spatial covariance can be estimated).

Table 2.2.5.2.4. Modeling applied in EU GSAs for mapping red mullet.

Life Stage	Gsa	Depth Range	Period	Model Type	Covariates	Explained Variance (%)	Goodness of fit (R^2)
Spawner females	05	50-300	2007-2010	Pres./Abs.	(Lon,Lat), depth	50.4	0.24
				Abundance	Year, depth	28.7	
Spawner females	01, 06	25-350	1994-2010	Pres./Abs.	(Lon,Lat), depth	31.6	0.41
				Abundance	Year, (Lon,Lat), depth	28.1	
Spawner females	7	20-200	1994-2010	GAM	Distance from the coast, bottom stepness		*CV=1.01, 0.40
Spawner females	9	20-200	1994-2010	GAM	Distance from the coast, bottom stepness		*CV=1.02, 0.42
Recruits	18	10-200	1999, 2005, 2007	Ordinary Kriging			
Spawner females	10	10-400	1994-2010	Gaussian GAM	Depth	14.9	0.11
				Binomial GAM	Depth	26.9	0.26
				Ordinary Kriging			
Spawner females	11	10-400	1995-2010	Gaussian GAM	Depth	18.9	0.14
				Binomial GAM	Depth	12.5	0.1

				Ordinary Kriging					
Spawner females	18	10-400	1996-2010	Gaussian GAM	Depth	7.4		0.1	
				Binomial GAM	Depth	10.9		0.1	
				Ordinary Kriging					
Spawner females	19	10-400	1994-2010	Gaussian GAM	Depth	22.6		0.17	
				Binomial GAM	Depth	27.9		0.27	
				Ordinary Kriging					
Spawner females	15+16	20-550	2003-2010	GAM with spatial component	Year, Latitude, Distance from the coast			*CV=1.036, 0.521	
Spawner females	17	10-600	2002-2010	Ordinary Kriging					
Recruits	17	10-600	2002-08	ZIGAM	Year, Lon, Lat, depth	LR	GAM	LR	GAM
						41.8	54.8	0.31	0.42
Spawner females	20	35-350	1998-2008	GAM (delta - lognormal)	Year, Lon, Lat, depth	57.8		0.50	
Spawner females	22_23	25-380	1996-2008	GAM (delta - lognormal)	Year, Lon, Lat, depth	48.2		0.41	

* cross validation index

2.2.5.2.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.2.5 summarizes the main environmental features of the most persistent areas identified for red mullet in European GSAs. Details can be seen at http://mareaproject.net/mediseh/viewer/med.html.

GSAs 1-6, 5

In the GSA 05, a persistent spawning area was detected from Southern to Western Mallorca. The predictions showed that the largest areas in which spawners are found are located SW Mallorca (Fig. 2.2.5.2.1). Besides certain environmental characteristics (e.g. hydrography, bottom type) lower fishing effort (e.g. the activity of the bottom trawl fishery) characterizes this area.

In the GSA 06 the areas with the highest abundance of spawners were identified, mainly on the shelf in front of the Ebro River delta, off Alicante, the Gulf of Valencia and the coast from Barcelona to Cape Creus. Three main spawning areas were detected, i.e.one far from the coast off southern Ebro River delta and another near the coast in the northern part of the GSA 06, and a third important spawning area in the GSA 01, around Cape Gata and near the coast (Fig. 2.2.5.2.1). The spawning areas showed higher proportion of persistence in the GSA 01 and 06 (maximum persistence between 80 and 100%) than in the GSA 05 (maximum persistence between 60 and 80%). In the GSA01, the areas with higher abundance are the Gulfs of Almeria and Vera (Fig. 2.2.5.2.1).

The offshore distribution in front the Ebro River delta could be due to the bathymetric (the 100 m isobath is far from the coast, up to 60 km) and the environmental characteristics of this area (e.g. fresh water input from the river or and/or to a different type of bottom, mainly composed by terrigenous sediments), which determine the demersal fish assemblages found in the coastal shelf of this area (Demestre et al., 2000).

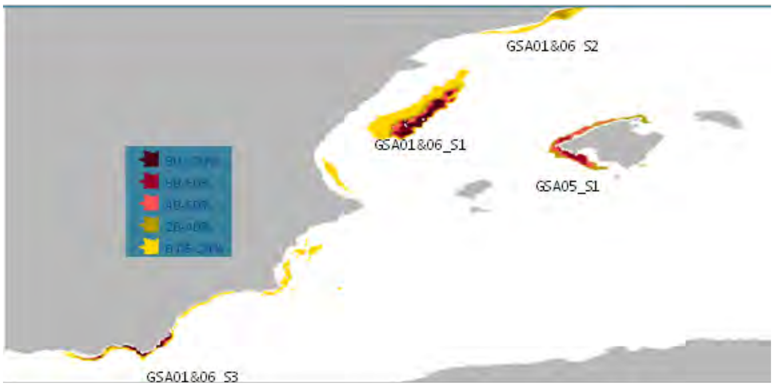


Fig. 2.2.5.2.1. Position of persistent spawning areas of red mullet in GSA 05, 01 and 06.

GSA 7

In the Gulf of Lions spawners concentrate persistently over time over a wide area located in the the central-western deep shelf between 90 and 130 m depth. Small patches of spawning aggregations appear in different positions along the shore between 20 and 40 m depth (Fig. 2.2.5.2.2.). According to the knowledge on size-depth distribution of the species in Western Mediterranean, the offshore spawning areas are dominated by large spawners, whereas smaller spawners seem to aggregate in inshore areas.

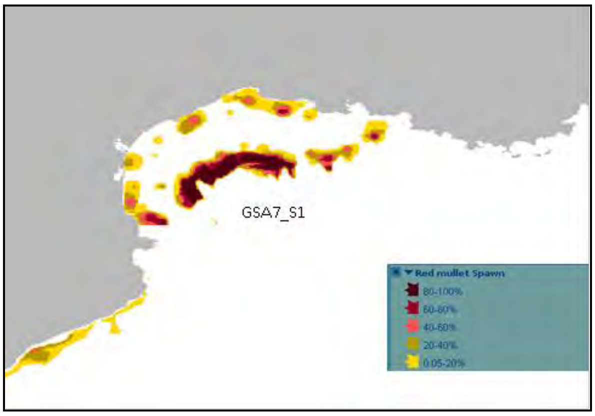


Fig. 2.2.5.2.2. Position of persistent spawning areas of red mullet in GSA 07

GSA 9

Hot spot areas with high persistency and density of spawners have been evidenced off the coasts of Tuscany, from Livorno to the northern side of the Elba Island (Fig. 2.2.5.2.3). At least two evident areas of concentration of spawners are present. The first is located to the north of the Piombino promontory, from 30 to 80 m depth, where detric bottoms are present. The most important accompanying species are *Pagellus erythrinus,* Triglidae*, Eledone cirrhosa, Boops boops* and *Merluccius merluccius*. The second is located the other off the northern coast of Elba, from 90 to 130 m over detritic bottoms on the outer shelf. This area is also characterized by relevant presence of *Lepidotrigla cavillone*, other gurnard species and *P. erythrinus*. As observed for GSA 7, inshore and offshore areas are probably determined by the aggregation of different age groups of spawners.The lack of persistent and dense aggregation of spawners in the southern part of the GSA (Latium) could be linked to the very high fishing pressure in this area compared with the North sector of the GSA (North Tuscany). The effect of fishing on the identification of spawning grounds based on density measures would need to be better investigated.

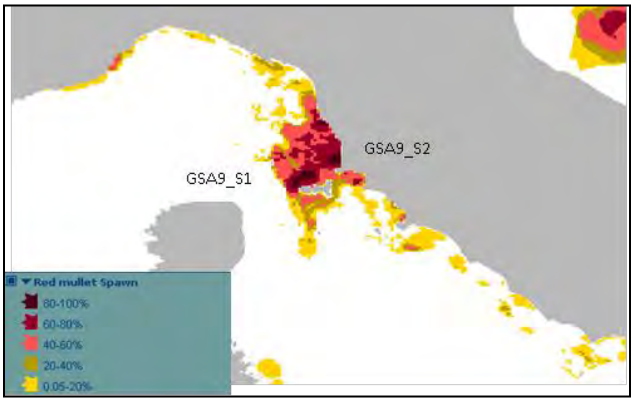


Fig. 2.2.5.2.3. Position of persistent spawning areas of red mullet in GSA 09

GSA 10

In the GSA10 several spawning aggregations were identified. Those more relevant were located in the Castellammare Gulf (GSA10_S1), along the North Sicily coasts and in the Patti Gulf (GSA10_S2). This is consistent considering that in these gulfs trawling is forbidden (Fiorentino et al., 2008). Another important aggregation along the mainland coast was localised along Amantea (GSA10_S3 spawning aggregation, Calabrian coasts) and Capo Palinuro (GSA10_S4, Fig. 2.2.5.2.4), confirming previous observations obtained using the spatial indicator approach (Spedicato et al., 2007).

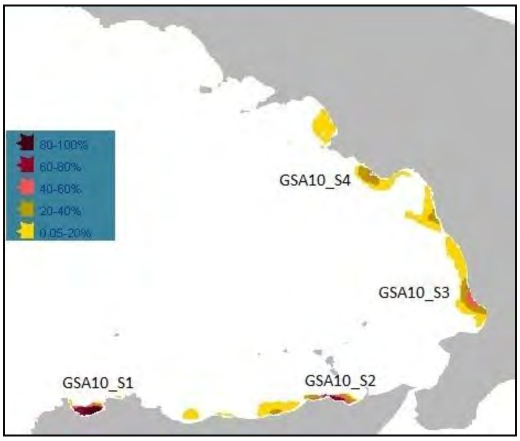


Fig. 2.2.5.2.4. Position of persistent spawning areas of red mullet in GSA10

GSA 11

Spawning areas of red mullet are found around all coasts of Sardinia at depths between 50 – 100 m with a general low temporal persistence. The associated biocenosis is that of terrigenous mud with characteristic macrobenthic species as *Aphrodite aculeata*, *Stichopus regalis Alcyonum palmatum* (Fig. 2.2.5.2.5).

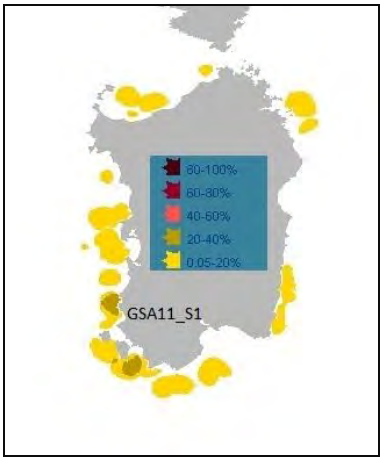


Fig. 2.2.5.2.5. Position of persistent spawning areas of red mullet in GSA11

GSA 18

In the GSA18 nursery areas of red mullet were localized using few years and the main place was offshore Gargano promontory, while a smaller nursery was localised in fron of Bari. Persistent spawning grounds were mainly identified in the eastern side, along the Albanian coasts at the latitude of Dürres (Fig. 2.2.5.2.6), on muddy bottom with coastal terrigenous muds biocenosis (VTC). The main current is from south to north. Other nuclei were identified north of Vlora and along the coasts of Otranto on the west side.

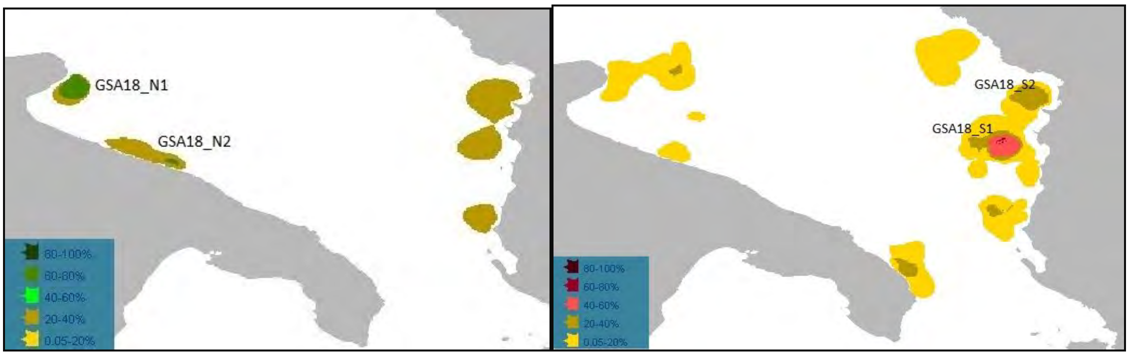


Fig. 2.2.5.2.6. Position of persistent nursery (left) and spawning (right) areas of red mullet in the GSA18

GSA 19

The main spawning areas detected for *M. barbatus* in the North-Western Ionian Sea-GSA11 were generally observed on the shelf bottoms down to 100-150 m distributed offshore Policoro, Cape Trionto and Cirò as well as in the very narrow coastal area from Punta Stilo to Cape Spartivento, offshore Catania and southern Siracusa. The more persistent spawning areas for the red mullet in GSA19 were located from Punta Stilo to Caulonia (GSA19_S1) and offshore Cape Bruzzano on the shelf grounds down to 165 m depth (Fig. 2.2.5.2.7).

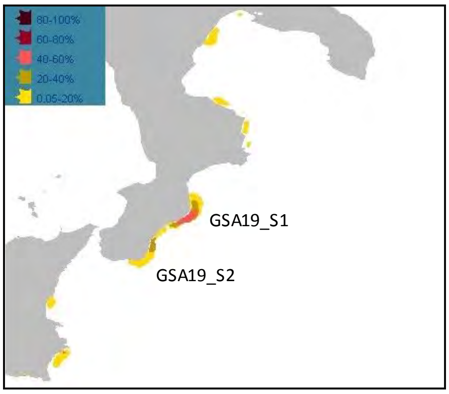


Fig. 2.2.5.2.7. Position of persistent spawning areas of red mullet in GSA19

GSAs 15-16

The distribution of red mullet spawners shows a high degree of spread across space and habitat (with preference for muddy substrates), and is characterized by several persistent patches. Very important areas (GSA15+16_S1 and GSA15+16_S2) are located in coastal waters (up to 60 m depth) of south Sicilian coast characterized by permanent upwelling and coastal currents with high longshore variability. Coastal upwelling is believed to be the main source of nutrient pumping in the area (Fig. 2.2.5.2.8). Other persistent spawning areas are observed in offshore waters and are located respectively over the Adventure Bank (GSA15+16_S3) along the southwest edge of the 100 m isobath, on the Malta Bank (GSA15+16_S5) to the east of Malta, straddling the border of the 25 nautical mile FMZ at a depth of around 100 m, and south-east of Linosa island (GSA15+16_S4) at deeper depth (between 250 and 400 m) (Fig. 2.2.5.2.x8). Overall, the observed spatial distribution of persistent spawning areas confirms and substantiates the results of previous investigations.

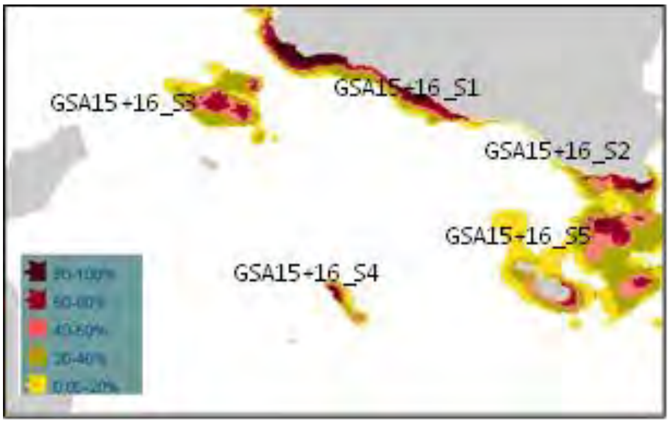


Fig. 2.2.5.2.8. Position of persistent spawning areas of red mullet in GSA 15+16

GSA 17

The persistent area identified for the recruits of red mullet in GSA 17 is comprised between 10 and 20 m, located in the mud-sandy coastal areas of the Italian side (Fig. 2.2.5.2.9). The western coastal area is characterized by high fresh water inflow, especially by the Po River, determining eutrophication state from nutrient discharge. The sea bottom of coastal areas consists mostly of mud and sand-detritic sediments. The biocenosis of the area is numerically dominated by polychaetes and other filter-feeding bivalves (mainly *Corbula gibba*), followed by small crustaceans (mostly amphipodes and decapods as *Liocarcinus spp.*) and burrowing Ophiuroids.

The areas of persistency identified for the spawners of red mullet in GSA 17 are principally two (Fig. 2.2.5.2.9). S1 is the widest one; located from the middle line to the Croatian coast. This area is characterized by relict sand (from times when the water level was lower and the area was a sandy beach), with high densities of holothurian (e.g. *Holoturia forskali*) and bivalves (e.g. *Atrina pectinata*), and by upwelling events, associated to the prevailing NW winds, frequent along the Croatian coast during summer months (Cushman-Roisin et al., 2001). S2 is located between Brac, Hvar and Korcula Islands, where bottoms are rocky and muddy and upwelling events may occur.

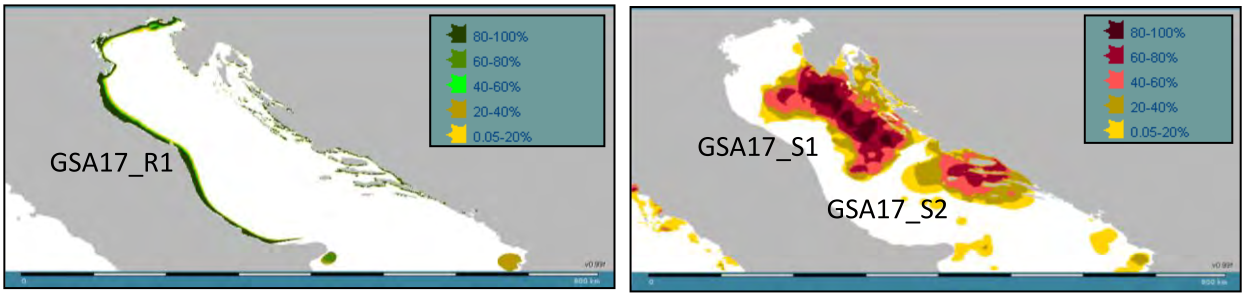


Fig. 2.2.5.2.9. Position of persistent nursery (left) and spawning areas (right) of red mullet in GSA 17

GSA 20, 22-23

Red mullet was captured mainly in coastal areas from depths ranging from ~30m to almost 400m in both the Aegean and the Ionian Seas. Recruits have by default very coastal distribution hence they are in many cases inaccessible by the MEDITS survey. Besides, the timing of the survey did not favour the capture of recruits as they mostly appear in late summer. In the few instances that red mullet recruits were captured in GSAs 20, 22 and 23, these were in very shallow coastal stations. The sporadic character of captures of red mullet recruits did not allow for modeling and hence the only available distribution maps are annual bubble plot maps.

On the contrary, the distribution of spawners of red mullet was well documented by MEDITS in the Greek Seas. The performed analysis indicated that the higher abundances were located from shallow waters up to ~100m in both the Aegean and Ionian Seas. The density maps revealed that red mullet is widely distributed over the examined area, but spawners are relatively more abundant in several areas of the Aegean Sea (e.g. Saronikos gulf, the islands of the eastern Aegean Sea and the north part of Crete, Fig. 2.2.5.2.10). In the Ionian Sea the most persistent area of red mullet spawners' distribution was between Korinthiakos and Patraikos gulfs and near the coasts of Epirus (northwestern Greece, Fig. 2.2.5.2.10).

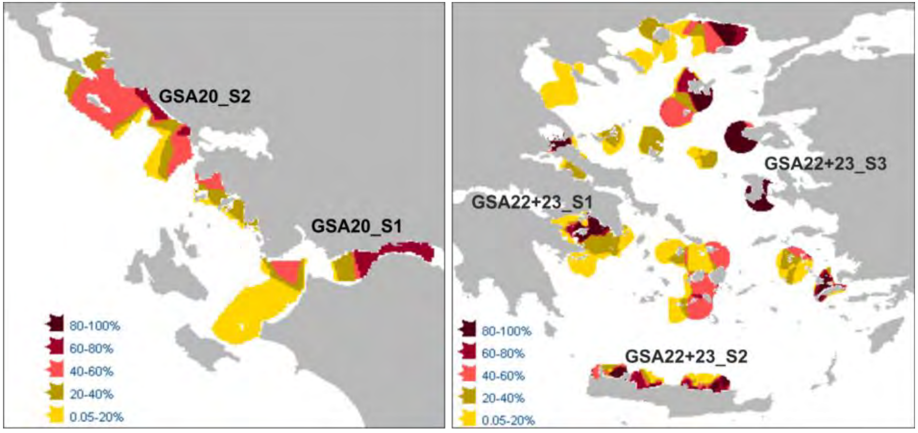


Fig. 2.2.5.2.10. Position of persistent spawning areas of red mullet in GSA 20 (left) and in GSA 22_23 (right).

Table 2.2.5.2.5. Environmental characteristics on nurseries and spawning grounds for red mullet.

GSA	Type of area	Code	Depth range (m)	Description

GSA	Type of area	Code	Depth range (m)	Description
05	Spawning	GSA05_S1	80-100	Large area from Southern to Western Mallorca Shallow continental shelf
01 and 06	Spawning	GSA01 and 06_S1	80-500	Southern Ebro River far from the coast Shallow continental shelf and upper slope
01 and 06	Spawning	GSA01 and 06_S2	80-100	In the Northern of the GSA06 and near the coast Shallow continental shelf
01 and 06	Spawning	GSA01 and 06_S2	80-100	Around Cape of Gata Shallow continental shelf
7	Spawning	GSA7_S1	90-130	Large area of muddy terrigenous sediments on the deep shelf in the central-western part of the Gulf of Lions.
9	Spawning	GSA9_S1	90-130	Detritic bottoms off the northern coast of Elba, on the outer shelf. This area is also characterized by relevant presence of *Lepidotrigla cavillone*, other gurnard species and *P. erythrinus*.
9	Spawning	GSA9_S1	30-60	Muddy and detritic bottoms north of Piombino promontory, from 30 to 60 m depth. The most important accompanying species are *Pagellus erythrinus,* Triglidae*, Eledone cirrhosa, Boops boops* and *Merluccius merluccius*.
10	Spawning	GSA10_S1	61-120	The Castellammare Gulf is characterized by the coastal detritic biocenosis (DC) on the tanatocenosis of Neopycnodonte cochlear with characteristic species as *Alcyonium palmatum, Pennatula phoshorea, Stichopus regalis, Peltaster placenta*. The superficial current during the sampling period is circular inside the gulf.
10	Spawning	GSA10_S2	18-58	The area is characterized by fine sands (SFBC) with the characteristic species as *Ophiura ophiura, Philine aperta, Astropecten bispinosus*. The direction of superficial currents in the sampling period is from west to east.
10	Spawning	GSA10_S3	31-41	The bottom is muddy-sand with coastal terrigenous muds biocenosis (VTC) characterized by species as *Alcyonium palmatum, Stichopus regalis, Diazoma violacea*. The direction of superficial currents in the sampling period is from south to north.
10	Spawning	GSA10_S4	76-177	The bottom is muddy characterized by detritic coastal biocenosis (DC) with the characteristic species as *Alcyonium palmatum, Suberites dumuncula, Stichopus regalis.* The direction of superficial currents in the sampling period is from south to north.
11	Spawning	GSA11_S1	50-100 m	Biocenosis of terrigenous mud
15+16	Spawning	GSA15+16_S1	30-55	Coastal terrigenous mud and Posidonia oceanica meadows. The area is interested by permanent upwelling and costal currents characterized by a noticeable longshore variability. The mean value of SST observed in late spring-early summer ranges from 20.2 to 20.9 °C proceeding eastward.

GSA	Type of area	Code	Depth range (m)	Description
15+16	Spawning	GSA15+16_S2	34-38	Coastal terrigenous mud and Posidonia oceanica meadows. The area is interested by permanent upwelling and costal currents characterized by a noticeable longshore variability The mean value of SST observed in late spring-early summer is 22 °C.
15+16	Spawning	GSA15+16_S3	65-100	Coastal Detritic Bottom with Laminaria rodriguezii. The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the extension of upwelling over the shelf and the temperature regime of surface waters. The mean value of SST observed in late spring-early summer is 22 °C.
15+16	Spawning	GSA15+16_S4	255-400	Bathyal muds biocenosis (compacted muds). The area is located in the proximity of Linosa island. This area is under the dominant influx of the two major water masses, ATC (Atlantic Tunisian Current) and LIW (Levantine Intermediate Water), flowing along the Tunisian side of the Strait of Sicily. The mean value of SST observed in late spring-early summer is 23 °C.
15+16	Spawning	GSA15+16_S5	130-133	Bathyal muds biocenosis in association with Funiculina quadrangularis. The topography of the shelf in this area is characterized by a plateau in the middle part, with an average depth of 150 m and a bank (Hurds Bank) to the northeast of Malta with shallow depth of just over 50 m. Due to the presence of different hydrodynamical processes and interesting phenomena within the Malta Bank, the upwelling can extend its influence far offshore and actually engulf the whole Maltese shelf. The mean value of SST observed in late spring-early summer is 22.7 °C.
17	Nursery	GSA17_R1	10-20	- mud and sand-detritic sediments - high fresh water inflow and eutrophication - biocenosis dominated by Polychaetes
17	Spawning	GSA17_S1	30-80	- upwelling events - relict sand - holothurians community
17	Spawning	GSA17_S2	50-150	- upwelling events - muddy and rocky bottoms
18	Nursery	GSA18_N1	15-36	The infralittoral of Manfredonia Gulf is characterized by sand-muddy bottom with coastal terrigenous muds biocenosis (VTC) with characteristic species as *Astropecten irregularis Polycarpa pomaria Turritella communis and fine sands biocenosis (SFBC) with characteristic species as Astropecten irregularis, Schizaster canaliferus, Laetmonice hystrix* etc. The superficial current during the sampling period is from north to south.
18	Nursery	GSA18_N2	28-49 37-42	The bottom is muddy with coastal terrigenous muds biocenosis (VTC) and characteristic species as Astropecten irregularis Dorippe lanata, Turritella communis, *Gonoplax rhomboids* Marthasterias glacialis etc. The superficial current during the sampling period is from north to south.

GSA	Type of area	Code	Depth range (m)	Description
18	Spawning	GSA18_S1	82-116	The bottom is muddy with coastal terrigenous muds biocenosis (VTC) and characteristic species as *Astropecten irregularis, Pteria hirundo, Marthasterias glacialis, Alcyonium palmatum* etc. The superficial current during the sampling period is from south to north.
18	Spawning	GSA18_S2	39-81	The bottom is muddy with coastal terrigenous muds biocenosis (VTC) and characteristic species as *Astropecten irregularis Stichopus regalis, Alcyonium palmatum Pteria hirundo, Turritella communis, Dorippe lanata* etc. The superficial current during the sampling period is from south to north.
19	Spawning	GSA19_S1	20-171	The shallower coastal area from Punta Stilo to Caulonia is characterized by the biocenosis of coarse sands and fine well-sorted sands and by the biocenosis of the terrigenous mud.
19	Spawning	GSA19_S2	19-165	The shallower coastal area offshore Cape Bruzzano is characterized by the biocenosis of coarse sands and fine well-sorted sands and by the biocenosis of the terrigenous mud and shelf-edge detritic.
20	Spawning	GSA20_S1	50-400	Eastern Patraikos and western Korinthiakos gulfs. Mainly deep water areas with narrow and steep shelf. Largely affected from currents travelling through the narrow connection channel of the two gulfs. The main sediment type is mud. Other environmental information is unavailable.
20	Spawning	GSA20_S2	50-200	The continental shelf of Epirus (western Greece). The main sediment type is mud. Other environmental information is unavailable.
22_23	Spawning	GSA22-23_S1	50-200	Central and northern part of Saronikos gulf. Largely protected from large-scale oceanographic features. The main sediment type is mud. Other environmental information is unavailable.
22_23	Spawning	GSA22-23_S2	50-200	Cretan continental shelf. Highly affected by northern winds. The main sediment type is mud. Other environmental information is unavailable.
22_23	Spawning	GSA22-23_S3	50-200	Several scattered areas of the eastern Aegean. Highly affected by the both the outflowing waters of the Black Sea into the Aegean and the north-moving Levantine-origined waters from the south Aegean Sea. Main sediment type is rock and mud.

2.2.5.2.4 Gaps in knowledge

The main identified gaps in knowledge are linked to the spatial distribution of recruits. Information on nursery areas are scant given the time of MEDITS survey that is carried out before the recruitment period of the species (late summer-early autumn). A coastal survey in late summer (August-September) should be necessary to identify nursery areas.

In Greek GSAs mapping of nursery areas was not feasible as the peak of recruitment occurs after the timing of the MEDITS survey; hence information from MEDITS is largely fragmented or lacking. Regarding the spawning areas, the timing of the survey is also a serious issue since the spawning period is not adequately covered; hence results should be considered as indicative and not fully representative of the real situation.

Because of the reasons explained in the previous sections information of nursery and spawning grounds of red mullet in GSA 25 are not available. Anyway, considering the bubble plot maps (see Annex 2 is possible to assume that the coastal areas from Larnaca to Chrysochuo bays represent a suitable environment for nursery and spawning grounds of the species. In Eastern Mediterranean, MEDITS seems that it does not cover adequately the spawning period. Therefore results should be considered as indicative and not fully representative of the actual situation.

2.2.5.3 Mullus surmuletus

2.2.5.3.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

In GSA 05 recruitment period occurs in August-September, with a mode at 12-13 cm. In the North-Western Mediterranean, the recruitment of *Mullus surmuletus* was found to occur mainly over *Posidonia oceanica* beds (García-Rubies and Macpherson, 1995).

In GSA9 bottom settlement of postlarvae of striped red mullet takes place in late spring and summer at about 65 mm total length. Length at age 1 is 19.6 cm for females and 16.8 for males. Recruits in the GSA 7 have been observed from October to February.

In GSAs 10 and 18, recruitment occurs inshore during summer within 50 m depth.

In Sardinian seas (GSA11), the recruitment period starts in summer when the first small specimens of about 6 cm TL are caught by the trawl net. Recruitment season is shorter than that of *M.barbatus* and is completed by July. The size at capture is about 11 cm TL.

In GSA 17 juveniles are concentrated along shallow coastal waters. Recruitment occurs in summer.

In Greek GSAs (20, 22-23) recruits of striped red mullet occurs mainly in late summer – autumn months and recruits are most common in depths below 75m.

In the Strait of Sicily (GSAs 15-16), as for its congeneric *M. barbatus*, the recruitment of *M.surmuletus* is discrete and occurs in late summer–early autumn. High concentrations of immature specimens are recorded in GSA 15 within the 25 nautical mile Malta's Fisheries Management Zone, at a depth of 100-200m to the east of Malta. In the North-Western Ionian Sea (GSA19) reproduction of striped red mullet occurs from May to August and recruits are found mostly during late summer-autumn on the shelf in very coastal areas not perfectly matched by the experimental trawl surveys carried out in the basin. Up to date, no clear neither persistent nursery areas were detected for *M. surmuletus* in the GSA19.

Spawning

In GSA 05 the reproductive biology of these species is fairly known. The spawning period of *M. surmuletus* is situated around spring for females and from December to June for males, while the length of first maturity has been estimated at 16.8 and 15 cm, for females and males respectively (Reñones *et al.*, 1995a).

The species spawns in a similar period of red mullet either in GSA 9 or GSA7. In GSA9 the size at first maturity is 15 cm TL for males and 18 cm TL for females.

In GSA10 spawning takes place in late spring-early summer. According to the data obtained from DCR in 2008, the proportion of mature females by length class (period 2006-2008) gave an estimate of maturity ogive which indicates a $L_{50\%}$ of about 13.3 cm (±0.25 cm; MR=3±0.26).

In Sardinia waters (GSA 11) reproduction mainly occurs from April to June, when the mature specimens are found. The size at first maturity is 15.9 cm of TL for females and 15.8 cm for males. In the Strait of Sicily (GSAs 15-16), the estimate of length at maturity is equal to 195 mm TL for females. The spawning season of striped red mullet is spring-summer.

In GSA18 spawning takes place in late spring-early summer. According to the data obtained from DCR in 2008, the proportion of mature females by length class (period 2006-2008) gave an estimate of maturity ogive which indicates a $L_{50\%}$ of about 14.3 cm (±0.13 cm; MR=1.7±0.17).

In GSA19 the smallest mature female and male were 160 and 125 mm TL, respectively. No spawning areas were detected for *M. surmuletus* in the North-Western Ionian Sea.

In GSA 17 reproduction occurs in late spring. Size at maturity shows variation between various areas of the Eastern Mediterranean in GSAs 20 and 22-23 (however, we have to take in account the way in which this index has been calculated by the various authors). Spawning occurs during spring.

2.2.5.3.2. Modeling approach

Identification of recruits and spawners

The frequency of positive hauls and the number of specimens caught in each survey and GSA are reported in Tables 2.2.5.3.1 and 2.2.5.3.2 Table 2.2.5.3.3 shows recruitment and spawning size identificated for modeling purposes.

GSA 05

The spawning fractions of females were extracted by means of the length at first maturity (L_{50} or length at which 50% of the individuals are mature) and the maturity ogive (L_{25-75}). For this purpose, data on monthly biological samplings of commercial catches, obtained within the Data Collection Framework, were used to identify the spawning periods of each species, from monthly average of the Gonadosomatic Index (GSI) and the percentage of maturing or mature individuals. Only data compiled during these spawning periods was used to calculate L_{50}, from the logistic curve: PL= e(a+b*L)/(1+e(a+b*L)), where PL is the proportion of mature individuals for a given size class L. Logistic curves were fitted by maximizing the log-likelihood function, using Solver in EXCEL (Tokai, 1997).

GSA 7, 8, 9

The occurrence of *M. surmuletus* was low in GSA7 and GSA9; the frequency of positive hauls ranged from 0.09 to 0.27 in GSA7 and from 0.11 to 0.31 in GSA9. In GSA8 the species was more frequent, with values generally around 0.4-0.5, except very low values in certain years.

A low number of individual was generally caught in the three GSAs: in general the catches of each year did not reach 100 specimens except for GSA9 in some years (e.g. 320 in 2009 and 704 in 1999).

Spawners were identified based on the selection of females with maturity stage = 3; recruits were single out using a cutoff of 65 mm TL, according to literature data.

GSAs, 10, 11, 18, 19

The frequency of positive hauls for *M. surmuletus* in GSA10 reaches the maximum of 0.13 (MEDITS 2007), with a maximum overall catch fluctuating of 485 sampled specimens (MEDITS 2000).

The frequency of positive hauls for *M. surmuletus* in GSA11 ranges between 0.27 (MEDITS 1994) and 0.54 (MEDITS 1998), with an overall catch fluctuating from a minimum of 240 (MEDITS 2006) and a maximum of 1117 (MEDITS 2002) sampled specimens.

The frequency of positive hauls for *M. surmuletus* in GSA18 ranges between 0.04 (MEDITS 2001) and 0.40 (MEDITS 2004), with an overall catch fluctuating from a minimum of 8 (MEDITS 2001) and a maximum of 234 (MEDITS 1999) sampled specimens.

The catch of striped red mullet was almost negligible, with the exception of MEDITS 2002 and 2007 when a total of 1238 and 1109 specimens were sampled in the GSA19, respectively. The frequency of positive hauls fluctuated between 0.07 and 0.24 indicating not a perfect match between sampling and spatio-temporal distribution of the species in the basin.

In GSAs 10, 11 and 18, the recruits have been identified annually according to the ability of the survey to intercept the phenomenon. The threshold to separate the recruits has been estimated as the mean length of the first modal component + 2* sd using the Bhattacharya's method and the R_RSI MEDISEH routine, specifically developed for the MEDISEH project. In the case of GSA19 an empirical value was adopted as threshold size, generally derived from other research studies carried out in the area.

To identify the adults or potential spawners, an average of the parameters of the maturity ogive among the years from the MEDITS survey and/or from biological samplings of DCR and DCF has been used in GSAs 10 and 18, selecting those better fitting to the model. The identification of spawners in the North-western Ionian Sea (GSA19) and in the GSA11 was carried out using the corresponding maturity stages 3.

GSA 16

Both the number of positive hauls and the number of specimens caught were rather variable from year to year. Positive hauls ranged between 27% and 53% of the total number of hauls, but they were found almost exclusively on limited areas of the shelf.

A signal of recruitment of *M.surmuletus* was detected in GSA 15+16 in two years only (2003 and 2005), hence the juvenile fraction of the species was not analyzed. Density indices of spawners were calculated from the fraction of mature females (MEDITS maturity stage "3"). The mean maturity size by year resulted comprised between 181 and 236 mm TL.

GSA 17

GSA 17 MEDITS data are available for the period 2002-2010. The period 1994-2001 has been excluded from the analyses because data of the eastern side of the basin were not available.

Striped red mullet is quite occasional in MEDITS catch, often less than 20% of positive hauls and an average of more than 200 specimens collected each year. A fixed threshold sizes of 8 and 13 cm has been utilized respectively to identify recruits and spawners (Piccinetti et al., 2012).

GSA 20, 22-23

MEDITS data from 1996-2008 were used for modeling striped red mullet in GSAs 22_23. The proportion of positive hauls for this species ranged from 26-38%, whereas for GSA20 the proportion was very low (6-19%) (Table 2.5.3.1). Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates following the aforementioned approaches, threshold values were established based on literature information and expert knowledge (Table 2.5.3.3)

GSA 25

In GSA 25 MEDITS data are available for the period 2005-2010. Striped red mullet is quite occasional with usually less than 20% of positive hauls and an average of less than 30 specimens collected each year. Given the low abundance of striped red mullet, recruits and spawners threshold sizes have been derived from the data of GSAs 22-23.

Table 2.2.5.3.1. Frequency of positive MEDITS hauls (n of positive hauls/n. of total hauls) for striped red mullet by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.07	0.33	0.14	0.08	0.27		0.28	0.07			0.23		
1995		0.18	0.27	0.16	0.12	0.39		0.26	0.12			0.38		
1996				0.16	0.04	0.37		0.08	0.15			0.31		0.28
1997		0.18	0.08	0.25	0.07	0.31		0.15	0.08			0.21		0.26
1998		0.13	0.35	0.20	0.04	0.54		0.20	0.24	0.06		0.36		0.36
1999		0.27	0.52	0.14	0.08	0.53		0.17	0.12	0.09		0.26		0.29
2000		0.21	0.23	0.18	0.05	0.35		0.21	0.11	0.19		0.26		0.31
2001		0.23	0.32	0.15	0.09	0.39		0.04	0.09	0.13		0.37		0.26
2002		0.11		0.31	0.11	0.37	0.16	0.10	0.13			0.31		
2003		0.16	0.43	0.26	0.10	0.40	0.10	0.18	0.20	0.09		0.30	0.27	0.38
2004		0.15	0.27	0.06	0.03	0.35	0.24	0.40	0.19	0.19		0.30	0.41	0.30
2005		0.12	0.35	0.11	0.09	0.36	0.09	0.06	0.10	0.06	0.24	0.28	0.24	0.30
2006		0.19	0.13	0.05	0.00	0.28	0.08	0.09	0.10	0.06	0.2	0.29	0.36	0.33
2007	0.68	0.18	0.30	0.18	0.13	0.38	0.13	0.07	0.21		0.24	0.33	0.27	
2008	0.56	0.17	0.36	0.16	0.11	0.36	0.20	0.07	0.11	0.13	0.11	0.33	0.53	0.36
2009	0.72	0.18	0.45	0.13	0.03	0.34	0.10	0.16	0.11		0.15	0.44	0.37	
2010	0.72	0.09	0.45	0.14	0.04	0.54	0.04	0.11	0.07		0.15	0.26	0.37	

Table 2.2.5.3.2. Number of specimens of striped red mullet caught during MEDITS by GSA and year.

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		35	24	49	14	431		54	69			162		
1995		24	88	71	18	560		45	45			319		
1996		0		97	3	530		23	84			203		1059
1997		37	1	244	18	302		38	24			100		1298
1998		47	51	121	4	764		51	97	1760		196		10541
1999		55	67	704	18	907		234	29	1224		194		11148
2000		35	13	168	485	369		86	32	499		169		3698
2001		60	55	138	17	472		8	31	1252		185		453
2002		30		191	117	1117	106	25	1238			300		
2003		43	128	89	10	573	123	38	36	1489		167	2320	4096
2004		32	61	35	7	559	140	198	55	1475		436	667	912
2005		15	87	38	6	430	36	10	76	641	104	145	458	2153
2006		17	5	27	0	240	101	13	24	1076	15	505	362	1132
2007	3986	38	46	96	28	740	1244	19	1109		13	347	1173	
2008	1301	27	47	61	66	527	112	13	37	1517	20	123	2541	4061
2009	4411	59	129	320	2	327	60	37	23		9	321	1180	
2010	955	9	41	72	5	860	17	14	7		11	134	703	

Table 2.2.5.3.3. Recruitment and spawning size identification for modeling purposes.

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (TL mm)**	**Data source)**	**Method used**	**Mean maturity length (Tl mm) /Maturity stage**
05, 01 and 06	2003-2011	-	-	-	DCF	Fixed threshold length (L_{50})	154
7	1994-2010	DCF/MEDITS	Fixed threshold length	65	DCF/MEDITS		MS = 3
8	1994-2010	DCF/MEDITS	Fixed threshold length	65	DCF/MEDITS		MS = 3
9	1994-2010	Bartolino et al., 2008	Fixed threshold length	65		DCF/MEDITS	MS = 3
10	1994-2010	MEDITS	Bhattacharya	67.2	Biological sampling	Maturity ogive	143
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya		MEDITS	MS maturity stages estimation	193
15+16	2003-2010				MEDITS	Maturity stage "3"	200 (annual mean: 181-236)
17	2002-2010	Piccinetti et al., 2012	Fixed threshold length	8	Piccinetti et al., 2012	Fixed threshold length (L_{50})	130
18	--	--	--		Biological sampling	Maturity ogive	143
19	1994-2010	MEDITS	fixed		MEDITS	Length at maturity stage 3	MS = 3
20	1998-2008	MEDITS	No specimens		MEDITS	Fixed threshold length (L_{50})	120
22_23	1996-2008	MEDITS	Bhattacharya	65	MEDITS	Fixed threshold length (L_{50})	120

Mapping of density and identification of hot spot areas

A summary of the spatial model implemented for mapping recruits and adults/spawners of striped red mullet is provided in Table 2.2.5.4.4

GSA 1-6, 5

The spawners were modeled only in GSA 5 using GAM. Two models were developedindependently, one for presence/absence data, and another for standardized abundances restricted to presence data only. The final presence/absence model included depth and the interaction between longitude and latitude, whereas the final abundance restricted to presence samples model included year and depth as factors, these models explaining 50 and 29% of the total variance, respectively. According to both models, the spawners are found from the minimum depth sampled (50 m) down to 350 m depth, with a maximum at 100-200 m.

The spawners of striped red mullet were not modeled in the GSA 01 and 06 due to the very low amount of individuals captured in the MEDITS surveys. The recruits of this species were not modeled in any of the GSAs due to the mismatch between the sampling period and the time of the year the recruits are able to be found (spawning occurs in summer, after the survey).

GSA 7, 8, 9

Due to the very scarce number of specimens captured duting MEDITS, no modeling of density data of recruits and spawners was carried out. Abundance of recruits and spawners has been shown only using bubble plot maps (Suppl 2.2.3).

GSA 11

In GSA11 annual abundance values were predicted by means of ordinary kriging on raw abundance values. In GSA 10, 18 and 19 occurrence of *Mullus surmuletus* was scattered in space and time and insufficient for any modeling approach.

GSA 16

In GSA 15+16, spawners of *M.surmuletus* were modelled using a GLM with spatial component and a fixed intercept. Only data from 2006 to 2010 were used for modeling because the number of hauls with presence of mature females was very scant in the first three years of the time series. The model goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km.

GSA 17

In GSA 17 occurrence of *Mullus surmuletus* was scattered in space and time and insufficient for any modeling approach.

GSAs 20, 22-23

Generalized Additive Models were employed to model the distribution of recruits and spawners of hake in GSA 22_23. The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots. The period analyzed was from 1996-2008. The depth distribution spawners ranged from 30 - 600 m.

GSA 25

Due to the occasional catches, no modeling has been attempted for the striped red mullet in GSA 25

Table 2.2.5.3.4. Modeling applied in EU GSAs for mapping striped red mullet.

Life stage	GSA	Depth range (m)	Period	Model type	Covariates	% dev. expl.	Goodness of fit (R^2)
Spawner females	05	50-400	2007-2010	Pres./Abs.	Year, depth	17.7	0.41
				Abundance	Year, (Lon,Lat)	50.1	
Spawners	11	10-400	1995, 1998, 1999. 2001, 2003, 2010	Ordinary kriging**			
Spawners females	15-16	25-550	2006-2010	GLM with spatial component	Lat, Lon		CV=0.986 0.52
Spawners	22-23	30-600	1996-2008	GAM(delta - lognormal)	Year, Lon, Lat, depth	32.3	0.27

2.2.5.3.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.3.5 summarizes the main environmental features of the most persistent areas identified for striped red mullet in European GSAs. For details see http://mareaproject.net/mediseh/viewer/med.html.

GSA 1-6, 5

In the GSA05, hot-spots were detected in the Menorca channel, the east of Menorca and the south-west of Mallorca (Figure 2.2.5.3.1). Other than the environmental characteristics (e.g. hydrograghy, bottom type), also the fishing effort, could be on the basis of the predicted distribution. In fact, the identified areas are located in areas of the continental shelf where the activity of the bottom trawl fishery seems to be low.

Fig. 2.2.5.3.1. Position of persistent spawning areas of striped red mullet in GSA 05

GSA 11

Spawning areas of red-striped mullet are found around the south- eastern and north- eastern coasts of Sardinia (GSA11) at depths comprised between 50 and 120 m (Fig. 2.2.5.3.2). At these depths the biocenosis of terrigenous mud with features macrobenthic species *Aphrodite aculeata*, *Stichopus regalis, Alcyonum palmatum* were mainly found

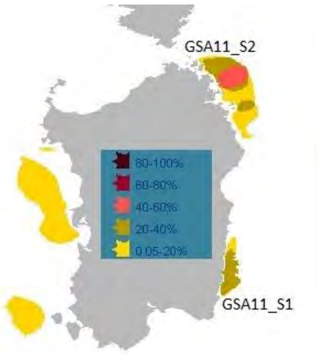


Fig. 2.2.5.3.2. Position of spawning areas of striped red mullet in GSA11

GSAs 15-16

The spawning of the striped red mullet appears to be limited, in the northern part of the Strait of Sicily, to the shallow waters (up to 80 m depth) of Adventure and Malta Bank respectively.

Differently from what observed for the congeneric *M.barbatus*, the distribution of spawners is much more localized and no coastal spawning area is observed. In particular, a large and persistent spawning area (GSA15+16_S1) is located in the west side of the Adventure Bank on coastal detritic bottoms with *Laminaria rodriguezii* (Fig. 2.2.5.3.3). Another concentration of spawners, which however doesn't attain temporal persistency, is located on the area off the east of Malta within the 25 nautical mile FMZ

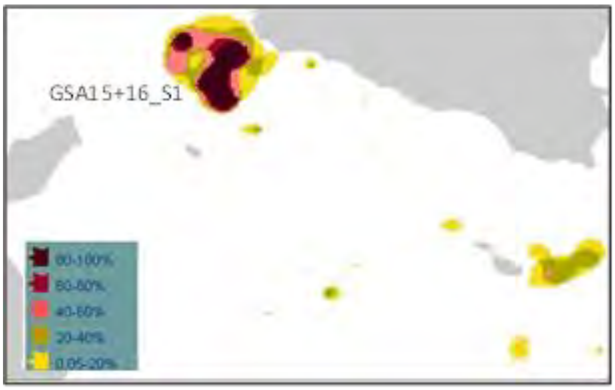


Fig. 2.2.5.3.3. Position of persistent spawning areasof striped red mullet in GSA 15+16

GSA 22-23

Striped red mullet capture depth range was extending from 30 to 600m in the Aegean Sea, whereas in the few occurrences that striped red mullet was captured in the Ionian Sea the depth range extended up to 350m. Recruits have by default very coastal distribution hence they are in many cases inaccessible by the MEDITS survey. Besides, the timing of the survey did not favor the capture of recruits as they mostly appear in late summer. In the few instances that red mullet recruits were captured in hauls in the Aegean Sea, these were captured in depths below 100m. The sporadic character of captures of red mullet recruits did not allow for modeling, hence the only available distribution maps are annual bubble plot maps.

On the contrary, the distribution of spawners of striped red mullet was well documented by MEDITS in the Aegean Sea. The performed analysis indicated that the higher abundances were located from shallow waters up to ~300m in the Aegean Sea.

The density maps revealed that striped red mullet spawners are mainly distributed over the central Aegean Sea and particularly in the Cyclades island complex and the Saronikos gulf. Smaller persistent areas were found all around but not in the northern part the Aegean Sea Fig. 2.2.5.3.4).

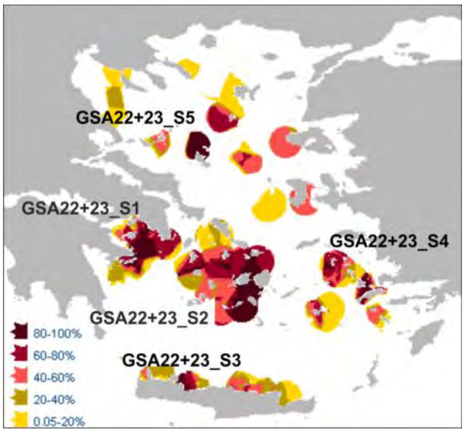


Fig. 2.2.5.3.4. Position of persistent spawning areas of striped red mullet in GSA 22_23.

Table 2.2.5.3.5. Environmental characteristics on nurseries and spawning grounds of striped red mullet

GSA	Type of area	Code	Depth range	Description (few lines of text)
05	spawning	GSA 05_S1	80-250	Located in the south of the Menorca Channel Shallow shelf to shelf break
05	spawning	GSA05_S2	80-250	Located in the East of Menorca Shallow shelf to shelf break
05	spawning	GSA05_S3	250-more than 800 m	Located in the South-West of Mallorca Deep shelf to shelf break
11	spawning	GSA11_S1	50-120 m	Biocenosis of terrigenous mud
11	spawning	GSA11_S2	50-120 m	Biocenosis of terrigenous mud
15+16	spawning	GSA15+16_S1	65-85	Coastal Detritic Bottom with Laminaria rodriguezii. The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the extension of upwelling over the shelf and the temperature regime of surface waters. The mean value of SST observed in late spring-early summer changes from 20 °C to 23.7 °C when moving southward.
22_23	spawning	GSA20_S1	50-300	Central and southern part of Saronikos gulf. Affected by southern winds but protected from large-scale oceanographic features. Relatively shallower areas with hard substrates and mud. No other environmental information is available.
22_23	spawning	GSA20_S2	50-150	Central and southern part of the Cyclades Island complex. Relatively shallower areas with hard substrates and largely exposed to harsh wind conditions.
22_23	spawning	GSA20_S3	50-200	Cretan continental shelf. Highly affected by northern winds. The main sediment type is mud. Other

GSA	Type of area	Code	Depth range	Description (few lines of text)
				environmental information is unavailable.
22_23	spawning	GSA20_S4	50-400	South-east Aegean Sea (Dodecanese complex). Relatively deep, saline (Levantine-origin) waters. Main sediment type is mud.
22_23	spawning	GSA20_S5	50-200	Southern part of the north Aegean Sea (north of Skyros island). Area affected by oceanographic features (Black Sea Water circulation in the north Aegean Sea). Main sediment type is mud.

2.2.5.3.4. Gaps in knowledge

Since the MEDITS survey is carried out before the recruitment period of the species (summer-autumn), the MEDITS data cannot be used to identify nursery grounds.

In addition, due the preference of *M. surmuletus* for coastal habitats and rocky bottoms, trawl survey cannot appropriately sample the species. More information could be obtained from artisanal gears, in particular from trammel nets. In GSA 17 the occasional catches of recruits and spawners of striped red mullet did not allow the identification of nursery and spawning grounds.

In GSAs 20 and 22-23, knowledge gaps are similar to those already mentioned for the other member of the genus Mullus, the red mullet. Similarly, nursery areas could not be identified due to the timing of the MEDITS survey (June) which precedes the species recruitment. Regarding the spawning areas, timing of the survey is also a serious issue since the spawning period is not adequately covered; hence results should be considered as indicative and not fully representative of the real situation.

2.2.5.4 Pagellus erythrinus

2.2.5.4.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

In GSA 1-6, 5 recruitment of *Pagellus erythrinus* takes place in September, appearing on muddy and sandy bottoms up to 40 m depth. In October, recruits tend to move into deeper waters (25 – 50 depth) concentrating in sandy bottoms and close to rocky bottoms. In November-December no clear bathymetric differenciation is observed between juveniles and adults. Between January and June some inversion between juvenile and adult bathymetric distribution seem to occur (Larrañeta, 1964).

Recruitment of *P.erythrinus* in GSA 15+16 occurs mainly in autumn. The age at capture is 0.5 year corresponding to about 100 mm TL. Concentration areas of recruits are known to be located along the central southern Sicilian coast.

In GSA9 recruitment of *P. erythrinus* takes place in early summer (June-July) on shallow sandy bottoms, less than 20 m. Juveniles move progressively offshore achieving a mean size of 12 cm at the end of the first year of life, 9.4 cm in the Gulf of Lions (GSA7).

In GSA 17 juveniles are distributed in shallow coastal water (Piccinetti et al., 2012). Recruitment process of *P. erythrinus* extends from spring to early autumn (Manfredi et al., 2006).

In GSA10 and GSA18 the pattern of recruitment is almost discrete with higher occurrence in summer and autumn seasons (Spedicato et al., 2002). The presence of nursery areas was not previously studied in these geographical sub-areas.

In Sardinian seas-GSA11, juveniles are more abundant in shallow waters between June and November. No historical information on the localization of nursery is reported for this GSA.

In GSA19 recruits of the common pandora were found during autumn season mainly distributed on the shelf. In the past nursery areas were not detected for *P. erythrinus* in this basin.

In the northern part of GSA22_23 common pandora recruits are found from spring to winter, generally in waters <50m, whereas in the southern part of GSA22_23 the peak of the recruitment period occurs in December with individuals being found in waters <70 m depth. In GSA 20 recruitment occurs around November.

Spawning

In GSA 1,5,6 spawning takes place in May-June, with minimum length at maturity of 135 mm and minimum age at maturity of 1-year (Larrañeta, 1964). The 0-year class in May and June have a total length of 125-130 mm (Larrañeta, 1964). In the Gulf of Lions (GSA7) the common Pandora spawns from May to August; the minimum maturity size has been estimated at 10 cm FL (Fork Length).

In GSA10 the size at first maturity for femalesof common Pandora was estimated in the SAMED project using the maturity ogive and a value of 15.4 cm was estimated. According to the data obtained from DCF in 2009, the proportion of mature females by length class gave an estimate of maturity ogive which indicates a $L_{50\%}$ of about 16 cm (±0.3 cm; MR=0.9±0.38) a value similar to that of DCF in 2010 ($L_{50\%}$= 15.6 ± 0.23; MR= 1.24 ± 0.34) when the estimate was obtained using a GLM. Spawning mainly occurs during spring-summer seasons. The presence of spawning aggregations has not been investigated in previous studies in this area.

In GSA11 spawning takes place in spring and autumn according the hydrological condition. The range of $L_{50\%}$ from MEDITS data was 12.8-17.7 cm TL. The presence of spawning aggregations has not been investigated in previous studies in this area.

Spawning activity of *P.erythrinus* in the Strait of Sicily (GSA 15+16) takes place in late spring-early summer. Estimates of length at maturity (Lm50%) are 120-130 mm for females and 160-170 mm for males.

In GSA 17 common pandora spawns once a year in the spring and the beginning of the summer. Size at first sexual maturity of female was estimated between 11 and 12 cm (Vrgoč et al., 2004).

In GSA18, according to the data obtained from DCF in 2009, the proportion of mature females by length class gave an estimate of maturity ogive which indicates a $L_{50\%}$ of about 14.5 cm (±0.10 cm; MR=1.1±0.13) a value similar to that of DCF in 2010 ($L_{50\%}$= 13.8 ± 0.2; MR= 1.2 ± 0.32) when the estimate was obtained using a GLM. Spawning mainly occurs during spring-summer seasons. The presence of spawning aggregations has not been investigated in previous studies in this area.

In the North-Western Ionian Sea-GSA19 spawning mainly occurrs during spring, but some mature specimens of were also observed during autumn. The smallest mature female and male of *P. erythrinus* were 120 and 130 mm TL, respectively. Up to date, no spawning areas were detected for the species in the basin.

The peak of spawning period for the common Pandora in is during late spring/early summer in GSA 22_23, but has been found to range from summer to winter in certain areas. In GSA 20 the spawning period extends from late spring to early autumn with a peak around June.

2.2.5.4.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.4.1-2.2.5.4.2 list results of MEDITS survey in terms of frequency of positive hauls and number of specimens of common pandora by GSA and year. In Table 2.2.5.4.3 are listed the mean threshold length of recruits and spawners by GSAs.

GSAs 1-6, 5

The spawning fractions of females were extracted by means of the length at first maturity (L50 or length at which 50% of the individuals are mature) obtained from published literature.

GSAs 7, 8, 9

The occurrence of common Pandora was rather low in GSA7 and GSA9; the frequency of positive hauls ranged from 0.04 to 0.45 showing anyway an increasing trend. In GSA8 the species was caught more frequently, from 31 to 52% of the hauls performed each year. In GSA9 the frequency of positive hauls varied between 0.18 and 0.32.

A low number of individual was generally caught in GSA7; only in 1998, 1999 and 2009 the catches per year were higher than 100 individuals (121, 135 and 180 specimens, respectively.). In GSA8 the catches were low and highly variable: from 20 to 202 specimens. In GSA9 a higher number of individuals was caught (294 - 592).

The catches of the three GSAs were characterized by the scarce presence of small-sized specimens, even though the recruitment period in GSA9 is reported to peak in June-July coinciding with the MEDITS survey period. Female spawners have been detected in all the three GSAs from the maturity ogive study, even though only in a few yearsa good fit of the maturity ogive was obtained. An average values from the better estimates was computed by GSA: 17 cm TL for GSA7, 14 for GSA 8, 16 for GSA9.

GSA 10, 11, 18, 19

The frequency of positive hauls for *P. erythrinus* in GSA10 ranges between 0.13 (MEDITS 1994) and 0.29 (MEDITS 2006), with an overall catch fluctuating from a minimum of 107 (MEDITS 2008) and a maximum of 649 (MEDITS 2007) sampled specimens. The frequency of positive hauls for *P. erythrinus* in GSA11 ranges between 0.22 (MEDITS 2006) and 0.38 (MEDITS 2008), with an overall catch fluctuating from a minimum of 160 (MEDITS 2006) and a maximum of 429 (MEDITS 2008) sampled specimens.

The frequency of positive hauls for *P. erythrinus* in GSA18 ranges between 0.01 (MEDITS 1994) and 0.29 (MEDITS 2001), with an overall catch fluctuating from a minimum of 1 (MEDITS 1994) and a maximum of 498 (MEDITS 1999) sampled specimens.

The frequency of positive hauls for P. erythrinus resulted almost negligible in GSA19, oscillating from 0.07 to 0.22 with a maximum of 278 specimens sampled during MEDITS 2000

In GSA10 and 18 the recruitment threshold was an empirical value set as the mean length of the individuals at maturity stage 1. In the case of GSA19 an empirical value was adopted as threshold size, derived from other research studies carried out in the area. In GSA11 both the mean length of the first modal component and empirical values were used, depending on the year.

To identify the adults or potential spawners, an average of the parameters of the maturity ogive among the years from the MEDITS survey and/or from biological samplings of DCR and DCF has been used in GSAs 10 and 18, selecting those better fitting to the model. The adult fraction of *P. erythrinus* in GSA19 was separated using the empirical values of 14.5 cm TL. In GSA11 a fixed value of 15 cm TL from MEDITS survey was used.

GSAs 15-16

MEDITS catches of *P.erythrinus* were generally low in the Strait of Sicily (GSA 15+16), being 0.18 the mean frequency of positive hauls over the time series. However they were restricted to the bathymetric range 20-160 m. The mean number of specimens caught varied from 193 to 405.

Recruitment of *P.erythrinus* wasn't ever detected in the annual length frequency distributions. Female individuals showing maturity stage "3" (MEDITS maturity scale) were used to compute the abundance indices of spawners. Annual mean size of mature females varied between 190 and 213 mm TL.

GSA 17

GSA 17 MEDITS data are available for the period 2002-2010. The period 1994-2001 has been excluded from the analyses because data of the eastern side of the basin were not available.

In GSA 17 MEDITS data the common pandora is quite abundant with usually more than 40% of positive hauls and an average of around 1.500 specimens collected each year. The approach employed to detect the recruits was the Bhattacharya, which identified threshold sizes between 6.3-8.8 cm of total length. The threshold sizes utilized to identify the spawners, estimated from the maturity ogives in each year, were between 11.4-12.3 cm of total length.

In GSAs 20 and 22_23 the available data for common pandora extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 the proportion of positive hauls for common pandora was almost 50% (Table 2.5.4.1), whereas for GSAs 22_23 it ranged from 14-24%. Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

GSAs 20, 22-23

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates following the aforementioned approaches, threshold values were established based on literature information and expert knowledge.

GSA 25

GSA 25 MEDITS data are available for the period 2005-2010. In this area common pandora is quite abundant with usually more than 55% of positive hauls and an average of about 230 specimens collected each year. Recruits have been detected using otolith reading from DCR data. The threshold sizes utilized to identify the spawners, estimated from the maturity ogives in each year, were comprised between 10-15.9 cm of total length.

Table 2.2.5.4.1. Frequency of positive MEDITS hauls (n of positive hauls/n. of total hauls) for common pandora by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.19	0.33	0.28	0.13	0.25		0.01	0.07			0.15		
1995		0.04	0.41	0.31	0.16	0.25		0.04	0.14			0.24		
1996				0.24	0.13	0.26		0.06	0.11			0.23		0.16
1997		0.10	0.31	0.24	0.18	0.24		0.11	0.11			0.20		0.18
1998		0.27	0.52	0.29	0.19	0.33		0.20	0.20	0.47		0.27		0.21
1999		0.31	0.48	0.31	0.24	0.32		0.21	0.16	0.44		0.29		0.19
2000		0.22	0.41	0.29	0.27	0.24		0.25	0.18	0.41		0.24		0.14
2001		0.21	0.41	0.31	0.25	0.28		0.29	0.22	0.38		0.30		0.23
2002		0.15		0.29	0.17	0.23	0.31	0.10	0.07			0.32		
2003		0.21	0.43	0.18	0.19	0.29	0.46	0.18	0.19	0.5		0.28	0.17	0.21
2004		0.21	0.45	0.25	0.24	0.32	0.38	0.14	0.14	0.47		0.28	0.17	0.18
2005		0.14	0.39	0.20	0.27	0.27	0.42	0.07	0.19	0.41	0.48	0.24	0.14	0.24
2006		0.21	0.43	0.30	0.29	0.22	0.32	0.11	0.17	0.47	0.64	0.28	0.20	0.21
2007	0.34	0.28	0.35	0.28	0.27	0.31	0.43	0.22	0.11		0.68	0.33	0.17	
2008	0.28	0.38	0.44	0.30	0.20	0.38	0.42	0.20	0.20	0.44	0.67	0.34	0.24	0.2
2009	0.32	0.35	0.45	0.32	0.23	0.34	0.43	0.16	0.10		0.56	0.27	0.23	
2010	0.26	0.45	0.45	0.29	0.27	0.33	0.46	0.19	0.21		0.59	0.37	0.18	

Table 2.2.5.4.2. Number of specimens of common pandora caught during MEDITS by GSA and year.

	GSA													
YEAR	5	7	8	9	10	11	17	18	19	20	25	1_6	15_16	22_23
1994		29	108	387	194	270		1	13					
1995		3	136	394	218	215		13	26					
1996		0		433	227	273		72	49					714
1997		17	20	426	251	167		74	66					641
1998		121	140	522	244	342		187	138	459				1064
1999		135	121	489	263	325		498	187	365				971
2000		61	100	402	231	212		219	278	283				1218
2001		59	89	409	386	281		197	98	241				1039
2002		15		424	354	234	1351	35	32					
2003		41	127	250	267	272	1376	172	62	455		214	214	1671
2004		41	74	312	126	171	1281	73	63	226		193	193	776
2005		21	97	246	139	165	1399	84	177	419	219	331	331	2121
2006		61	70	294	115	160	1381	106	55	338	328	318	318	1338
2007	394	80	44	439	649	392	1448	153	92		276	375	375	
2008	295	180	202	402	107	429	1669	129	133	535	173	579	579	951
2009	154	69	183	424	205	325	1372	232	192		159	281	281	
2010	89	85	166	394	130	411	2044	282	236		261	405	405	

Table 2.2.5.4.3. Recruitment and spawning size identification for modeling purposes.

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (TL mm)**	**Data source**	**Method used**	**Mean maturity length (cm) /Maturity stage**
05, 01 and 06	-	-	-	-	Larrañeta et al. (1964)	Fixed threshold length (L_{50})	135
7	1994-2010	DCF/MEDITS	A very scarce number of recruits was observed		DCF/MEDITS	Maturity ogive	170
8	1994-2010	DCF/MEDITS	A very scarce number of recruits was observed		DCF/MEDITS	Maturity ogive	140
9	1994-2010	DCF/MEDITS	A very scarce number of recruits was observed		DCF/MEDITS	Maturity ogive	160
10	1994-2010	MEDITS	cut-off size calculated as mean length of individuals at maturity stage 1 in all the years	146	MEDITS and biological sampling	Maturity ogive	160
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya	122.7	MEDITS	Fixed threshold length (L_{50})	150
15+16	2003-2010	-	-	-	MEDITS	Maturity stage “3”	196 (annual mean:190-213
17	2002-2010	MEDITS	Bhattacharya	77	MEDITS	Maturity ogive	119
18	1994-2010	MEDITS	cut-off size calculated as mean length of individuals at maturity stage 1 years 1995:2010	140	MEDITS and biological sampling	Maturity ogive	145
19	1994-2010	MEDITS	fixed	120	MEDITS	fixed	145
20	1998-2008	MEDITS	Bhattacharya	60	MEDITS	Fixed threshold length (L_{50})	140
22_23	1996-2008	MEDITS	Bhattacharya	65	MEDITS	Fixed threshold length (L_{50})	135
25	2005-2010	DCR data	Otolith reading	100	MEDITS	Maturity ogive	120

Mapping of density and identification of hot spot areas

A summary of the spatial model implemented for mapping recruits and adults/spawners of red pandora is provided in Table 2.2.5.4.4. Details can be seen at http://mareaproject.net/mediseh/viewer/med.html.

GSAs 1-6

Pagellus erythrinus was not included within the analyzed species due to the limited capacity of MEDITS to sample coastal species, like *P. erythrinus* as noted in the STECF meeting "Assessment of Mediterranean Sea stocks - Part 1 (STECF-11-05)", that reviewed the quality of all data collected under the umbrella of the Data collection Framework. The same working group suggested that in these cases, "MEDITS data can only be used as a recruitment index". However, the recruitment of this species in the GSA 06 has been found in September-October (Larrañeta, 1967), not coinciding with the MEDITS survey period (late spring and early summer). Spawning occurs in summer, after the period of the survey. Therefore, no spawners could also be modelled.

GSAs 7, 8, 9

No models for recruits were developed due the very scanty catch of juveniles during MEDITS in the three GSAs. Spawners were mapped only in GSA7, where both the number of positive hauls and catch of adult specimens during MEDITS have allowed modeling. A GAM model with spatial component and a smooth effect on Longitude was built. The spatial component was allowed to change each year using an exponential or spherical covariance function depending on the year.

GSA 10, 11, 18, 19

A detailed description of models used to map distributions and identify hot spots is provided in Suppl 2.2.1. In this chapter the modeling approach followed (method for mapping, covariates, etc.) is summarized. In GSA10-11-18-19 annual abundace values were predicted by means of a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging was applied on raw abundance values. For modelling, the R MEFH MEDISEH routine 2.0 was used. The low number of stations positive for this species made the modeling difficult especially for the recruits.

GSAs 15-16

In GSA 15+16, density indices of spawners of *P.erythrinus* were modeled using a GAM with spatial component and a smooth effect on Latitude and Longitude. Both the intercept and the spatial component were allowed to change each year. The model goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km. The persistence was obtained as the rate of years in which a point was a hot spot.

Spatial distribution of recruits of red pandora was not modeled in GSA 15+16 because the sampling period was inappropriate to intercept the species recruitment.

GSA 17

Modeling approaches employed to identify nursery and spawning grounds of common pandora in GSA 17 were the zero-Inflated Generalized Additive Model (Liu and Chan, 2010) and local G statistic (Getis and Ord, 1992), respectively to define the spatial distribution and the hot spots, considered as the place where high values of densities cluster together. The covariates employed to identify the spatial patterns of recruits and spawners of common pandora were year (as factor), latitude, longitude and depth.

The diagnostics of the ZIGAM model employed for recruits and spawners of common pandora in GSA 17 (table 2.2.5.4.4) show a better fitting for spawners, although the model results seems appropriate also for the recruits.

GSAs 20, 22-23

Generalized Additive Models were employed to model the distribution of spawners of common pandora in each GSA (GSA 20 and GSA 22_23). The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots. The depth distribution of common pandora spawners ranged from 25 - 465 m in GSAs 22_23.

GSA 25

In GSA 25, attempts of modeling have been undertook for recruits and spawners of common pandora, but as is possible to observe in Suppl 2.2.2, both GAM and geostatistical methods did not provide any appropriate result. The relative high distance between hauls did not allow to implement any reasonable model (no spatial covariance can be estimated).

Table 2.2.5.4.4. Modeling applied in EU GSAs for mapping common pandora.

<table>
<tr><th>Life stage</th><th>GSA</th><th>Depth range (m)</th><th>Period</th><th>Model type</th><th>Covariates</th><th colspan="2">% dev. expl.</th><th colspan="2">Goodness of fit (R^2)</th></tr>
<tr><td>Recruits</td><td>10</td><td>10-200</td><td>1994-2010</td><td>Ordinary Kriging (*)</td><td>--</td><td colspan="2">--</td><td colspan="2">--</td></tr>
<tr><td>Recruits</td><td>11</td><td>10-200</td><td>1994-2010</td><td>Ordinary Kriging</td><td>--</td><td colspan="2">--</td><td colspan="2">--</td></tr>
<tr><td>Recruits</td><td>18</td><td>10-200</td><td>1996-2010</td><td>Ordinary Kriging</td><td>--</td><td colspan="2">--</td><td colspan="2">--</td></tr>
<tr><td rowspan="3">Spawners</td><td rowspan="3">10</td><td rowspan="3">10-300</td><td rowspan="3">1994-2010</td><td>Gaussian GAM</td><td>Depth</td><td colspan="2">8.6</td><td colspan="2">0.06</td></tr>
<tr><td>Binomial GAM</td><td>Depth</td><td colspan="2">34.8</td><td colspan="2">0.38</td></tr>
<tr><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Spawners</td><td rowspan="3">11</td><td rowspan="3">10-200</td><td rowspan="3">1994-2010</td><td>Gaussian GAM</td><td>Depth</td><td colspan="2">7.5</td><td colspan="2">0.05</td></tr>
<tr><td>Binomial GAM</td><td>Depth</td><td colspan="2">31.9</td><td colspan="2">0.35</td></tr>
<tr><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Spawners</td><td rowspan="3">18</td><td rowspan="3">10-400</td><td rowspan="3">1996-2010</td><td>Gaussian GAM</td><td>Depth</td><td colspan="2">14.9</td><td colspan="2">0.1</td></tr>
<tr><td>Binomial GAM</td><td>Depth</td><td colspan="2">21.1</td><td colspan="2">0.17</td></tr>
<tr><td>Gaussian GAM</td><td colspan="5"></td></tr>
<tr><td>Spawners</td><td>7</td><td>10-200</td><td>1998-2010</td><td>GAM with spatial component</td><td>Latitude</td><td colspan="2"></td><td colspan="2">*CV=1.055
0.44</td></tr>
<tr><td>Spawners</td><td>15+16</td><td>20-150</td><td>2003-2010</td><td>GAM with spatial component</td><td>Year, Latitude, Longitude</td><td colspan="2"></td><td colspan="2">*CV=0.98
0.443</td></tr>
<tr><td rowspan="2">Spawners</td><td rowspan="2">17</td><td rowspan="2">10-600</td><td rowspan="2">2002-10</td><td rowspan="2">ZIGAM</td><td rowspan="2">Year, Lon, Lat, depth</td><td>LR</td><td>GAM</td><td>LR</td><td>GAM</td></tr>
<tr><td>40.8</td><td>42.8</td><td>0.44</td><td>0.388</td></tr>
<tr><td rowspan="2">Recruits</td><td rowspan="2">17</td><td rowspan="2">10-600</td><td rowspan="2">2002-10</td><td rowspan="2">ZIGAM</td><td rowspan="2">Year, Lon, Lat, depth</td><td>LR</td><td>GAM</td><td>LR</td><td>GAM</td></tr>
<tr><td>31.3</td><td>33.1</td><td>0.18</td><td>0.23</td></tr>
<tr><td>Spawners</td><td>20</td><td>35-150</td><td>1998-2008</td><td>GAM(delta - lognormal)</td><td>Year, Lon, Lat, depth</td><td colspan="2">60.8</td><td colspan="2">0.49</td></tr>
<tr><td>Spawners</td><td>22_23</td><td>25-465</td><td>1996-2008</td><td>GAM(delta - lognormal)</td><td>Year, Lon, Lat, depth</td><td colspan="2">45.3</td><td colspan="2">0.40</td></tr>
</table>

* cross-validation index, ** see Annex 2

2.2.5.4.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.4.5 summarizes the main environmental features of the most persistent areas identified for common pandora in European GSAs.

GSA 7

Several hot spot areas with high density and temporal persistency of spawners resulted from the analysis. These were distributed in the coastal zone, from20 to 50 m depth, in particular on the western sector of Gulf of Lions. However al large patch (GSA7_S1) occurs also in the Eastern sector (Fig. 2.2.5.4.1).

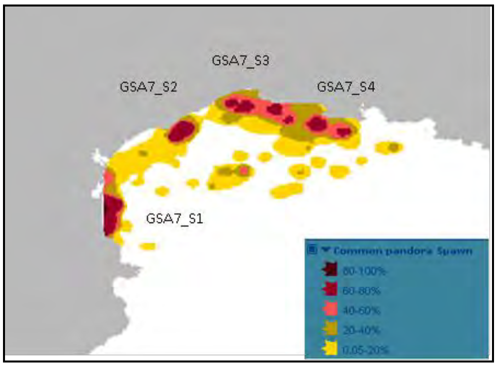


Fig. 2.2.5.4.1. Position of persistent nursery (left) and spawning areas (right) of commonPandora in GSA7

GSA 10

In the GSA 10 nursery areas with higher level of persistence (>40%) were identified in the Gaeta (GSA10_N1) and Patti (GSA10_N2) Gulfs. In the latter, also a spawning aggregation was identified (GSA10_S2) with a level of persistence (>40%) comparable with that of GSA10_S3, localized along the coasts of Capo Suvero. In the Castellammare Gulf (GSA10_S1) the level of persistence was even higher (60-80%, Fig. 2.2.5.4.2).

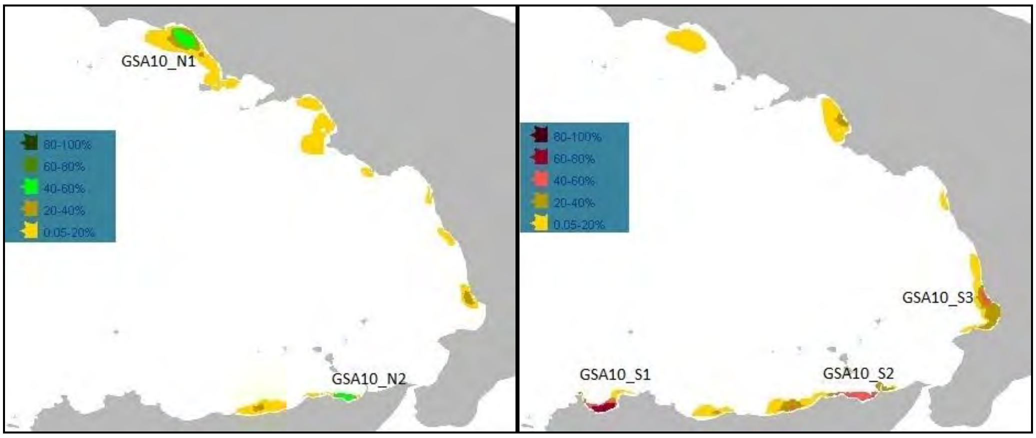


Fig 2.2.5.4.2 Position of persistent nursery (left) and spawning areas (right) of red Pandora in GSA10

GSA 11

Nursery areas are mainly found in the western and south eastern coasts of Sardinia at depth lower than 100 m. The beds are mainly characterized by the presence of the Biocenosis of Posidonia (upper levels) and that of terrigenous mud (lower levels) with macro organisms like *Aphrodite aculeata*, *Stichopus regalis*, *Alcyonium palmatum.* Spawning areas are present around all Sardinian coasts mainly in the western and northern coasts. Few zones with lower level of persistence are found also in the north-eastern coast, at depth lower than 100 m (Fig. 2.2.5.4.3).

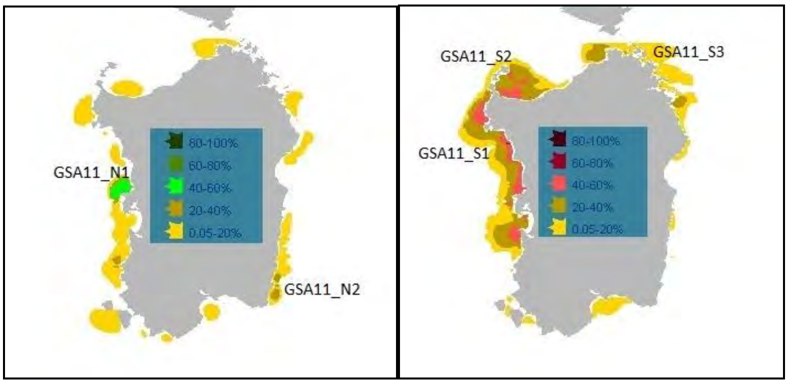


Fig 2.2.5.4.3. Position of persistent nursery (left) and spawning areas (right) of red Pandora in GSA11

GSAs 15-16

The spatial modeling of the spawning fraction of common pandora in GSA 15+16 reveals that spawners of this species prefer the shallow detritic bottoms (60-85 m) with *Laminaria rodriguezii*. Two large persistent spawning areas have been identified on the northern sector of the Straits of Sicily: the first on the western side of Adventure Bank (GSA15+16_S1) and the second in the east of Malta (GSA15+16_S2) within the 25 nautical mile FMZ. Both areas extend offshore and overlap with the spawning areas of *M.surmuletus*. Some inshore areas along the southern coast of Sicily seem to provide further spawning grounds for common Pandora (Fig. 2.2.5.4.4).

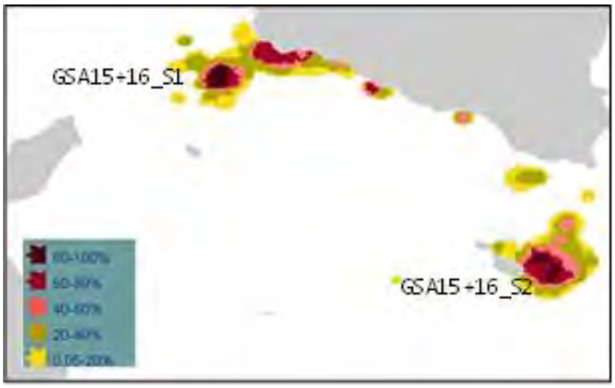


Fig. 2.2.5.4.4. Position of persistent spawning areas of common Pandora in GSA 15+16

GSA 17

The areas of persistency identified for the recruits of common pandora in GSA 17 are essentially four. R1 is located from Pula (Istria) to Rimini, R2 extends from Fano to the Conero Promontory and R3 is located northwards the Lesina Lagoon. All these three nursery areas extend along the coastline at depths ranging from 5 to 20 m (Fig. 2.2.5.4.5).The edaphic factors do not seem to play a decisive role in the distribution of this species; primarily, the kind and amount of accessible food and hydrography seem to be decisive (Rijavec, 1975; Županović and Rijavec, 1980). The area of recruitment is characterized by upwelling events, associated to the prevailing NW winds, especially along the Istrian peninsula coast, while fresh water inflow characterize the rest of the northwest area (Cushman-Roisin et al., 2001) . The sea bottom of coastal areas consists mostly of mud and sand-detritic sediments, in particular the area comprised between Venice lagoon and Trieste gulf is characterized by the presence of "trezze" and "tegnùe", submersed rocky aggregates consisting of detritus and organogenic matter, in form of multiple and dispersed spots. The "tegnùe" consist of rocky materials which are often classified as beachrocks, while "trezze" more often consist of organogenic materials, and they usually arise from Posidonia meadows, which are mainly extinct nowadays. Over these meadows secondarily developed the coralligenous (calcareous algae, briozoa, serpulids, mollusks). The biocenosis of the sand-mubby bottom is numerically dominated by Polychaetes and other filter-feeding bivalves (mainly Corbula gibba), followed by small crustaceans (mostly amphipodes and decapods as Liocarcinus spp.) and burrowing Ophiuroisis. R4 extends from Makarska to Dubrovnic and is characterized by rocky bottoms at depths ranging from 5 to 50 m.

Three persistent areas were identified for the spawners of common pandora in GSA 17 (Fig. 2.2.5.4.5). The main area (S1) is comprised between 20-70 m, located in the eastern side of the basins especially within channel waters of the central Adriatic between Croatian islands and southwards from Istria peninsula. The spawning grounds are characterized by upwelling events, associated to the prevailing NW winds, frequent along the Croatian coast during summer months (Cushman-Roisin et al., 2001). The area is characterized by relict sand (from times when the water level was lower and the area was a sandy beach), with high densities of holothurian (e.g. *Holoturia forskali*) and bivalves (e.g. *Atrina pectinata*). S2 is similar to the southern portion of S1 and extends until the limit of the GSA 17. S3 has a very small extension, being located from Ortona to Vasto.

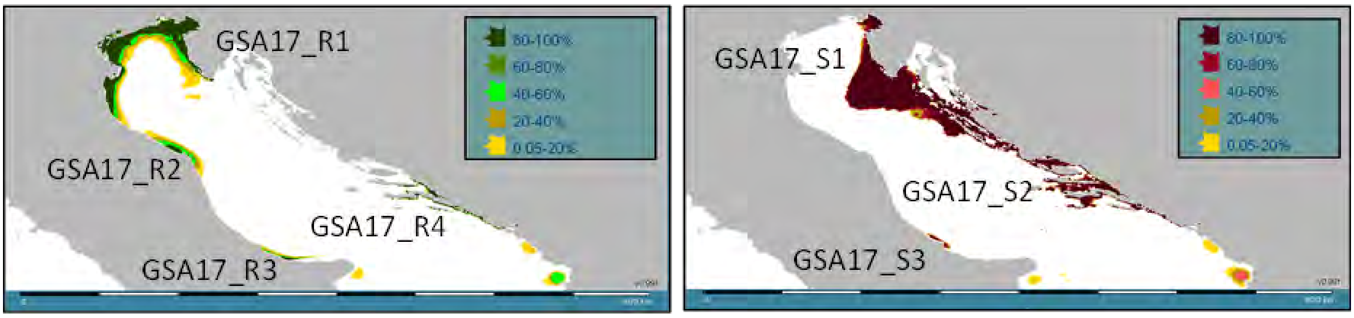


Fig. 2.2.5.4.5. Position of persistent nursery (left) and spawning areas (right) of common Pandora in GSA 17

GSA 18

In the GSA18 both nursery areas and spawning aggregation of common pandora were localised in the eastern side along the coast of Albania in the Gulf of Lezhë. A remarkable level of persistence (40-60%) was observed fort the GSA18_N1 and GSA18_S1 (Fig. 2.2.5.4.6).

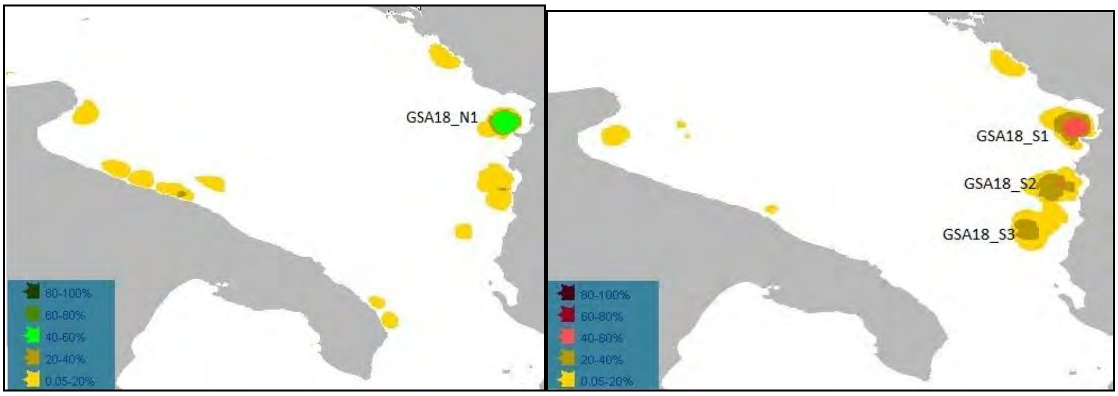


Fig 2.2.5.4.6. Position of persistent nursery (left) and spawning areas (right) of common Pandora in GSA10

GSA 20, 22-23

Common pandora capture depth extended from 25 to 465m in the Aegean and 35-150m in the Ionian Sea. Our analysis however showed that spawners are generally more abundant up to ~150m depth.

Recruits of the species have by default very coastal distribution hence they are largely inaccessible by the MEDITS trawl. In the few instances that common pandora recruits were captured in hauls in the Aegean Sea, their depth distribution did not exceed 65m. The sporadic character of common pandora recruits did not allow for modeling and hence the only available distribution maps are annual bubble plot maps.

The density maps revealed that common pandora spawners show a local distribution, mainly distributed in Saronikos gulf, outside Pagasitikos gulf and to a lesser extent in Crete and Dodecanese islands. Some areas were also identified in the Ionian Sea area, mainly outside the large Messolonghi laggon and near the coasts of Epirus (northwestern Greece). Moreover, no persistent locations were identified in the northern Greece (Fig. 2.2.5.4.7).

The water circulation pattern, largely driven by the complex bathymetry of the Aegean Sea, is most probably the reason for the north-south barrier in common pandora's distribution.

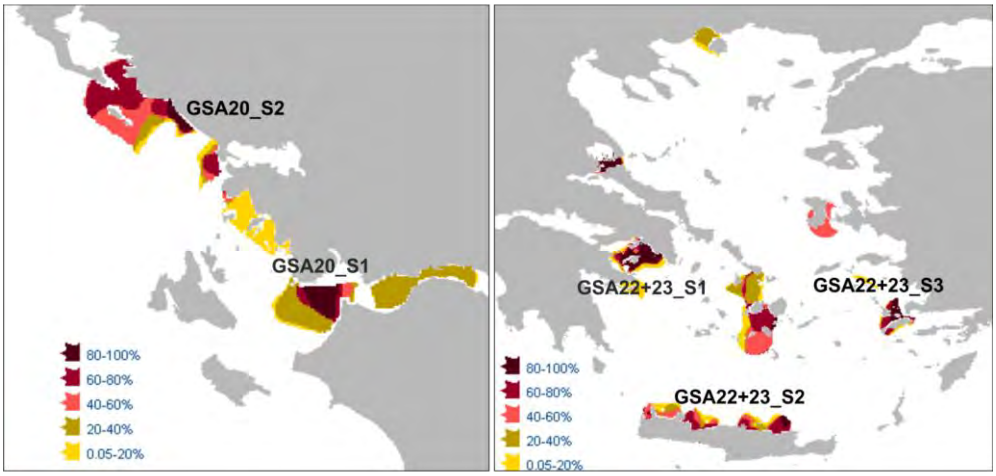


Fig. 2.2.5.4.7. Position of persistent spawning areasof common Pandora in GSA 20 (left) and GSA 22_23 (right).

Table 2.2.5.4.5. Environmental characteristics on nurseries and spawning grounds of red pandora.

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
9	spawning	GSA9_S1	10-55	Sandy and muddy-sandy sediments in the western aprt of the Gulf of Lions
9	spawning	GSA9_S2	10-50	Coastal area in front of Sète
9	spawning	GSA9_S3	8-40	Coastal zone in the Rhone estuary area.
9	spawning	GSA9_S4	20-55	Coastal zone in the Rhone estuary area.
10	nursery	GSA10_N1	15-68	The bottom is muddy-sand with coastal terrigenous muds biocenosis (VTC) characterized by species as *Alcyonium palmatum, Stichopus regalis, Philine aperta, Goneplax rhomboides Dorippe lanata, Ascidia mentula* etc. The direction of the mainstream current in is from south to north.
10	nursery	GSA10_N2	43-58	The area is characterized by fine sands biocenosis (SFBC) with facies at *Cymodocea nodosa* and associated species as *Ophiura ophiura, Astropecten bispinosus, Astrospartus mediterraneus, Amathia convolute* etc. The direction of the mainstream current in is from west to east
10	spawning	GSA10_S1	61-120	The infralittoral of Castellamare Golf is characterized by the coastal detritic biocenosis (DC) on the tanatocenosis of Neopycnodonte cochlear with characteristic species as *Alcyonium palmatum, Pennatula phoshorea, Stichopus regalis, Peltaster placenta Marthasterias glacialis*. The

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
				direction of the mainstream current in is from west to east. The superficial current during the sampling period is circular inside the Gulf.
10	spawning	GSA10_S2	18-283	The area is characterized by fine sands biocenosis (SFBC) with Cymodocea nodosa facies and associated species as *Ophiura ophiura, Astropecten bispinosus, Astrospartus mediterraneus, Amathia convolute* etc. The direction of the mainstream current in is from west to east.
10	spawning	GSA10_S3	32-126	The bottom is muddy-sand with coastal terrigenous muds biocenosis (VTC) characterized by species as *Alcyonium palmatum, Stichopus regalis, Diazoma violacea*. The direction of the mainstream current in is from west to east.
11	nursery	GSA11_N1	<100 m	Biocenosis of Posidonia (upper levels) and that of terrigenous mud (lower levels) with macro organisms like *Aphrodite aculeata, Stichopus regalis, Alcyonium palmatum.*
11	nursery	GSA11_N2	<100 m	Biocenosis of Posidonia (upper levels) and that of terrigenous mud (lower levels) with macro organisms like *Aphrodite aculeata, Stichopus regalis, Alcyonium palmatum.*
11	spawning	GSA11_S1	<100 m	Mainly Biocenosis of *Posidonia oceanica*
11	spawning	GSA11_S2	<100 m	Mainly Biocenosis of *Posidonia oceanica*
11	spawning	GSA11_S3	<100 m	Mainly Biocenosis of *Posidonia oceanica*
15+16	nursery	GSA15+16_S1	60-75	Coastal Detritic Bottom with *Laminaria rodriguezii*. The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the extension of upwelling over the shelf and the temperature regime of surface waters. The mean value of SST observed in late spring-early summer is 22 °C.
15+16	nursery	GSA15+16_S2	75-85	Coastal Detritic Bottom with *Laminaria rodriguezii* Due to the presence of different hydrodynamical processes and interesting phenomena within the Malta Bank, the upwelling can extend its influence far offshore and actually engulf the whole Maltese shelf. The mean value of SST observed in late spring-early summer is 23.2 °C.
17	nursery	GSA17_R1	5-20	- Muddy-sand sediments with presence of hard substrata - Upwelling (Istria and Trieste Gulf) and freshwater inflow - Muddy-sand communities (especially Polychaetes)
17	nursery	GSA17_R2	5-20	- Muddy-sand sediments - Freshwater inflow - Muddy-sand communities (especially Polychaetes)
17	nursery	GSA17_R3	5-20	- Muddy-sand sediments - Muddy-sand communities (especially Polychaetes)
17	nursery	GSA17_R4	5-50	- Hard substrata

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
17	spawning	GSA17_S1	20-80	- upwelling events - relict sand - holothurians community
17	spawning	GSA17_S2	20-80	- rocky bottoms
17	spawning	GSA17_S3	10-30	- Muddy-sand sediments - Muddy-sand communities (especially Polychaetes)
18	nursery	GSA18_N1	39-49	The bottom is muddy with coastal terrigenous muds biocenosis (VTC) with characteristic species as Astropecten irregularis *Stichopus regalis, Alcyonum palmatum Pteria hirundo, Turritella communis, Dorippe lanata Macropipus depurator, Philine aperta* etc. The mainstream current is from south to north.
18	spawning	GSA18_S1	39-49	The bottom is muddy with coastal terrigenous muds biocenosis (VTC) with characteristic species as *Astropecten irregularis Stichopus regalis, Alcyonum palmatum Pteria hirundo, Turritella communis, Dorippe lanata, Macropipus depurator, Philine aperta* etc. The mainstream current is from south to north.
18	spawning	GSA18_S2	77-84	The bottom is muddy with coastal terrigenous muds biocenosis (VTC) on tanatocenosis of Neopycnodonte cochlear with the characteristic species as *Astropecten irregularis Stichopus regalis, Pteria hirundo, Ascidia mentuala, Phallusia mammillata, Dorippe lanata, Macropipus depurator, Antedon mediterranea* etc The mainstream current is from south to north.
18	spawning	GSA18_S3	101-197	The bottom is muddy with coastal terrigenous muds biocenosis (VTC) on tanatocenosis of Neopycnodonte cochlear with the characteristic species as *Stichopus regalis, Pteria hirundo, Diazona violacea, Ascidia mentuala, Phallusia mammillata, Macropipus depurator, Cidaris cidaris* etc The mainstream current is from south to north.
20	spawning	GSA20_S1	50-100	West entrance of Patraikos gulf. In the vicinity of the Messolonghi estuary. Sediment type is mud. Oceanographic circulation affected by strong currents in the straits between Patraikos and Korinthiakos gulfs.
20	spawning	GSA20_S2	50-250	Continental shelf of Epirus (western Greece). Main sediment type is mud.
22_23	spawning	GSA22-23_S1	40-200	Central part of Saronikos gulf. Largely protected from large-scale oceanographic features.
22_23	spawning	GSA22-23_S2	50-200	Cretan continental shelf. Highly affected by northern winds. The main sediment type is mud. Other environmental information is unavailable.
22_23	spawning	GSA22-23_S3	50-200	South-east Aegean Sea (Dodecanese complex). Relatively deep, saline (Levantine-origin) waters. Main sediment type is mud.

2.2.5.4.4 Gaps in knowledge and future actions

The main identified gaps in knowledge for common Pandora are related to the lack of time series of spatio-temporal abundance data on recruits, due to the MEDITS survey period which was often before the recruitment period of the species. Also the MEDITS catchability for spawners and recruits appears in general rather low because big specimens are widely distributed also in untrawable areas.

Identification of nursery grounds would require sampling in late summer-autumn. In Greek GSAs nursery areas cannot be identified for the species as the timing of the MEDITS survey (June) does not allow for captures of common pandora recruits in sufficient numbers and/or stations, hence information is largely lacking. Bearing in mind that the spawning period is only partially overlapping with the MEDITS survey, spawning areas may have not fully identified. No information is available for nursery and spawning grounds of common pandora in GSA 25. Anyway considering the bubble plot maps is possible to assume that the coastal areas of Laranca, Limassol and Chrysochuo bays represent a suitable environment for spawning ground of the species.

2.2.5.5 Raja clavata

2.2.5.5.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Annex 1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

There is no published information in GSA 1-6, 5 regarding recruitment. However, in Portuguese waters, the recruits or age-0 individuals presented lengths below 20 cm (Serra-Pereira et al., 2008). According to the estimated growth rate, juveniles at age 1 were measured at 20 cm TL (males) – 24 cm TL (females) in GSA7 and about 36 cm TL in GSA9. In GSAs 10 and 18 the experimental catches of *R. clavata* are generally very scant, thus the recruitment pattern is unclear. In Sardinian waters -GSA11, information on the recruitment of R.clavata is poor. In the North-Western Ionian Sea-GSA19 only one specimen *of R. clavata* was collected (GRUND survey 2001), evidencing as the species is quite rare in the basin. The young of *R.clavata* hatch at 100-110 mm TL and small size specimens are caught throughout the year in the Strait of Sicily (GSA 15+16). In GSA 15, the distribution of immature specimens is restricted to the edge of the continental shelf northwest of Malta. In the Central Adriatic (GSA 17) this species is currently at low abundance with a rather scarce knowledge on its reproduction and recruitment features.

Bibliographic information on recruitment for the species is lacking for GSAs 20, 22 and 23.

Spawning

In GSA 1-6, 5 the spawning of thornback ray, *Raja clavata*, occurs all year around in the Mediterranean (Capapé *et al.,* 2007).The length at first maturity seems to vary greatly depending on the area studied. In Southern France the minimum mature male and female were 60 and 76 cm, respectively (Capapé *et al.,* 2007). This species spawns in January – February in the Gulf of Lions (GSA 7). In GSA9 a spawning peak was observed in Autumn-Winter; L50 was estimated for females to be at about 57 cm TL. Hatching occurs after 4-5 months, so that recruitment takes place from May to July. In GSAs 10 and 19 no maturity ogive is available, neither informaton on the reproduction cycle. In GSA 11 reproduction occurs throughout the year with a peak in fall-winter. The maturity is reached for the females between 74 and 76 cm of TL and for males between 54 and 56 cm TL. In GSA18, according to the data obtained from DCF in 2010, the proportion of mature females by length class gave an estimate of maturity ogive which indicates a L50% of about 79.1 cm (±1.17 cm; MR=5.4±1.0). In the Straits of Sicily (GSA 15+16), mature individuals are observed all year around. Spawning activity has a peak in autumn and the minimum in winter. Specimen length at first maturity (Lm50%) is 770-790 mm TL for females and 570-590 mm TL for males. Krstulovic Sifner et al. (2009) found that length of first sexual maturity of females in the GSA 17 was 61.2 cm with 47.5 cm TL for thesmallest mature female. Bibliographic information on spawning for the species is lacking for GSAs 1, 5, 6, 20, 22 and 23.

2.2.5.5.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.5.1-2.2.5.5.2 list results of MEDITS in terms of frequency of positive hauls and number of specimens of common pandora by GSA and year. In Table 2.2.5.5.3 are listed the mean threshold lengths of recruits and spawners by GSAs.

GSAs 1-6, 5

The length distribution and the amount of individuals per length-class did not allow computing Bhattacharya's method to obtain a threshold value and thus bibliographic information was used. The mean length of the first modal component was applied as a threshold value of total length. This threshold and the swept area of each haul were used to calculate the standardized abundance index of recruits (n/km^2). The spawning fractions of females were extracted by means of the length at first maturity (L_{50} or length at which 50% of the individuals are mature) obtained from published literature.

GSAs 7, 8, 9

The presence of thornback ray was in general low in GSAs 7, 8 and 9. The proportion of positive hauls was at maximum 22% in GSA7 and 14% in GSA9; the species was more frequent in GSA8, with values from 0.16 to 0.55. Also the number of specimens caught per year in the three GSAs was low: the maximum value was 136 in 1994 in GSA8. Due to the scarce abundance of the species, both the presence of recruits and spawners was not significantly detected in the yearly length frequency distribution of the three GSAs.

GSA 10, 11, 18, 19

The frequency of positive hauls for *R. clavata* in GSA10 ranges between 0 (MEDITS 1998) and 0.10 (MEDITS 2006 and 2009), with a maximum overall catch fluctuating around 34 sampled specimens (MEDITS 2005).

The frequency of positive hauls for *R. clavata* in GSA11 ranges between 0.23 (MEDITS 2008) and 0.36 (MEDITS 2007), with an overall catch fluctuating from a minimum of 129 (MEDITS 2002) and a maximum of 379 (MEDITS 1999) sampled specimens. The frequency of positive hauls for *R. clavata* in GSA18 ranges between 0 (MEDITS 1995) and 0.14 (MEDITS 2008), with a maximum overall catch of 47 sampled specimens. *R. clavata* with only 1 specimens sampled during the GRUND survey 2001, resulted to be very rare in the GSA19 preventing any possible further analysis.

GSAs 15-16

In the Strait of Sicily, *R.clavata* was caught in the 26-35% of the hauls from shallow waters to the bathyal zone (60-700 m). The mean total number of specimens for year was 326.

Data for the first cohort of R.clavata were limited in GSA 15+16, then a broader length range of juveniles was considered, by using, as cut-off size, the mean length of specimens at the maturity stage "1" (all the years combined) at 410 mm TL.

Female individuals with maturity stage "3" (MEDITS maturity scale) were counted to estimate the spawning fraction of the population. Their annual mean size ranged from 642 to 758 mm TL

GSA 17

In GSA 17 the period 1994-2001 was excluded from the analyses because data of the eastern side of the basin were not available. Thornback ray was rare during MEDITS with usually less than 10% of positive hauls and an average of less than 50 specimens collected each year. A fixed threshold sizes of 30 and 50 cm has been utilized respectively to identify recruits (Relini et al., 1999) and spawners (smallest mature female observed in the MEDITS survey).

GSAs 20, 22-23

The available data for thornback ray in GSA 20 and 22-23 that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 and in GSAs 22_23 the proportion of positive hauls for thornback ray was ~55% (Table 2.5.5.1), with fluctuating catches in each GSA (Table 2.5.5.2). Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates based on the aforementioned approaches, threshold values were established based on literature information and expert knowledge

GSA 25

In GSA 25 MEDITS data are available for the period 2005-2010. Thornback ray is rare with usually less than 15% of positive hauls and an average of around 7 specimens collected each year. Given the low abundance of recruits and spawners threshold sizes have been derived from the data of GSAs 22-23.

Table 2.2.5.5.1. Frequency of positive MEDITS hauls (n of positive hauls/n. of total hauls) for thornback ray by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.20	0.38	0.04	0.06	0.23		0.01	--			0.01		
1995		0.22	0.23	0.08	0.02	0.27		0.00	--			0.02		
1996				0.09	0.04	0.27		0.02	--			0.03		0.53
1997		0.20	0.54	0.12	0.05	0.29		0.03	--			0.01		0.54
1998		0.08	0.52	0.08	0.00	0.24		0.04	--	0.53		0.01		0.64
1999		0.19	0.39	0.11	0.04	0.32		0.02	--	0.5		0.01		0.58
2000		0.09	0.55	0.04	0.08	0.30		0.03	--	0.41		0.01		0.53
2001		0.08	0.41	0.07	0.05	0.33		0.01	--	0.47		0.00		0.5
2002		0.02		0.05	0.04	0.30	0.06	0.03	--			0.00		
2003		0.00	0.43	0.05	0.04	0.31	0.08	0.06	--	0.5		0.00	0.26	0.5
2004		0.07	0.55	0.08	0.06	0.34	0.10	0.08	--	0.41		0.00	0.32	0.48
2005		0.03	0.26	0.07	0.09	0.26	0.09	0.02	--	0.5	0.12	0.00	0.26	0.47
2006		0.03	0.39	0.09	0.10	0.30	0.07	0.09	--	0.53	0.12	0.01	0.32	0.5
2007	0.58	0.03	0.40	0.13	0.07	0.36	0.09	0.04	--		0.2	0.00	0.27	
2008	0.56	0.09	0.16	0.11	0.07	0.23	0.13	0.14	--	0.66	0.15	0.02	0.35	0.56
2009	0.56	0.10	0.27	0.09	0.10	0.28	0.07	0.08	--		0.11	0.02	0.33	
2010	0.58	0.09	0.27	0.14	0.09	0.32	0.11	0.10	--		0.22	0.00	0.31	

Table 2.2.5.5.2. Number of specimens of thornback ray caught during MEDITS by GSA and year.

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		31	136	10	15	191		1	--			2		
1995		44	78	24	6	287		0	--			2		
1996		0		30	20	236		2	--			3		527
1997		29	47	46	8	301		6	--			2		447
1998		14	104	19	0	281		12	--	62		2		624
1999		21	39	30	11	379		4	--	49		2		626
2000		14	97	9	20	237		6	--	63		1		592
2001		9	44	38	14	415		1	--	68		0		377
2002		6		26	9	129	40	7	--			0		
2003		0	52	16	5	250	42	11	--	72		0	200	350
2004		8	33	55	11	263	64	28	--	65		0	199	314
2005		2	27	40	34	336	63	3	--	78	5	0	307	472
2006		6	31	57	24	247	31	22	--	66	4	2	465	495
2007	269	3	28	93	22	285	65	7	--		9	0	215	
2008	155	9	72	93	15	163	46	47	--	109	6	2	512	467
2009	177	14	28	115	20	215	32	26	--		4	6	313	
2010	197	11	19	73	30	349	44	19	--		16	0	401	

Table 2.2.5.5.3. Recruitment and spawning size identification for modeling purposes of the thornback ray.

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (TL mm)**	**Data source**	**Method used**	**Mean maturity length (cm) /Maturity stage**
05, 01 and 06		Serra-Pereira et al., 2008	Fixed threshold length	200	Serra-Pereira et al., 2008	Fixed threshold length (L_{50})	61.2
7	1994-2010	DCF/MEDITS	The number of recruits was negligible:		DCF/MEDITS	The number of spawners was negligible	
8	1994-2010	DCF/MEDITS	The number of recruits was negligible		DCF/MEDITS	The number of spawners was negligible	
9	1994-2010	DCF/MEDITS	The number of recruits was negligible		DCF/MEDITS	The number of spawners was negligible	
11	1994-2010	MEDITS	Fixed threshold length	354	MEDITS	MS maturity stages estimation	692
15+16	2003-2010	MEDITS	Fixed threshold	410	MEDITS	Maturity stage "3"	690 (annual mean:642-758)

17	2002-2010	Relini et al., 1999	Fixed threshold length	30	MEDITS	Smallest mature female	500
20	1998-2008	MEDITS	Batthacharya	14	MEDITS	(L50)	370
22_23	1996-2008	MEDITS	Batthacharya	14	MEDITS	(L50)	435
25	2005-2010	MEDITS GSAs 22-23	Bhattacharya	14	MEDITS GSAs 22-23	Maturity ogive	435

Mapping of density and identification of hot spot areas

A summary of the spatial model implemented for mapping recruits and adults/spawners of thornback ray is provided in Table 2.2.5.5.4.

GSAs 1-6, 5

This species was not modeled due to the low number of specimens captured, between 0 and 6 depending on the year considering all the size-classes together.

GSAs 7, 8, 9

Due to the low number of specimens caught it was impossible to apply the modeling approach to map the spawning areas in the three GSAs.

GSA 10, 11, 18, 19

In GSA11 annual abundance values were predicted by mean a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging was applied on real abundance values.

GSAs 15-16

In GSA 15+16, distributions of juveniles of *R.clavata* were modelled using a GLM with spatial component and fixed intercept. The spawners were best modelled using a GAM with spatial component and independent smooth effects on the covariates Latitude and Longitude. Both the intercept and the spatial component were supposed to change depending on the year. The models goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km. The persistence was obtained as the rate of years in which a point was a hot spot.

GSA 17

No modeling has been attempt for the thornback ray in GSA 17 due to lack of additional data.

GSAs 20, 22-23

Generalized Additive Models were employed to model the distribution of spawners of thornback ray in each Greek GSA (GSA 20 and GSA 22_23). The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots.

The period analysed was from 1996-2008 and from 1998-2008 for GSA 20 and GSAs 22_23, respectively. The depth distribution of thornback ray spawners was found to range between 40 - 650 m and 40 - 750 m in GSA20 and GSAs 22_23, respectively.

The numbers of recruits caught were very low to allow modeling.

GSA 25

Due to the occasional catches, modeling has not been attempted for thornback ray in GSA 25.

Table 2.2.5.5.4. Modeling applied in EU GSAs for mapping thornback ray. CV=Cross Validation Index

Life stage	GSA	Depth range (m)	Period	Model type	Covariates	% Deviance explained	Goodness of fit (R^2)
Recruits	11	10-600	1994-2010	Gaussian GAM	Depth	9.48	0.05
				Binomial GAM	Depth	22.24	0.19
				Ordinary Kriging			
Spawners	11	10-400	2001, 2004, 2007, 2010	Ordinary Kriging			
Recruits	15-16	70-650		GLM with spatial component			CV=1.558 0.395
Spawners	15-16	70-650		GAM with spatial component	Year, Latitude, Longitude		CV=1.117 0.342
Spawners	20	40-650	1998-2008	GAM(delta ognormal)	Year, (Lon, Lat), pth	41.8	0.28
Spawners	22_233	40-750	1996-2008	GAM(delta ognormal)	Year, (Lon, Lat), pth	38.3	0.33

2.2.5.5.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.5.5 summarizes the main environmental features of the most persistent areas identified for thornback ray in European GSAs. Details can be seen at http://mareaproject.net/mediseh/viewer/med.html.

GSA 11

High concentration of juveniles is mainly found in the north-western (GSA11_N1) and north eastern coasts (GSA11_N2) of the island at depth of 100-300 m, where a higher level of persistence (40-60%) was estimated. Three main hot spots of spawning aggregations are found in the western and north eastern coasts of the Island (level of persistence of 40-60%, Fig 2.2.5.5.1) at depths between 100 and 300 m where the Biocenosis of *Leptometra phalangium* are typically found. The spawning aggregation GSA11_S3 is partially overlapping with the nursery GSA11_N2 (Fig 2.2.5.5.1).

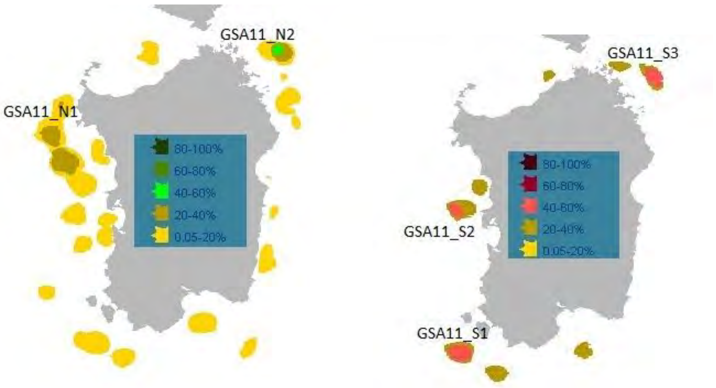


Fig 2.2.5.5.1. Position of persistent nursery (left) and spawning areas (right) of thornback ray in GSA11

GSAs 15-16

The modeling of spatial distribution of juveniles and spawners of *Raja clavata* in the Strait of Sicily has shown spatial coincidence of persistent nursery and spawning grounds. Both life stages prefer muddy substrates up to a depth of 125 m on the Adventure Bank (GSA15+16_N1 and GSA15+16_S1) and at depth between 250 m and 275 m to the southeast of Linosa Island (GSA15+16_N2 and GSA15+16_S2) and to the northwest of Maltese Islands (GSA15+16_N3 and GSA15+16_S3, see Fig 2.2.5.5.2). In the Sicilian-Maltese platform, the location of the persistent hotspots seems to be the southwest edge of the two Banks where upwelling events may occur, linked to the westward flow of the Levantine Intermediate Water, bringing deep water onto the shelf. Instead, no occurrence of *Raja clavata* has been observed in the shelf area along the south Sicilian coast.

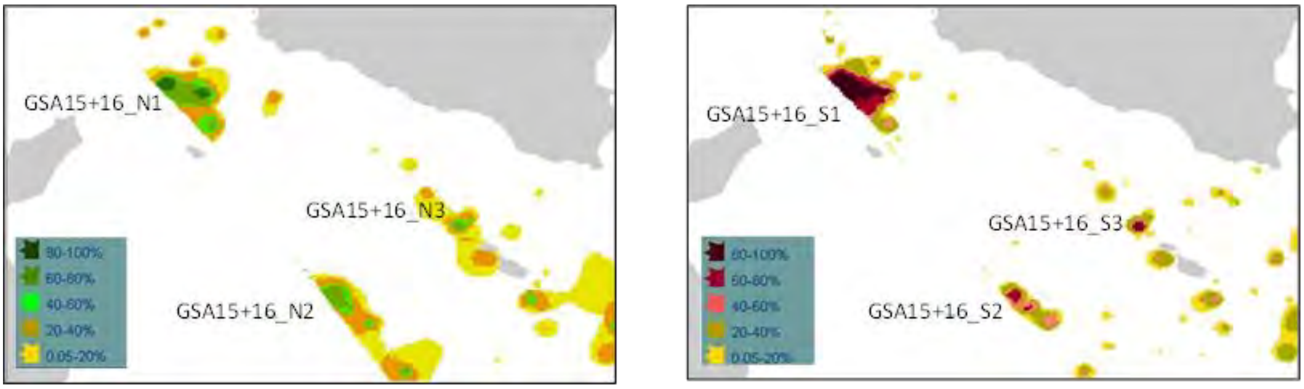


Fig. 2.2.5.5.2. Position of persistent nursery (left) and spawning areas (right) of thornback ray in GSAs15-16

GSAs 20, 22, 23

Thornback ray has a wide distribution all over the Greek Seas. Spawners of the species were captured in a very wide depth range (40-750m). However our analysis showed that the higher abundances were found up to 400m in both the Ionian and Aegean Sea. The sporadic character of captures of recruits did not allow any modeling to be performed hence the only available distribution maps are annual bubble plot maps.

The density maps revealed that thornback ray spawners have a wide distribution pattern, mainly located in the central Aegean, especially in the Cyclades island complex (Fig 2.2.5.5.3). To some lesser extent several other persistent locations were identified in the Aegean, although the species was captured to a minor extent in the northernmost and southernmost parts of the Aegean. In the Ionian, less persistent locations of elevated abundance of spawners of thornback ray were identified (Fig 2.2.5.5.3).

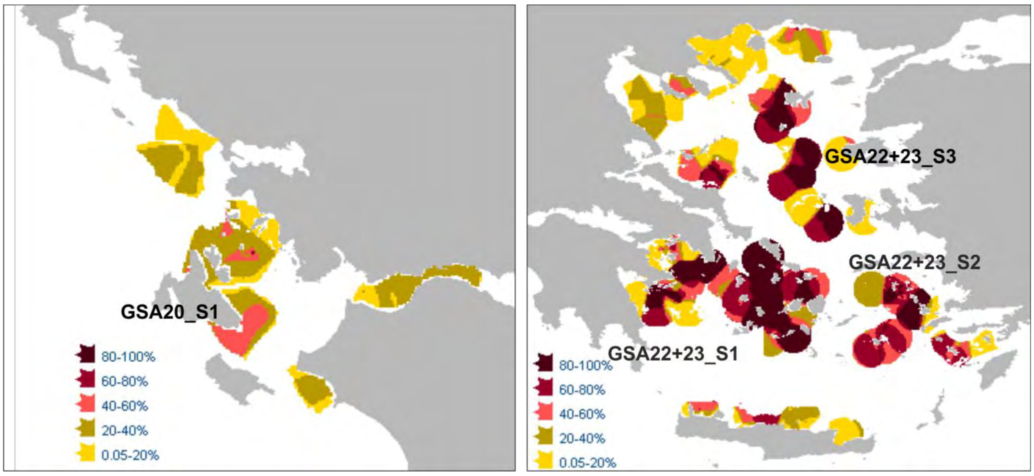


Fig 2.2.5.5.3. Position of persistent spawning areas of *Raja clavata* in GSA 20 (left) and in GSA 22_23 (right).

Table 2.2.5.5.5. Environmental characteristics of nurseries and spawning grounds of thornback ray

GSA	**Type of area**	**Code**	**Depth range (m)**	**Description (few lines of text)**
11	nursery	GSA11_N1	100-300	The biocenosis of the crinoid *Leptometra phalangium*
11	nursery	GSA11_N2	100-300	The biocenosis of the crinoid *Leptometra phalangium*
11	spawning	GSA11_S1	100-300	Biocenosis of *Leptometra phalangium*
11	spawning	GSA11_S2	100-300	Biocenosis of *Leptometra phalangium*
11	spawning	GSA11_S3	100-300	Biocenosis of *Leptometra phalangium*
15+16	nursery	GSA15+16_N1	75-125	Muddy bottom. The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the extension of upwelling over the shelf and the temperature regime of surface waters. Moreover, upwelling events may occur, linked to the westward flow of the Levantine Intermediate Water, bringing deep water onto the shelf. The mean value of SST observed in late spring-early summer is 22.2 °C.
15+16	nursery	GSA15+16_N2	250-275	Bathyal muds. The area is located in the proximity of Linosa island. This area is under the dominant influx of the two major water masses, ATC (Atlantic Tunisian Current) and LIW (Levantine Intermediate Water), flowing along the Tunisian side of the Strait of Sicily. The mean value of SST observed in late spring-early summer is 23 °C.
15+16	nursery	GSA15+16_N3	265-275	Bathyal muds. The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the temperature regime of surface waters. Moreover, upwelling events may occur, linked to the westward flow of the Levantine Intermediate Water,

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
				bringing deep water onto the shelf. The mean value of SST observed in late spring-early summer is 22.9 °C.
15+16	spawning	GSA15+16_S1	75-125	Muddy bottom. The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the extension of upwelling over the shelf and the temperature regime of surface waters. Moreover, upwelling events may occur, linked to the westward flow of the Levantine Intermediate Water, bringing deep water onto the shelf. The mean value of SST observed in late spring-early summer is 22.2 °C.
15+16	spawning	GSA15+16_S2	255-275	Bathyal muds. The area is located in the proximity of Linosa island. This area is under the dominant influx of the two major water masses, ATC (Atlantic Tunisian Current) and LIW (Levantine Intermediate Water), flowing along the Tunisian side of the Strait of Sicily. The mean value of SST observed in late spring-early summer is 23 °C.
15+16	spawning	GSA15+16_S3	265-275	Bathyal muds. The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the temperature regime of surface waters. Moreover, upwelling events may occur, linked to the westward flow of the Levantine Intermediate Water, bringing deep water onto the shelf. The mean value of SST observed in late spring-early summer is 22.9 °C.
20	Adults aggregation	GSA20_S1	50-200	Relatively shallow waters in the southern part of Kefallonia Island (Ionian Sea). Main sediment type is mud.
22_23	Adults aggregation	GSA22-23_S1	200-400	Relatively deep waters of the central Aegean (mainly around the Cyclades Island complex). Areas largely affected by strong winds. Main sediment is mud.
22_23	Adults aggregation	GSA22-23_S2	200-400	Relatively deep waters in southeastern Aegean Sea. The areas is affected by north-moving Levantine-origin. Main sediment type is mud.
22_23	Adults aggregation	GSA22-23_S2	50-200	Relatively deep waters in the northeastern Aegean Sea. The oceanographic circulation is largely affecting this area. Main sediment type is mud.

2.2.5.5.4 Gaps in knowledge and future actions

There is a lack of age and growth studies for this species in the Mediterranean. Published data on length at first maturity presents a high spatial variability and also information on spawning/recruitment periods are scattered. Due to the scarce occurrence and abundance of this species in GSAs 7, 8 and 9, a great sampling effort would be necessary to have sufficient catches to model the distribution of recruits and spawners and identify their essential fish habitats. This kind of knowledge could be gathered both within the Data Collection Framework and through tagging monitoring programs. The biology of the species has been poorly studied in the Greek GSAs, hence the spawning season is largely unknown and not well covered by the MEDITS survey. For this reason, findings on hot spot spawning areas should be considered as indicative and by no means representative of the real situation. It seems also that the timing of the survey (June) does not allow for captures of thornback ray recruits, hence juvenile hot-spot areas could not be identified. In GSAs 17 and 25 there is no information on the distribution of spawning and recruitment areas of the species.

2.2.5.6 Galeus melastomus

2.2.5.6.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

Information on recruits of the blackmouth catshark in the GSAs 1, 5, 6, in the GSA 7,8,9 as well as in the Greek GSAs is lacking.

In the Strait of Sicily (GSA 15+16), blackmouth catshark recruits to fishing grounds throughout the year.

In GSA10 and GSA18 recruits of *G. melastomus* seem more present in late autumn, along the upper slope.

In GSA11 there aren't past information on the recruitment of *G.melastomus*.

In GSA19 the blackmouth catshark was collected at depth ranging from 140 to 1500 m. The minimum and maximum sizes of *G. melastomus* were 85 and 620 mm TL. The blackmouth catshark is oviparous and iteroparous. No nurseries were detected for *G. melastomus* in the North-Western Ionian Sea.

Spawning

In the western Mediterranean (GSA 1-6, 5), its reproduction takes place all year round and its size at first maturity is 44 and 49 cm of total length for males and females, respectively (Rey *et al.,* 2005).

In GSA9 the main reproductive peak occurs in spring-summer while in autumn takes place a secondary one; females reach sexual maturity at 35-48 cm of total length. The available information for GSA7 indicates a length at maturity for females from 38 to 50 cm TL.

In GSA10 the distribution of the adults is tipically on the slope and spawning period occurs mainly in Spring-Summer. Males reach sexual maturity between 34-45 cm TL and females between 38-45. No maturity ogive is available.

In the Strait of Sicily (GSAs 15-16) the species shows a continuous reproductive cycle with peaks reported in late spring-summer. The length at 50% of sexual maturity (Lm50%) and corresponding maturity range (Lm25% - Lm75%) are 433 (423-443) mm and 380 (366-394) mm, for females and males respectively.

In GSA18 the distribution of the adults is tipically on the slope and spawning period occurs in Spring-Summer. According to the data obtained from DCF in 2009, the proportion of mature females by length class gave an estimate of maturity ogive which indicates a $L_{50\%}$ of about 49.7 cm (±0.4 cm; MR=2.9±0.59) a value similar to that of DCF in 2010 ($L_{50\%}$= 47.9 ± 0.37; MR= 2.32 ± 0.45) when the estimate was obtained using a GLM.

In the GSA19 adults of *G. melastomus* were generally collected on the slope. Reproduction occurred throughout the year and the smallest mature female and male of blackmouth catshark were 225 and 165 mm TL, respectively. The size at first maturation estimated for females was 459 mm TL. No spawning areas were detected for *G. melastomus* in the North-Western Ionian Sea, however an important refuge area for adults specimens was detected southern Santa Maria di Leuca (D'Onghia et al., 2012).

In GSA 22 23 smaller specimens (100-280mm) of *G. melastomus* are found mainly in the depth zone 300-500m while larger ones (>340mm) mostly in deeper waters (>500m). The presence of mature females is mainly recorded in summer. In GSA10 the distribution of the adults on the slope, spawning period occurs mainly in Spring-Summer. Males reach sexual maturity between 34-45 cm TL and females between 38-45. No maturity ogive is available.

2.2.5.6.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.6.1 and 2.2.5.6.2 list the frequency of positive hauls and the number of blackmouth catshark specimens caught during MEDITS in each GSA. Recruitment and maturity sizer are indicated in Table 2.2.5.6.3.

GSAs 1-6, 5

Following the protocol developed in the R_RSI_MEDISEH script, we applied the Bhattacharya's method to extract the first modal component of the length-frequency distribution of *G. melastomus*, on a yearly basis. The mean length of the first modal component plus the standard deviation was applied as a threshold value of total length. This threshold and the swept area of each haul were used to calculate the standardized abundance index of recruits (n/km^2). If differences in the length frequencies between GSAs were observed, the method was applied separately in each GSA.

The spawning fractions of females were extracted by means of the length at first maturity (L_{50} or length at which 50% of the individuals are mature) obtained from published literature.

GSAs 7, 8, 9

In GSA7 *G. melastomus* was caught between 12 and 19% of the hauls, in the different years. In GSA8 the species showed higher occurrence: the frequency of positive hauls ranged between 0.45 to 0.57, while in GSA9 it varied from 0.31 to 0.42. In GSA7 and GSA8 the catches of this species were rather low: they ranged from 104 to 345 specimens per year in GSA7 and from 219 to 479 individuals per year in GSA8. Higher values were registered in GSA9, between 1055 specimens in 2006 to 4606 in 2007. The study of recruits and spawners of this species from MEDITS database was possible only since 1999 because the sizes of *G. melastomus* were collected from that year onwards. Bhattacharya's method was applied to detect cut off size for recruits in GSA9, while for GSA 7 and 8 a fixed cutoff size was adopted, of 180 and 210 mm, respectively.

Spawners were identified using the female cutoff size of 450 mm TL in the three GSAs.

GSAs 10, 11, 18, 19

The frequency of positive hauls for *G. melastomus* in GSA10 ranges between 0.33 (MEDITS 2002) and 0.51 (MEDITS 1999), with an overall catch fluctuating from a minimum of 476 (MEDITS 2002) and a maximum of 2799 (MEDITS 2010) sampled specimens. The frequency of positive hauls for *G. melastomus* in GSA11 ranges between 0 (MEDITS 1997 and 1998) and 0.34 (MEDITS 2008), with a maximum overall catch of 1077 (MEDITS 1999) sampled specimens. The frequency of positive hauls for *G. melastomus* in GSA18 ranges between 0 (MEDITS 2003) and 0.26 (MEDITS 1999), with a maximum overall catch of 1107 (MEDITS 1999) sampled specimens. The number of *G. melastomus* specimens collected in the GSA19 fluctuated between 212 (MEDITS 2002) and 943 (MEDITS 2003). Thus, the frequency of positive hauls for the blackmouth catshark oscillated between 0.32 and 0.46.

GSA 15-16

In the Strait of Sicily, *G.melastomus* occurs exclusively on the upper slope (200-800 m) where it is quite widespread (caught in the 42%-47% of the total hauls each year) and abundant (a total of 1050-3988 specimens caught each year). The identification of 0-group in annual LFDs was difficult due to the presence of 2-4 modes highly overlapped, hence the mean length of specimens at maturity stage "1" (all the years combined) was used as cut-off size (285 mm TL) to estimate the juvenile fraction of the population. Female specimens with maturity stage “3” (MEDITS maturity scale) were selected to estimate the spawning fraction of the population. Their annual mean size ranged from 441 to 487 mm TL.

GSA 17

GSA 17 MEDITS data are available for the period 2002-2010. The period 1994-2001 has been excluded from the analyses because data of the eastern side of the basin were not available. Blackmouth catshark is sporadically caught in the few deep hauls carried out during MEDITS, with usually less than 2% of positive hauls and an average of less than 25 specimens collected each year. A fixed threshold sizes of 28 and 38 cm has been utilized respectively to identify recruits and spawners (Relini et al., 1999).

GSAs 20, 22, 23

The data for blackmouth catshark used in the present work were obtained from the MEDITS survey. The available data for blackmouth catshark that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 the proportion of positive hauls ranged from 16-28%, while in GSAs 22_23 it ranged from 1-27 and (Table 2.5.6.1), with fluctuating catches in each GSA. Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (LM) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates following the aforementioned approaches, threshold values were established based on literature information and expert knowledge

GSA 25

GSA 25 MEDITS data are available for the period 2005-2010. Blackmouth catshark is sporadic with usually less than 15% of positive hauls and an average of 20 specimens collected each year. Given the low abundance of blackmouth catshark, recruits and spawners threshold sizes have been derived from the data of GSAs 22-23.

Table 2.2.5.6.1. Frequency of positive MEDITS hauls (n of positive hauls/total number of hauls) for blackmouth catshark by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994					--	0.02		--	0.00					
1995					--	0.03		--	0.32					
1996					--	0.01		--	0.46					0.12
1997					--	0.00		--	0.41					0.01
1998					--	0.00		--	0.39	0.19				0.16
1999		0.17	0.52	0.35	0.51	0.32		0.26	0.45	0.22				0.27
2000		0.16	0.50	0.36	0.38	0.28		0.22	0.46	0.16		0.32		0.24
2001		0.18	0.50	0.41	0.46	0.33		0.23	0.39	0.19		0.31		0.23
2002		0.15		0.31	0.33	0.30	0.01	0.19	0.34			0.27		
2003		0.16	0.57	0.31	0.39	0.31	0.02	0.00	0.41	0.16		0.27	0.43	0.19
2004		0.16	0.45	0.37	0.50	0.27	0.02	0.24	0.41	0.16		0.29	0.47	0.16
2005		0.18	0.48	0.34	0.44	0.28	0.01	0.22	0.39	0.22	0.12	0.27	0.42	0.23
2006		0.13	0.52	0.35	0.44	0.27	0.01	0.22	0.36	0.22	0.08	0.31	0.44	0.22
2007	0.30	0.16	0.55	0.42	0.49	0.29	0.01	0.20	0.40		0.08	0.33	0.46	
2008	0.28	0.19	0.56	0.40	0.46	0.34	0.01	0.17	0.44	0.28	0	0.25	0.47	0.24
2009	0.26	0.18	0.55	0.39	0.50	0.29	0.01	0.21	0.37		0.19	0.25	0.47	
2010	0.28	0.12	0.50	0.39	0.50	0.29	0.01	0.22	0.43		0.15	0.22	0.43	

Table 2.2.5.6.2. Number of specimens of blackmouth catshark caught during MEDITS by GSA and year.

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994					--	49		--	0			946		
1995					--	24		--	514			2674		
1996					--	1		--	748			4173		250
1997					--	0		--	418			4431		122
1998					--	0		--	331	153		2922		528
1999		211	243	2213	1271	1077		1107	553	248		2204		515
2000		177	294	2022	678	962		602	767	247		2199		319
2001		180	365	2928	999	1309		322	522	111		2614		414
2002		345		1990	476	1036	36	515	212			5832		
2003		247	328	1431	1063	986	32	0	943	173		4296	1050	462
2004		170	282	1543	1065	639	59	562	504	22		5513	1511	497
2005		184	322	1195	983	566	14	694	481	194		4316	1784	870
2006		218	418	1055	1055	622	3	360	263	283			2421	477
2007	2474	201	354	4606	1449	942	30	622	370			6688	3579	
2008	2856	276	479	2009	1034	863	7	566	850	416		5310	4815	832
2009	1434	154	414	1894	1472	831	1	283	437			5162	3988	
2010	972	104	219	1849	2799	1005	40	684	659			2191	2833	

Table 2.2.5.6.3. Recruitment and spawning size identification for modeling purposes.

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (TL mm)**	**Data source**	**Method used**	**Mean maturity length (TL cm) /Maturity stage**
5	2007-2010	MEDITS	Bhattacharya	192	Rey et al., 2005	Fixed threshold length (L50)	488
1	1994-2010 (excepting 2006, 2010)	MEDITS	Bhattacharya	186	Rey et al., 2005	Fixed threshold length (L50)	488
6	1994-2010 (excepting 2004)	MEDITS	Bhattacharya	201	Rey et al., 2005	Fixed threshold length (L50)	488
7	1994-2010	DCF/ MEDITS	Fixed threshold	180	DCF/ MEDITS	Fixed threshold	450
8	1994-2010	DCF/ MEDITS	Fixed threshold	210	DCF/ MEDITS	Fixed threshold	450
9	1994-2010	DCF/ MEDITS	Bhattacharya	180	DCF/ MEDITS	Fixed threshold	450
10	1999-2010	MEDITS	cut-off size calculated as mean length of individuals at maturity stage 1 in all	266	MEDITS	Maturity ogive	439

		Recruits			Spawners		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (TL mm)**	**Data source**	**Method used**	**Mean maturity length (TL cm) /Maturity stage**
			the years				
11	1994-2010	MEDITS	Fixed threshold length	250	MEDITS	MS maturity stages estimation	484
15+16	2003-2010	MEDITS	Fixed threshold	285	MEDITS	Maturity stage “3”	470
17	2002-2010	Relini et al., 1999	Fixed threshold length	280	Relini et al., 1999	Fixed threshold length (L50)	380
18	1999-2010	MEDITS	cut-off size calculated as mean length of individuals at maturity stage 1 in all the years	271	MEDITS and biological sampling	Maturity ogive	450
19	1995-2010	MEDITS	Bhattacharya	175	MEDITS	Length at maturity stage 3	495/3
20	1998-2008	MEDITS	Bhattacharya	150	MEDITS	Fixed threshold length (L50)	340
22_23	1996-2008	MEDITS	Bhattacharya	135	MEDITS	Fixed threshold length (L50)	320
25	2005-2010	MEDITS GSAs 22-23	Bhattacharya	135	MEDITS GSAs 22-23	Maturity ogives	320

Mapping of density and identification of hot spot areas

A summary of the spatial models implemented for mapping recruits and adults/spawners of blackmouth catshark is provided in Table 2.2.5.6.4. Due to the low abundance of the species no modeling has been attempted for the blackmouth catshark in GSAs 17 and 25.

GSAs 1-6, 5

The adult aggregations and recruits were modeled using GAMs. Two models were implemented independently, one for presence/absence data, and another for standardized abundances restricted to presence data only.

The final presence/absence model for recruits in GSA 5 included depth and year, whereas the final abundance restricted to presence samples model included only depth as significant factor, these models explaining 45 and 39% of the total variance, respectively. The predictions showed that recruits are predicted to be located in the entire surveyed slope (200-800 m depth) along the whole area, with the highest abundance between 300 and 450-500 m depth. In GSAs 1-6 both presence/absence and abundance models for recruits included depth, the interaction between longitude and latitude and year as factors, and explaining 33 and 36% of the total variance, respectively. The predictions showed that recruits are predicted to be located in the entire surveyed slope (300-800 m depth), with the highest abundance at 450-600 m. Presence/absence model for adult aggregations in GSAs 1-6. Presence/absence model for spawners in GSAs 1-6 included depth and the interaction between longitude and latitude, whereas the final abundance model included year, the interaction between longitude and latitude and depth as factors, these models explaining 42 and 46% of the total variance, respectively. The predictions showed that spawners are predicted to be located along the whole deeper part of the surveyed slope (600-800 m depth).

GSAs 7, 8, 9

A generalized additive model (GAM) was used to model hake recruits in GSAs 7 adding a spatial term with a spherical or exponential covariance function depending on the year. The covariates used in the GAM models were sampling year and geographical coordinates.

Hake recruits in GSA 9 were modelled using a Bayesian model with the INLA software/approach which uses a Matèrn spatial function. The prior distributions are defined through an estimation chain in which the parameters estimated in a generic year j are used to define the prior distributions for the year j+1.

GSAs 10, 11, 18, 19

In GSA10-11-18-19 annual abundance values were predicted by mean a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging was applied on real abundance values. For modelling, the R MEFH MEDISEH routine 2.0 was used. The density hot spots were found using the local G statistic.

GSAs 15-16

In GSA 15+16, juveniles of Blackmouth Catshark were modelled using a GLM with a spatial component (that included annual variability) and fixed intercept. The spawners were best modelled using a GLM with spatial component, a second order trend in Latitude and Longitude plus a linear effect on the covariate Distance from the coast. The models goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km. The persistence was obtained as the rate of years in which a point was a hot spot.

GSAs 20, 22, 23

Generalized Additive Models were employed to model the distribution of blackmouth catshark spawners in each GSA (GSA 20 and GSA 22_23). The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots. The period analysed was from 1996-2008 and the depth distribution of the spawners of the species ranged from 120 – 760 m. In GSA20 and GSAs 22_23 the numbers of recruits caught were very low to allow modeling. Similarly, in GSA 20 the number of spawners was very low to allow modeling.

Table 2.2.5.6.4. Models developed for mapping recruits and adults/spawners of blackmouth catshark in Mediterranean EU GSAs. CV=Cross Validation Index

Life stage	GSA	Depth range (m)	Period	Model type	Covariates	% dev. expl.	Goodness of fit (R^2)
Recruits	05	200-755	2007-2010	Pres./Abs.	Year, depth	45.4	0.63
				Abundance	depth	39	
Recruits	01, 06	200-820	2000-2010	Pres./Abs.	Year, (Lon, Lat), depth	26.2	0.28
				Abundance	Year, (Lon, Lat), depth	35.5	
Spawners females	01, 06	200-820	2000-2010	Pres./Abs.	(Lon, Lat), depth	41.9	0.48
				Abundance	Year, (Lon, Lat), depth	46	
Recruits	7		2003-2009	GAM	Year, Lon, Lat		0.42* CV=1.05
Recruits	9		1994-2010	Bayesian kriging (INLA)	Lon, Lat		0.84*CV=0.5
Spawners	9		1999-2010	GAM	Year, slope	0.98*	0.58*
Recruits	10	10-800	1999:2010	Gaussian GAM	Depth	19.31	0.16
				Binomial GAM	Depth	43.33	0.41
				Ordinary Kriging			
Spawners	10	10-800	1999:2010	Gaussian GAM	Depth	7.26	0.07
				Binomial GAM	Depth	61.95	0.64
				Ordinary Kriging			
Recruits	11	10-800	1999:2010	Gaussian GAM	Depth	21.78	0.17
				Binomial GAM	Depth	60.18	0.59
				Ordinary Kriging			
Spawners	11	10-800	1999:2001 2004 2006:2010	Gaussian GAM	Depth	19.19	0.15
				Binomial GAM	Depth	41.77	0.34
				Ordinary Kriging			
Recruits	15+16	200-800	2003-2010	GLM with spatial component			CV=1.028 0.642
Spawners	15+16	280-800	2003-2010	GAM with spatial component	Year, Latitude, Longitude, distance from the coast		CV=0.995 0.616
Recruits	18	200-800	1999:2002 2004:2010	Gaussian GAM	Depth	5.6	0.07
				Binomial GAM	Depth	32.26	0.32
				Ordinary Kriging			
Spawners	18	200-800	1999:2002 2004:2007 2008:2010	Gaussian GAM	Depth	1.5	0.08
				Binomial GAM	Depth	41.16	0.49
				Ordinary Kriging			
Recruits	19	200-800	1995:2010	Gaussian GAM	Depth	29.2	0.2
				Binomial GAM	Depth	8.4	0.1
				Ordinary Kriging			
Spawners	19	200-800	1995:2010	Gaussian GAM	Depth	24.3	0.2
				Binomial GAM	Depth	18.5	0.1
				Ordinary Kriging			
Spawners	22_23	120-760	1996-2008	GAM(delta - lognormal)	Year, Lon, Lat, depth	17.7	0.11

*cross validation index; ** see Annex 2

2.2.5.6.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.6.5 summarizes the main environmental features of the most persistent areas identified for blackmouth catshark in European GSAs. Details can be seen at http://mareaproject.net/mediseh/viewer/med.html.

GSA 1-6, 5

In the GSA 05, persistent hot-spots areas for recruits were detected in the northern Menorca and southern Mallorca. In the GSA 01 and 06, nursery grounds were persistently predicted in the middle of the Alboran Sea (Fig. 2.2.5.6.1). Some other areas were also predicted in the GSA 01 and 06 although the percentage of persistence was low, between 0.05 and 20%.

Persistent hotspots of density of adult aggregations were predicted in the middle of the Alboran Sea sub-basin, similarly than in the case of recruits, and in the upper slope off-shore the Castellon port and in the Northern Alboran Sea (Fig. 2.2.5.6.1). Besides the environmental characteristics (e.g. hydrograghy, bottom type), these locations correspond to areas of the western Mediterranean where the deep water bottom trawl fishery targeted to decapods crustaceans of the middle slope (mainly *Aristeus antennatus*) is not well developed. In these areas with low level of fishing impact, big concentrations of adult specimens of other species such as *Helicolenus dactylopterus* have also been described (Massutí *et al.*, 2001).

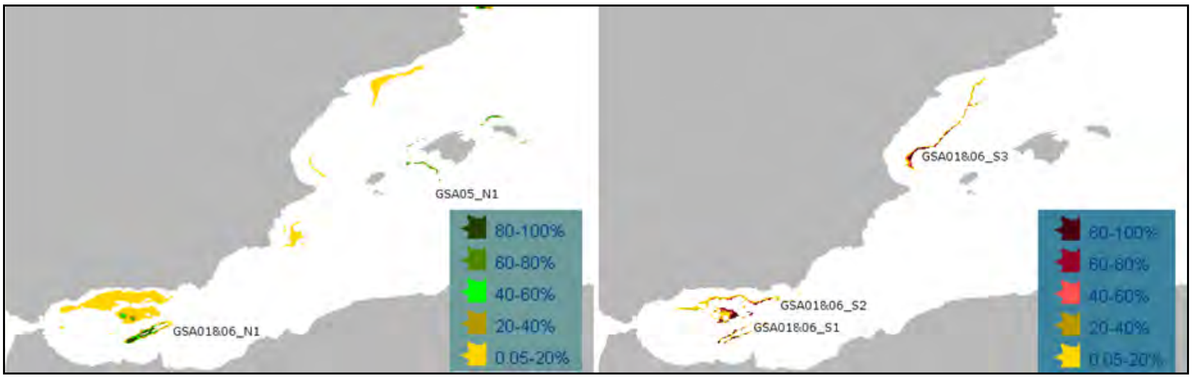


Fig. 2.2.5.6.1. Position of persistent nursery (left) and spawning areas (right) of blackmouth catshark in GSA 05, 01 and 06.

GSA 7

Two small areas with high persistency of recruits were evidenced both in the eastern and western side of the Gulf of Lions, from 200 to 400 m depth. Less persistent density hot spots of recruits were found also on the central part of the Gulf upper slope (Fig 2.2.5.6.2).

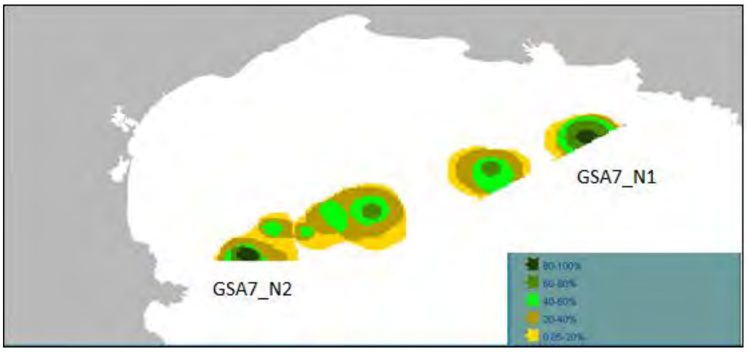


Fig 2.2.5.6.2. Position of persistent nurseries of blackmouth catshark in GSA 7

GSA 9

In the southern part of GSA9, south of Elba Island, two main high density and persistent areas of recruits were evidenced by the model. These areas are located at the beginning of the continental slope, from 300 to 500 m depth, on muddy bottoms (Fig 2.2.5.6.3).

Adult aggregations aggregate offshore the main nurseries indicating that a process of inshore spawning migration and offshore ontogenic dispersion of juveniles should occur. The main evident areas of concentrations *of G. melastomus* spawners occurred in the Ligurian Sea, in front of the northern coasts of Tuscany, on muddy bottoms between 450 to 700 m depth. Other two areas with high persistency values of adults are located south of Elba Island and off shore the Latium coasts.

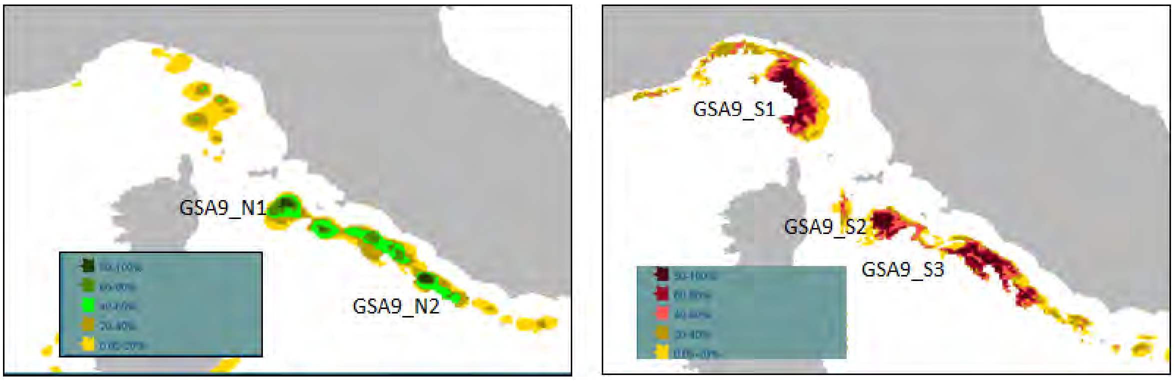


Fig 2.2.5.6.3. Position of persistent nurseries (left) and spawning areas (right) of blackmouth catshark in GSA 9

GSA 10

In the GSA10 nursey areas of *G. melastomus* were localized off Napoli Gulf (GSA10_N1, persistence 40-60%), Licosa promontory (GSA10_N2), where the highest level of persistence was observed (60-80%), off the Sant'Eufemia Gulf and along the slope off Capo Bonifati (GSA10_N3), where a wide area was estimated (Fig 2.2.5.6.4). This area was overlapping with the widest adult aggregation (GSA10_S1, persistence 80-100%) identified in the GSA10. Other remarkable adult aggregations were localized off Napoli Gulf (GSA10_S2), in partial overlapping with the nursery GSA10_N1, and off Capri island (GSA10_S3, Fig 2.2.5.6.4.). Nursery areas and adult aggregations are characterised by muddy bottoms with deep bathyal biocenosis (VP) and, depending on the site, *Gryphus vitreus* or *Isidella elongata* or *Funiculina quadrangularis* facies. The mainstream current is from south to north.

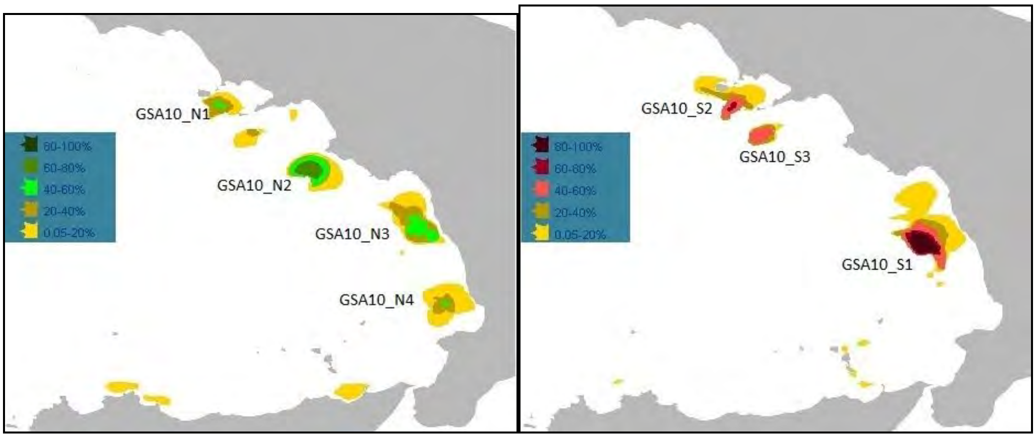


Fig 2.2.5.6.4. Position of persistent nurseries (left) and spawning areas (right) of blackmouth catshark in GSA 10

GSA 11

Nursery areas are present around all coasts of Sardinia. Greater level of persistence (60-80%) is found in the zones of juvenile's concentration of the north eastern coast at depths comprised between 300-500 m (GSA11_N1, Fig 2.2.5.6.5). These bottoms appear mainly characterized by the presence of bathyal muddy (Facies of *Funiculina quadrangularis* and Facies of *Isidella elongata*). Zones of high concentrations of mature specimens are identified both in the western and eastern coasts at depth > 500 m (level of persistence of 20-40%).

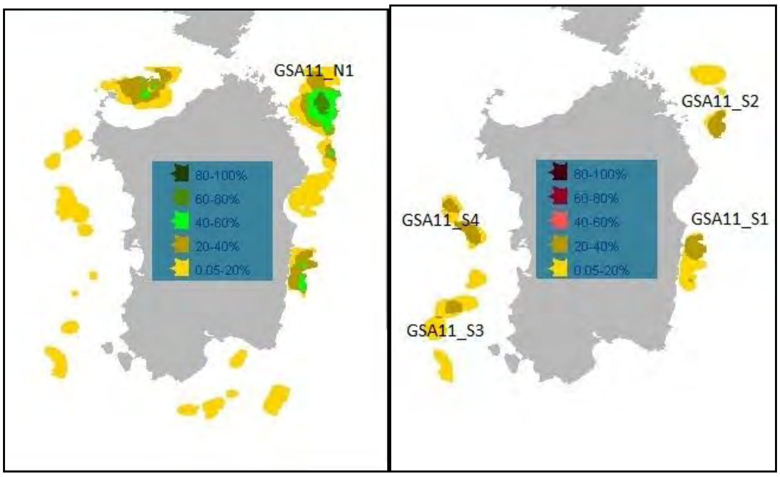


Fig 2.2.5.6.5. Position of persistent nurseries (left) and spawning areas (right) of blackmouth catshark in GSA 11

GSA 15-16

Blackmouth catshark has been prevalently caught on the muddy bottoms of the bathyal basin to the west of Malta. The basin has an average depth of 500 m, is extremely irregular, incised by many canyons and flat-bottomed deep troughs reaching depths between 1200 m and 1700 m. A persistent nursery as well as a persistent spawning area are located to the north and to the south of the Malta Graben (the deepest trough, elongated NW–SE). In the two zones, nurseries and spawning grounds are separate, being spawning areas located on deeper bottoms. Moreover, the persistent hotspots located south of the Malta Graben (GSA15+16_N2 at 450-650 m and GSA15+16_S2 at 630-720 m, Fig 2.2.5.6.6) are deeper than those in the north (GSA15+16_N1 at 340-400 m and GSA15+16_S1 at 530-730 m, Fig 2.2.5.6.6). Another persistent nursery is located to the south of Malta at 560-570 m. However, the lowest bathymetric limit of *G. melastomus* could not be determined using the MEDITS survey data, and no information is available for waters deeper than 800m in the Strait of Sicily.

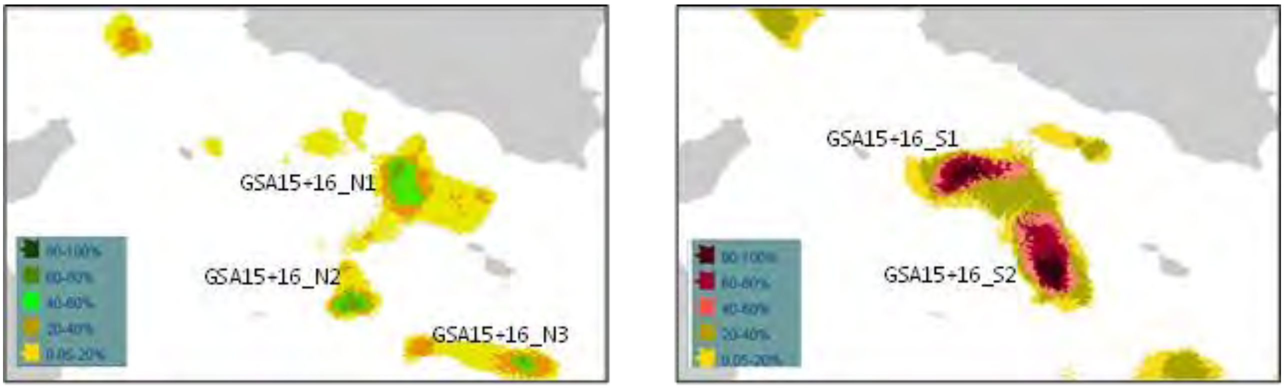


Fig 2.2.5.6.6. Position of persistent nurseries (left) and spawning areas (right) of blackmouth catshark in GSAs 15-16

GSA 18

In the GSA18 both nursey and adult aggregations of *G. melastomus* are localized along the border of the South Adriatic pit (GSA18_N1 and GSA18_S1 and GSA18_S2) in the Otranto Channel, respectively along the east and west border (Fig 2.2.5.6.7). A remarkable persistence of 40-60% is observed for both life stages in these areas. Nursery areas and adult aggregations are characterised by muddy bottoms with deep bathyal biocenosis (VP) and *Gryphus vitreus* or *Isidella elongata* facies. The mainstream current is from south to north for the main nurseries and from north to south for the main adult aggregation (GSA18_S1 and GSA18_S2).

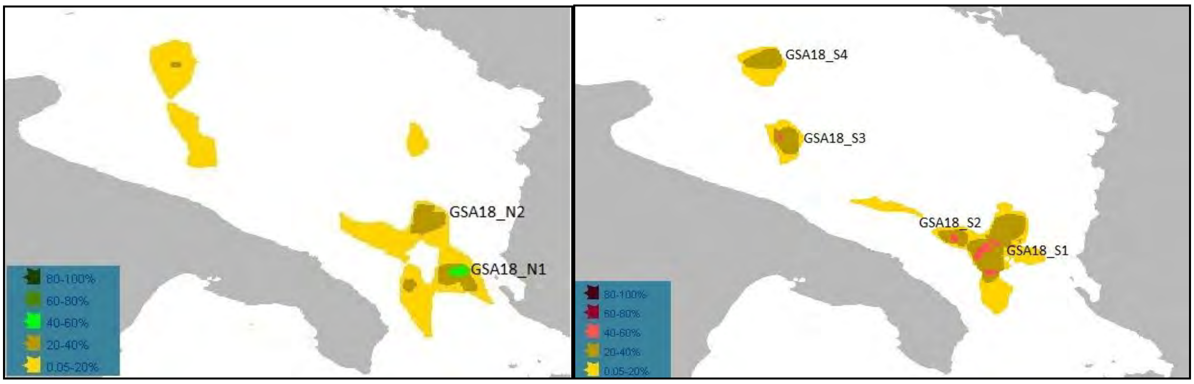


Fig 2.2.5.6.7. Position of persistent nurseries (left) and spawning areas (right) of blackmouth catshark in GSA 18

GSA 19

The more persistent nursery areas for the blackmouth catshark in GSA19 were observed on the shelf break eastern of Santa Maria di Leuca (GSA19_N1) as well as on the upper slope offshore Gallipoli (GSA19_N2) and Punta Stilo (GSA19_N3, Fig 2.2.5.6.8). A partial overlapping between nursery and spawning areas was detected for *G. melastomus* in the GSA19. In fact, the more persistent aggregations of *G. melastomus* spawners exist eastern Santa Maria di Leuca (GSA19_S1), offshore Crotone (GSA19_S3) and at Punta Stilo (GSA19_S3, Fig 2.2.5.6.8).

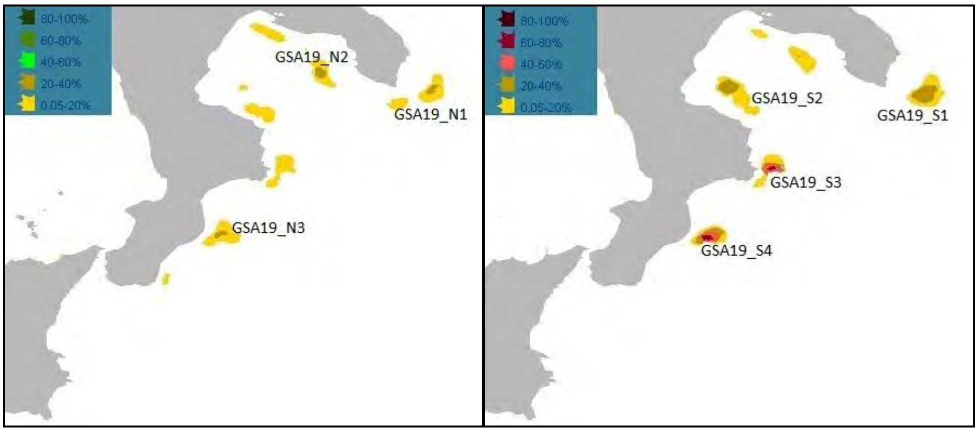


Fig 2.2.5.6.8. Position of persistent nurseries (left) and spawning areas (right) of blackmouth catshark in GSA 19

GSAs 22-23

Blackmouth catshark was captured in depth ranges from ~100-760m in the Greek Seas. Our analysis however demonstrated that the higher abundances of blackmouth catshark spawners in the Aegean Sea was in depths >400m (and up to 760m). Spawners of the species were also captured in the Ionian Sea, however the local distribution of the captures combined with the low numbers did not allow for any modeling. In the few instances that recruits of the species were captured these were distributed in depths that exceeded 250m in the Aegean and 350 in the Ionian Sea. Hence the only available distribution maps are annual bubble plot maps.

The density maps revealed that blackmouth catshark adults were found mainly in the southeast part of the Aegean Sea, mainly in the Dodecanese island complex. This could be linked to the specific topographic and bathymetric conditions of the Aegean Sea which is characterized by a complex bathymetry, the existence of numerous islands and the presence of a narrow continental shelf (with the exception of its north-eastern part). It is likely that the presence of spawners in the Dodecanese region is related to the general large-scale water circulation pattern of the Aegean Sea which brings warmer and more saline waters of Levantine origin in this region. This may create conditions favoring spawning activities.

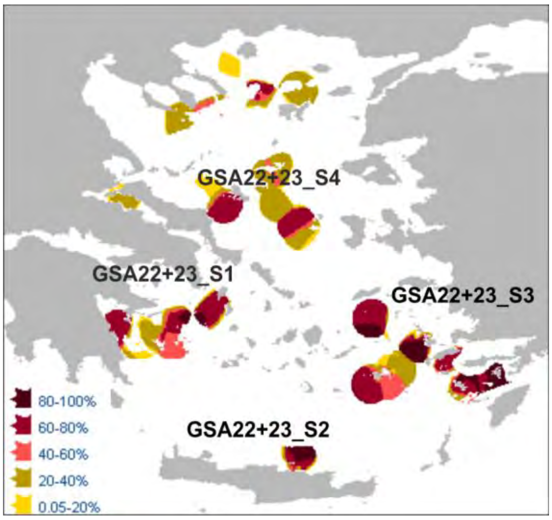


Fig 2.2.5.6.9. Position of persistent spawning areas of blackmouth catshark in GSA 19

Table 2.2.5.6.5. Main environmental features of the most persistent areas identified for blackmouth catshark in European GSAs.

GSA	Type of area	Code	Depth range (m)	Description
05	nursery	GSA05_N1	300-500	Balearic Islands Upper slope
01	nursery	GSA01 and 06_N1	300-500	Alboran Sea Upper slope
01	adults aggregation	GSA01 and 06_S1	500-800	Alboran Sea Middle slope
01	adults aggregation	GSA01 and 06_S2	500-800	Northern Alboran Sea Middle slope
7	nursery	GSA7_N1	360-700	Upper slope on the eastern sector of the Gulf of Lions. Canyon heads
7	nursery	GSA7_N2	280-520	Upper slope on the western sector of the Gulf of Lions. Canyon heads
9	nursery	GSA9_N1	320-500	Upper slope of the Tuscany shelf, south of Elba Island. The area is interested by the flowing of the Levantine current. A large cyclonic gyre, producing upwelling, occurs offshore Bonifacio

GSA	Type of area	Code	Depth range (m)	Description
9	nursery	GSA9_N2	300-600	Upper slope off the Latium coasts, south to Fiumicino harbour.
9	adults aggregation	GSA9_S1	450-700	Middle slope off North Tuscany. Muddy bottoms. The area is interested by the flowing of the Levantine current.
9	adults aggregation	GSA9_S2	300-600	Middle slope of the Tuscany shelf, south of Elba Island. The area is interested by the flowing of the Levantine current. A large cyclonic gyre, producing upwelling, occurs offshore Bonifacio
9	adults aggregation	GSA9_S2	500-700	Middle slope off the Latium coasts. Muddy bottoms. The area is interested by the flowing of the Levantine current.
10	nursery	GSA10_N1	123-791	The bottom is muddy with deep bathyal biocenosis (VP) and Gryphus vitreus facies with associated species as *Macropipus tuberculatus, Polycheles typhlops, Geryon longipes Anamathia rissoana Echinus spp* etc. The mainstream of the current direction is from south to north.
10	nursery	GSA10_N2	113-798	The bottom is muddy with deep mud biocenosis (VP) and Isidella elongata facies with associated species as *Polycheles typhlops, Geryon longipes, Anamathia rissoana Echinus spp* etc. The mainstream of the current direction is from south to north.
10	nursery	GSA10_N3	36-778	The bottom is muddy with deep mud biocenosis (VP) and Gryphus vitreus facies with associated species as *Macropipus tuberculatus, Polycheles typhlops, Geryon longipes, Echinus spp* etc. The mainstream of the current direction is from south to north.
10	nursery	GSA10_N4	384-740	The bottom is muddy with deep mud biocenosis (VP) inhabited from the shallower facies of Funiculina quadrangularis (along the slope) with associated species as *Munida intermedia, Macropipus tuberculatus Echinus melo and deepest facies of Isidella elongata* (bathial) with associated species as *Polycheles typhlops, Geryon longipes, Bathynectes maravigna* etc. The mainstream of the current direction is from south to north.
10	adults aggregation	GSA10_S1	328-651	The bottom is muddy with deep mud biocenosis (VP) and Isidella elongata facies with associated species as *Polycheles typhlops, Geryon longipes, Echinus spp etc*. The mainstream of the current direction is from south to north.
10	adults aggregation	GSA10_S2	410-645	The bottom is muddy with deep mud biocenosis (VP) and Gryphus vitreus facies with associated species as *Macropipus tuberculatus, Polycheles typhlops, Geryon longipes Anamathia rissoana Echinus spp* etc. The mainstream of the current direction is from south to north.
10	adults aggregation	GSA10_S3	564-664	The bottom is muddy with deep mud biocenosis (VP) and Gryphus vitreus facies with associated species as *Macropipus tuberculatus, Polycheles typhlops, Geryon longipes Anamathia rissoana Echinus spp* etc. The mainstream of the current direction is from south to north.

GSA	Type of area	Code	Depth range (m)	Description
11	nursery	GSA11_N1	300-500	These bottoms appear mainly characterized by the presence of bathyal muddy (facies of Funiculina quadrangularis and facies of Isidella elongata)
11	adults aggregation	GSA11_S1	500-700	Bathyal muddy bottoms
11	adults aggregation	GSA11_S2	500-700	Bathyal muddy bottoms
11	adults aggregation	GSA11_S3	500-700	Bathyal muddy bottoms
11	adults aggregation	GSA11_S4	500-700	Bathyal muddy bottoms
15+16	nursery	GSA15+16_N1	340-400	Bathyal muds. This area is under the dominant influx of two major water masses, the superficial inflow of the Atlantic Ionian Stream (AIS) (up to 100m depth) and the deep counterflow of the Levantine Intermediate Water (LIW) (core depth between about 200 m and 600 m) bringing salty and warm waters.
15+16	nursery	GSA15+16_N2	450-650	Bathyal muds. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74-38.75 % and temperature 14.0-14.18 °C.
15+16	nursery	GSA15+16_N3	560-570	Bathyal muds, facies with Isidella elongata. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
15+16	spawning	GSA15+16_S1	530-730	Bathyal muds, facies with Isidella elongata. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C
15+16	adults aggregation	GSA15+16_S2	630-720	Bathyal muds, facies with Isidella elongata. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
18	nursery	GSA18_N1	504-550	The bottom is muddy with deep mud biocenosis (VP) with characteristic species as *Macropipus tuberculatus, Munida intermedia, Polycheles typhlops, Geryon longipes, Homola barbata* etc. The mainstream current is from south to north.
18	nursery	GSA18_N2	500-570	The bottom is muddy with deep mud biocenosis (VP) and Isidella elongata facies with associated species as Polycheles typhlops, Geryon longipes, Bathynectes maravigna Anamathia rissoana etc. The mainstream current is from south to north.

GSA	Type of area	Code	Depth range (m)	Description
18	adults aggregation	GSA18_S1	323-575	The bottom is muddy with deep mud biocenosis (VP) and Isidella elongata facies with associated species as *Polycheles typhlops, Geryon longipes, Bathynectes maravigna Echinus spp* etc. The mainstream current is from north to south.
18	adults aggregation	GSA18_S2	521-575	The bottom is muddy with deep mud biocenosis (VP) and Isidella elongata facies with associated species as *Polycheles typhlops, Geryon longipes, Bathynectes maravigna Echinus spp* etc. The mainstream current is from north to south.
18	adults aggregation	GSA18_S3	398-558	The bottom is muddy with deep bathyal biocenosis (VP) and Gryphus vitreus facies with associated species as Macropipus tuberculatus, Cidaris cidaris, Geryon longipes, Echinus spp Poecillastra compressa etc. The mainstream current is from north to south.
18	adults aggregation	GSA18_S4	519-588	The bottom is muddy with deep mud biocenosis (VP) with characteristic species as Macropipus tuberculatus, Echinus spp, Polycheles typhlops, Geryon longipes, Argobuccinum olearium etc. The mainstream current is from north to south.
19	nursery	GSA19_N1	140-176	The shelf break eastern Santa Maria di Leuca was characterized by the biocenosis of the terrigenous mud and shelf-edge detritic.
19	nursery	GSA19_N2	249-463	The shelf break-upper slope offshore Gallipoli, were characterized by the biocenosis of the muddy detritic bottoms, terrigenous mud and shelf-edge detritic.
19	nursery	GSA19_N3	501-634	The slope offshore Punta Stilo is characterized by the biocenosis of the bathyal muds.
19	adults aggregation	GSA19_S1	140-176	The shelf break eastern Santa Maria di Leuca was characterized by the biocenosis of the terrigeneous mud and shelf-edge detritic.
19	adults aggregation	GSA19_S2	329-610	The slope eastern the Amendolara characterized by the biocenosis of the bathyal muds.
19	adults aggregation	GSA19_S3	502-779	The slope offshore Crotone characterized by the biocenosis of the bathyal muds.
19	adults aggregation	GSA19_S4	501-634	The slope offshore Punta Stilo was characterized by the biocenosis of the bathyal muds.
22_23	adults aggregation	GSA22-23_S1	250-500	West-central Aegean Sea. Deep waters with mud substrates. No other environmental information is available for the area
22_23	adults aggregation	GSA22-23_S2	150-400	Deep areas of the Cretan shelf (south Aegean). Main sediment type: mud. Additional environmental characteristics are unavailable.
22_23	adults aggregation	GSA22-23_S3	200-400	North-east Aegean Sea. Direct influence of the Levantine waters (increased salinity). Main sediment type is mud.
22_23	adults aggregation	GSA22-23_S4	150-450	South-east Aegean Sea (Dodecanese complex). Relatively deep, saline (Levantine-origin) waters. Main sediment type is mud.

2.2.5.6.4 Gaps in knowledge and future actions

In GSA 1-6, 5 In the north-western Mediterranean *Galeus melastomus* is distributed between 100 and 1800 m depth (Moranta, 2007), and its main fraction of the adult population is found below 800 m depth (Stefanescu *et al.*, 1992), the maximum depth prospected during the MEDITS survey. Thus, the results for spawners should be taken with care. To our knowledge, there is no published information on the age and growth of this species in the Mediterranean. In GSA 7, 8, 9 there is a poor knowledge about the recruitment processes. Spawning areas also cannot be identified due to the low number of mature specimens caught that did not allow implementing spatial models. Furthermore, the collection of maturity data during MEDITS has started in recent years. Considering that this species lays down benthic eggs the spawning areas should spatially overlap with recruitment areas, that is what has been observed in GSAs 10, 11 18 and 19, where modelling processes could be accomplished, though further knowledge are needed to better understand recruitment and spawning patterns. There is no knowledge for the blackmouth catshark spawning in GSAs 17 and 25. In Greek GSAs a major knowledge gap regards the biology of the species, which is poorly known in GSAs 20, 22 and 23. The existing information is scarce, based on sporadically collected data in the framework of projects addressing other issues. Therefore, it is unknown to what extent the MEDITS survey covers the species spawning season and findings on spawning hot spots should be faced with cautious. Nursery areas could not be identified as the timing of the MEDITS survey (June) does not allow for captures of blackmouth catshark recruits.

2.2.5.7 Aristaeomorpha foliacea

2.2.5.7.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. Below the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

In GSA10 juveniles of *A. foliacea* were mainly concentrated off southern Campania and Calabria coasts on the border of bathyal bottoms, as evidenced also by the approach of spatial indicators (Bitetto et al., 2012). More persistent nurseries were located off Cape Scalea and Cape Suvero. Nurseries had a density threshold from 2000 to 5500 N/km^2 (AA.VV., 2008) Recruitment follows a discrete pattern with peak in May (Spedicato et al., 1998; 1999a). Recruits of giant red shrimp mainly occur at depth between 450 and 550 m. Recruitment size ranges between 27 mm and 34 mm. In GSA11 the minimum size at capture is about 20 mm CL. Recruits can be found mainly in spring with a peak in March, at depths between 500 and 550 m (AA.VV., 2008). The minimum size of recruit was 7.6 and 7.3 for males and females respectively.

Recruitment of giant red shrimp in the Strait of Sicily (GSAs 15-16) is discrete and occurs in spring with a peak in summer. Recruits (CL < 30 mm) are widely distributed over the bathyal grounds (500–700 m) of the central area of the Strait of Sicily with two areas of stability to the west/northwest of the Maltese Islands.

The entrance of the recruits of giant red shrimp in the fishery of this species in the E. Ionian Sea (GSA 20) seems to take part mainly in spring and summer and temporally coincides to the recruitment period in other Mediterranean areas. The length range and the depth range of recruits in the Eastern Ionian Sea are also similar to those found in other Mediterranean areas.

In GSA18 nuclei of higher abundance of *A. foliacea* juveniles were localized off the Gargano Promontory and along the border of the South Adriatic pit. Recruitment follows a discrete pattern with peak in May. Recruits of giant red shrimp mainly occur at depth between 450 and 550 m. Recruitment size ranges between 17 mm and 29 mm.

In the GSA19 the giant red shrimp was collected from 127 to 1145 m depth. Reproduction starts from spring peaking in summer and the sizes of recruitment ranges between 18 and 27 mm CL. Different areas with aggregations of juveniles were detected for *A. foliacea* on the shelf break-upper slope between Otranto and Santa Maria di Leuca, Gallipoli and Taranto, in the Gulf of Corigliano, offshore Crotone and Punta Stilo. Only a nursery area was detected on the shelf break south-eastern the Amendolara Bank.

Spawning

In the western Mediterranean it reaches maximum densities at 450-650 m (Maurin, 1962; in Cartes *et al.,* 2011). However, there are evidences of the local extinction of the red shrimp *A. foliacea* in the northern Balearic Basin (GSA 5), except for some localities close to Eivissa Channel, at the end of the 1960s. This is probably related to changes in the temperature and salinity of its habitat, associated with reduced O_2 concentration at the core of the Levantine Intermediate Waters (Cartes *et al.*, 2011). The increase of temperature and salinity since 1957 in the LIW was parallel to a significant deepening in the shrimp's preferred depth habitat in the Balearic Basin, suggesting a search for colder and less saline waters. The metabolic expense to acclimate to these new conditions might provoke a response in *A. foliacea* in the Balearic Basin, with a decrease of density (perhaps by migration), its deepening and its near extinction.

In GSA9 the reproductive period of *A. foliacea* lasts from May to September, with a peak in summer (July-August). The average size at sexual maturity of females is at 40.59 mm CL. in the Northern Tyrrhenian Sea. The smallest female with spermatophore was observed at 40 mm CL. In the Central Tyrrhenian Sea the smallest mature female measured 28 mm CL; in the same area, it was reported a L50% for females with spermatophores of 35.54 mm CL. In the Central Tyrrhenian Sea the smallest female with spermatophore measured 33 mm CL.

In GSA10 mature females occur at deeper waters, down to 550 to 750 m depth. Peaks of mature individuals are observed in the summer season (Spedicato et al., 1998; 1999a). The maturity ogive was obtained from a maximum likelihood procedure applied grouping as mature individuals belonging to the maturity stage 2b and onwards. The fitting of the curve was fairly good, with estimates of the size at first maturity of $L_{50\%}$=35 mm ±0.23 mm (MR=3.6 mm ±0.20 mm).

In GSA11 mature females can be caught at depth from 500 to 780 m, mainly in summer from June to September. The smallest mature female captured in Sardinian seas measured 34 mm, but the size at first sexual maturity is estimated at 37-39 mm Carapace Length (CL). Males reach first sexual maturity at size of 30-32.5 mm at the end of the first five year of life.

In GSA18, mature females occur during summer in deeper waters down to 500 m depth. According to the data of DCF in 2009, the maturity parameters obtained using a maximum likelihood procedure applied grouping as mature individuals belonging to the maturity stage 2b-2e were as follows: $L_{50\%}$= 33.5 ±0.04; MR= 0.6 ±0.06. In DCF 2010 the maturity parameters obtained using a GLM approach, were as follows: $L_{m50\%}$= 39.4 ±0.4; MR= 1.66 ±0.38.

The giant red shrimp is a seasonal iteroparous with a reproductive period starting in spring and peaking in summer in the GSA19 (D'Onghia et al., 1998). The smallest mature female and male in the North-Western Ionian Sea were 20 and 13 mm CL, respectively. The size at maturity estimated in females was 44 mm CL (Carlucci et al., 2006). No spawning area has been identified up to date for *A. foliacea* in the GSA19.

The reproductive season of the giant red shrimp in GSA15+16 starts in spring and peaks in summer. The species shows a characteristic sexual dimorphism. The onset of sexual maturity occurs abruptly and in a narrow size range (28-35 mm CL) in males, whilst it takes place more gradually and over a large size range (28-62 mm CL) in females. Estimates of Lm50% for females are between 40 and 42 mm CL.

Reproduction of *A. foliacea* in GSA 20 conforms to the findings in other Mediterranean regions with regard to their major reproductive traits (i.e., reproductive period, presence of mature males throughout the year, etc.).

2.2.5.7.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.7.1 and 2.2.5.7.2 list the frequency of positive hauls and the number of giant red shrimp specimens caught during MEDITS in each GSA. Recruitment and maturity sizer are indicated in Table 2.2.5.7.3.

GSAs 1-6, 5

The proportion of positive hauls is very low in the three Spanish GSAs, varying from 0.02 to 0.06 in the GSA 05 and from 0.00 to 0.02 in the GSA 01 and 06. The amount of specimens is as well very low, ranging from 1 to 7 in the GSA 05 and from 0 to 5 in the GSA 01 and 06.

In order to extract the recruits' fraction the minimum threshold observed in the other GSAs included in the project was applied. Regarding the spawning fraction, females with maturity stage III (mature) were considered for modeling due to the lack of any other biological information or literature concerning this issue

GSAs 7, 8, 9

A. foliacea was practically absent GSA7 (it was caught in only one haul in 2000). In GSA 8 the species resulted present, but the catches were scarce: the frequency of positive hauls ranged from 0.09 to 0.25 and the number of specimens caught in the different years ranged from 28 to 152. In GSA9 the frequency of positive hauls ranged from 0.12 to 0.22; the number of specimens caught ranged from 450 to 1896.

In this area, the age 0 component was not clearly detected in the length frequency distributions from MEDITS surveys; in fact the first modal component separated by Batthacharya method had a mean size corresponding to specimens belonging to the second year of life, whereas the presence of small specimens was very scarce.

In GSA8 the spawners of *A. foliacea* were identified only in a restricted number of years, using the cutoff size of 35 mm CL. Spawners in GSA9 were identified from the values of L_{50} estimated year by year according to the maturity ogives; in the case of unreliable estimates the threshold size of 38 mm CL was adopted, corresponding to the average value of the good estimations.

GSA 10, 11, 18, 19

In GSAs 10, 11, 18 and 19, the recruits have been identified annually according to the ability of the survey to intercept the phenomenon. The threshold to separate the recruits has been generally estimated as the mean length of the first modal component + 2* sd using the Bhattacharya's method and the R_RSI MEDISEH routine, specifically developed for the Mediseh project. Only in few cases an empirical value was used. To identify the adults or potential spawners, an average of the parameters of the maturity ogive among the years from the MEDITS survey and/or from biological samplings of DCR and DCF has been used in GSAs 10 and 18, selecting those better fitting to the model. In GSA11 an $L_{m50\%}$ of 37-38 mm was set. An empirical value of 37 mm CL was adopted to separate the potential spawners of *A. foliacea* in GSA 19.

The frequency of positive hauls for *A. foliacea* in GSA10 ranges between 0.29 (MEDITS 2002) and 0.40 (MEDITS 2004), with an overall catch fluctuating from a minimum of 1163 (MEDITS 2007) and a maximum of 8229 (MEDITS 1997) sampled specimens.

The frequency of positive hauls for *A. foliacea* in GSA11 ranges between 0.13 (MEDITS 2003) and 0.24 (MEDITS 1998 and 2001), with an overall catch fluctuating from a minimum of 354 (MEDITS 2007) and a maximum of 1170 (MEDITS 1998) sampled specimens.

The frequency of positive hauls for *A. foliacea* in GSA18 ranges between 0.08 (MEDITS 1994) and 0.20 (MEDITS 2001, 2003, 2005 and 2009), with an overall catch fluctuating from a minimum of 35 (MEDITS 1995) and a maximum of 1148 (MEDITS 2009) sampled specimens.

The frequency of hauls positive to the catch of the giant red shrimp in GSA19 oscillated between 0.20 and 0.46. A minimum of 94 and a maximum of 4369 specimens of *A. foliacea* were sampled in GSA19 during MEDITS 2007 and MEDITS 2003, respectively.

GSAs 15-16

Catches of giant red shrimp, concentrated in the mesobathyal bottoms (200-800 m) of the Strait of Sicily, were abundant throughout the time series. The species occurred almost regularly in the 35% of the hauls and the total number of specimens ranged between 2686 and 6491.

The cutoff size of recruits was estimated taking the mean length of the first modal component + 1sd through the Bhattacharya approach. It ranged between 29 and 32 mm CL over the time series.

The Lm50% (37 mm CL for females) of maturity ogive obtained from biological sampling of commercial catches (DCF) was used to identify potential spawners.

GSA 17

In GSA 17 MEDITS data giant red prawn has been observed only in 2003 and 2004 in one haul with respectively 42 and 1 specimens collected. A fixed threshold sizes of 3 and 3.9 cm has been utilized respectively to identify recruits and spawners (Relini et al., 1999).

GSAs 20, 22-23

The available data for giant red shrimp that were suitable for analysis in Greek Seas extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 the proportion of positive hauls ranged from 3-9%, while in GSAs 22_23 it ranged from 4-9 and (Table 2.5.6.1). Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates following the aforementioned approaches, threshold values were established based on literature information and expert knowledge.

Table 2.2.5.7.1. Frequency of positive MEDITS hauls (n of positive hauls/total number of hauls) for giant red shrimp by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.00	0.19	0.12	0.35	0.20		0.08	0.28			0.00		
1995		0.00	0.23	0.14	0.34	0.18		0.10	0.28			0.02		
1996				0.16	0.32	0.20		0.13	0.27			0.01		0.06
1997		0.00	0.15	0.12	0.35	0.21		0.18	0.34			0.00		0.06
1998		0.00	0.22	0.18	0.38	0.24		0.15	0.36	0.06		0.00		0.08
1999		0.00	0.26	0.20	0.38	0.23		0.13	0.36	0.06		0.02		0.09
2000		0.01	0.14	0.17	0.36	0.21		0.17	0.43	0.03		0.01		0.08
2001		0.00	0.14	0.15	0.35	0.24		0.20	0.35	0.06		0.01		0.07
2002		0.00		0.13	0.29	0.18	0	0.17	0.30			0.01		
2003		0.00	0.09	0.17	0.33	0.13	0.01	0.20	0.41	0.09		0.00	0.35	0.07
2004		0.00	0.18	0.20	0.40	0.17	0.01	0.11	0.36	0.06		0.01	0.35	0.05
2005		0.00	0.09	0.19	0.37	0.18	0	0.20	0.46	0.09	0	0.02	0.36	0.05
2006		0.00		0.17	0.36	0.18	0	0.18	0.40	0.09	0.04	0.01	0.35	0.08
2007	0.06	0.00	0.25	0.14	0.34	0.14	0	0.10	0.20		0.04	0.00	0.35	
2008	0.02	0.00	0.16	0.18	0.36	0.16	0	0.11	0.37	0.09	0	0.00	0.35	0.04
2009	0.04	0.00	0.14	0.18	0.37	0.19	0	0.20	0.24		0.11	0.00	0.35	
2010	0.04	0.00	0.14	0.22	0.34	0.19	0	0.16	0.24		0	0.01	0.33	

Table 2.2.5.7.2. Number of specimens of giant red shrimp caught by GSA and year.

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0	118	450	1837	767		36	355			0		
1995		0	65	535	3066	948		35	687			5		
1996		0		802	1257	1125		353	473	253		1		48
1997		0	28	893	8229	972		417	334	643		0		178
1998		0	49	1702	3584	1170		313	186	271		0		1150
1999		0	152	1895	4613	1113		641	575	1418		4		573
2000		1	56	1862	3114	1118		665	1156			1		1833
2001		0	84	826	2920	1112		752	920	457		1		1540
2002		0		247	1555	633	0	576	1423	60		1		
2003		0	22	648	3916	392	42	896	4369	999		0	2686	1382
2004		2	127	1612	1574	744	1	517	1750	551		1	5254	701
2005		0	48	783	6578	686	0	745	1945		0	2	3773	1123
2006		0	0	513	4539	531	0	970	889	1951	1	2	3595	2604
2007	4	0	133	540	1163	354	0	169	94	253	3	0	3931	
2008	1	0	57	607	3250	443	0	323	2006	643	0	0	5060	1529
2009	3	0	60	987	3422	565	0	1148	600		5	0	6491	
2010	7	0		1896	5575	614	0	291	465		0	1	3563	

Table 2.2.5.7.3. Recruitment and spawning size identification of giant red shrimp for modeling purposes.

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (CL mm)**	**Data source**	**Method used**	**Mean maturity length (CL mm) /Maturity stage**
1,5,6	1994-2010	MEDITS (minimum from all GSAs)		20	MEDITS (minimum from all GSAs)		34
8	1994-2010	DCF/MEDITS				Fixed threshold length (L50)	35
9	1994-2010	DCF/MEDITS				Fixed threshold length (L50)	38
10	1994-2010	MEDITS	Bhattacharya	30	MEDITS and biological sampling	Maturity ogive	34
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya	28	MEDITS	Fixed threshold length (L50)	39

		Recruits			Spawners		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (CL mm)**	**Data source**	**Method used**	**Mean maturity length (CL mm) /Maturity stage**
15+16	2003-2010	MEDITS	Battacharia	30	DCF	Fixed threshold length (L50)	37
17	2002-2010	Relini et al., 1999	Fixed threshold length	30	Relini et al., 1999	Fixed threshold length (L50)	39
18	1994-2010	MEDITS	Bhattacharya	31	MEDITS and biological sampling	Maturity ogive	36
19	1994-2010	MEDITS	Bhattacharya	25	MEDITS	fixed	37
20	1998-2008	MEDITS	Bhattacharya	23	MEDITS	Fixed threshold length (L50)	35
22_23	1996-2008	MEDITS	Bhattacharya	20	MEDITS	Fixed threshold length (L50)	40
25	2005-2010	MEDITS GSAs 22-23	Bhattacharya	20	MEDITS GSAs 22-23	Maturity ogive	40

Mapping of density and identification of hot spot areas

A summary of the spatial models implemented for mapping recruits and adults/spawners of giant red shrimp is provided in Table 2.2.5.7.4.

GSAs 1-6, 5

This species was not considered for modeling due to the low number of specimens captured, varying between 0 and 5 individuals depending on the year considering all the size-classes together (Table 2.5.8.2). This is in agreement with the very low densities reported in previous studies (Cartes et al., 2011).

GSAs 7, 8, 9

In GSAs 8 and 9 the age 0 component of giant red shrimp was not detected in the length frequency distributions of MEDITS surveys; in fact the first modal component separated by Bhattacharya's method had a mean size corresponding to specimens belonging to the second year of life.

Modeling approach failed to map spawning areas both in GSA8 and GSA9: this was primarily due to the low values of occurrence and the scarce abundance of the species. Only bubble plot maps were produced.

GSA 10, 11, 18, 19

In GSA10-11-18-19 annual abundance values were predicted by means of a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging was applied on real abundance values. For modelling, the R

MEFH MEDISEH routine 2.0 was used. The models goodness-of fit was measured by the cross-validation index. The density hot spots were found using the local G statistic.

GSAs 15-16

In GSA 15+16, recruit density indices of giant red shrimp were modeled using a GAM with spatial component, a smooth effect on covariate “Distance from the coast” and a linear effect on Latitude (changing between years). Both the intercept and the spatial component were supposed to change each year. The spawners were best modeled using a GAM with spatial component, fixed intercept and a smooth term on the interaction of covariates Longitude and Distance from the coast. The spatial component was allowed to change in an annual basis.

The models goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km. The persistence was obtained as the rate of years in which a point was a hot spot.

GSA 17

No modeling has been attempted for the giant red prawn in GSA 17. In GSA 25 MEDITS data giant red prawn is almost absent.

GSAs 20, 22, 23

Generalized Additive Models were employed to model the distribution of spawners of giant red shrimp in GSA 22_23. The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots. The period analyzed was from 1996-2008 and the depth distribution of spawners ranged from 390-760 m in GSA 22_23.

Table 2.2.5.7.4. Modeling applied in EU GSAs for mapping giant red shrimp. CV=Cross Validation index

Life Stage	Gsa	Depth Range	Period	Model Type	Covariates	Explained Variance (%)	Goodness of fit (R2)
Recruits	15+16	300-780	2003-2010	GAM with spatial component	Year, Lat, Distance from the coast		CV=0.952 0.390
Spawners females	15+16	300-780	2003-2010	GAM with spatial component	Year, Long, Distance from the coast		CV=1.032 0.394
Spawners females	22_23	390-760	1996-2008	GAM(delta – lognormal)	Year, (Lon, Lat), depth	60.3	0.43
Recruits	10	200-800	1994:2010	Gaussian GAM	Depth	16.11	0.11
				Binomial GAM	Depth	38.54	0.41
				Ordinary Kriging			
Recruits	11	200-800	1994:2010	Gaussian GAM	Depth	9.48	0.1
				Binomial GAM	Depth	37.78	0.39
				Ordinary Kriging			
Recruits	18	200-800	1996:2006 2008:2010	Gaussian GAM	Depth	12.72	0.07
				Binomial GAM	Depth	32.25	0.3
				Ordinary Kriging			
Recruits	19	200-800	1994:2010	Gaussian GAM	Depth	41.6	0.4
				Binomial GAM	Depth	25.0	0.2
				Ordinary Kriging			

Life Stage	Gsa	Depth Range	Period	Model Type	Covariates	Explained Variance (%)	Goodness of fit (R2)
Spawners	10	200-800	1994:2010	--	--	--	--
				--	--	--	--
				Ordinary Kriging			
Spawners	11	200-800	1994:2004 2006:2010	Gaussian GAM	Depth	6.06	0.02
				Binomial GAM	Depth	53.38	0.59
				Ordinary Kriging			
Spawners	18	200-800	1996:2010	Gaussian GAM	Depth	9.35	0.12
				Binomial GAM	Depth	43.23	0.43
				Ordinary Kriging			
Spawners	19	200-800	1995:1999	Gaussian GAM	Depth	31.4	0.3
				Binomial GAM	Depth	32.6	0.3
				Ordinary Kriging			

In GSA20 and GSAs 22_23 the numbers of recruits caught were very low to allow modeling. Similarly, in GSA 20 the number of spawners was also very low to allow any modeling to be attempted. Finally for the female spawners in GSAs 22_23 the data of 1996, 2004, 2005, 2006 and 2008 (female spawners) could not be modelled due to the inapplicability of the tangent method.

2.2.5.7.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.7.5 summarizes the main environmental features of the most persistent areas identified for giant red shrimp in European GSAs

GSA 10

In the GSA10 persistent (probability 40-60%) hot spots of giant red shrimp recruits were localized off Capo Bonifati (GSA10_N2) and Capo Vaticano (GSA10_N2) between 500 and 550 m depth, both areas also localized in the past and persistent (40-60%) over a time horizon of about 17 years (Fig 2.2.5.7.1). These areas partially overlapped with the GSA10_S4 and GSA10_S5 hot spots spawning aggregations localized at depths between 550 and 700 m depth. A highly persistent spawning aggregation was also localized off-shore Punta Licosa (GSA10_S2, Fig 2.2.5.7.1.). Both nursey and spawning grounds are characterized by muddy bottoms with deep mud biocenosis and *Isidella elongata* facies. The mainstream current is from south to north.

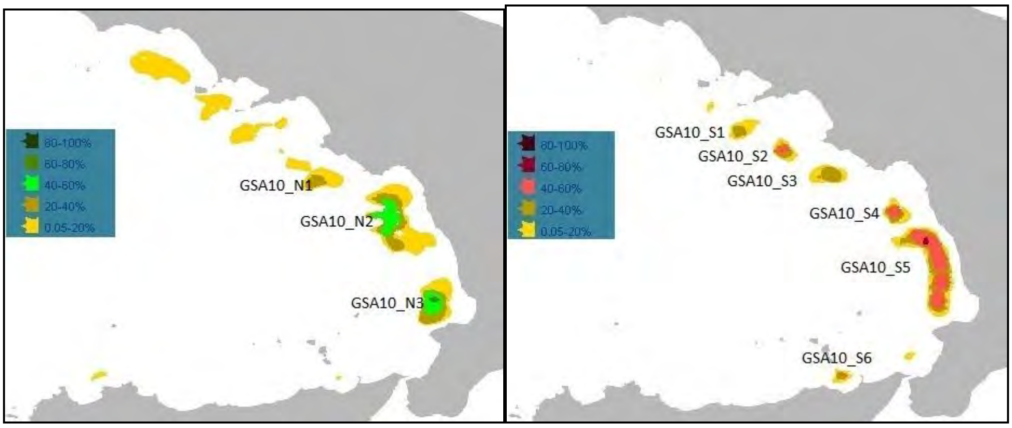


Fig 2.2.5.7.1. Position of persistent nursery (left) and spawning areas (right) of giant red shrimp in GSA10

GSA 11

Nursery areas (GSA11_N1) of the giant red shrimp in the GSA11 are mainly distributed in the south western coast at depths comprised between 500 and 550 m (Fig 2.2.5.7.2). These areas are characterized by muddy bottoms with a great presence of *Isidella elongata*. Persistent spawning hot spots are also located in the Southern coast of Sardinia (GSA11_S1) at depth >500 m where deep bottom are mainly characterized by muddy sediments (Fig 2.2.5.7.2).

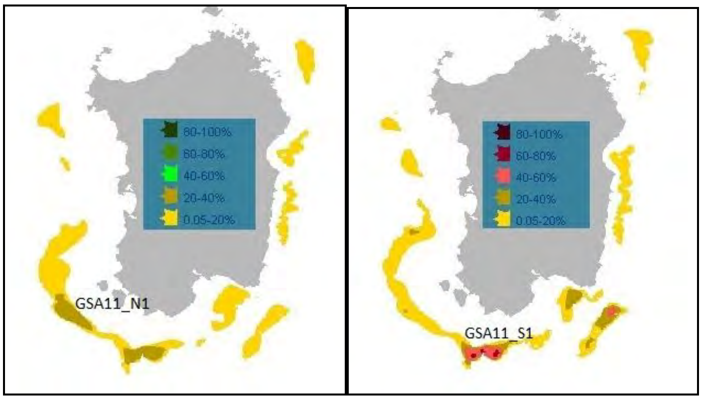


Fig 2.2.5.7.2. Position of persistent nursery (left) and spawning areas (right) of giant red shrimp in GSA11

GSAs 15-16

The giant red shrimp inhabits the meso bathyal basin between the Adventure Bank and the Malta Bank and the bottoms to the south of Malta. The bottoms are muddy and the characteristic facies is *Isidella elongata* (Gorgonacea). As already observed in a previous study, recruits are widely distributed in the depth range 500-700 m with several small density hotspots, more or less persistent. Two stability areas, (GSA15+16_N1 and GSA15+16_N2), can be identified to the west/northwest of the Maltese Islands, their major role in supporting recruitment (nurseries) cannot be stated (Fig 2.2.5.7.3). Conversely, two large adjacent spawning areas (GSA15+16_S1 and GSA15+16_S2), are located to the west and to the south of the Maltese islands (Fig 2.2.5.7.3). Overall, the distribution range of the species crosses the border between the GSA 15 and GSA 16.

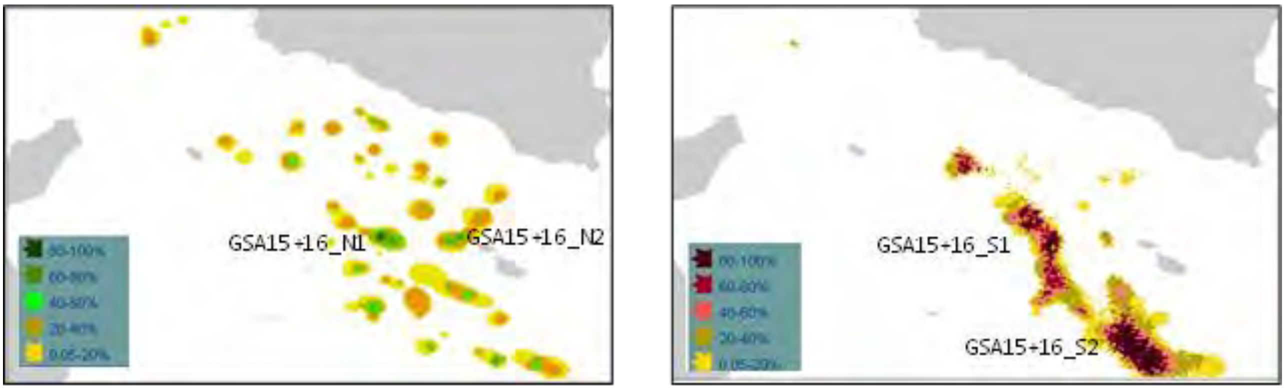


Fig. 2.2.5.7.3. Position of persistent nursery (left) and spawning areas (right) of giant red shrimp in GSA 15-16.

GSA 18

In GSA18 hot spots of giant red shrimp recruits with higher persistence (GSA18_N1; 40-60%) are mainly localized along the eastern border of the South Adriatic pit offshore the Albania coasts. This area is partially overlapping with the hot spot of spawner aggregation (GSA18_S1; 40-60%, Fig 2.2.5.7.4). Both nursery and spawning grounds are characterized by muddy bottom with deep mud biocenosis and *Isidella elongata* facies. The mainstream current is from south to north.

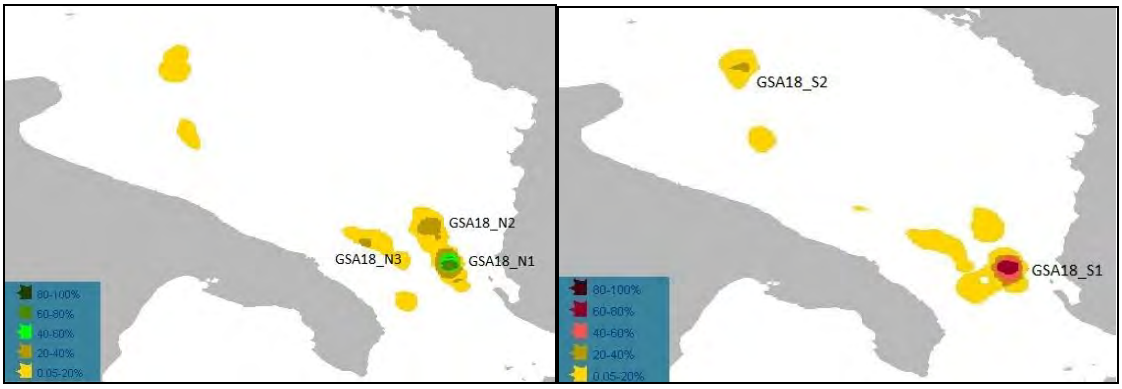


Fig 2.2.5.7.4. Position of persistent nursery (left) and spawning areas (right) in GSA19

GSA 19

The main nursery areas of the giant red shrimp in the GSA19 were frequently observed on the upper slope grounds distributed along the coast from Santa Maria di Leuca to Gallipoli (GSA19_N1), south-eastern the Amendolara Bank until the area between Cape Trionto and Punta Alice (GSA19_N2, GSA19_N3), offshore Crotone and Cape Rizzuto as well as on the upper slope offshore Catanzaro and Punta Stilo (Fig 2.2.5.7.5). The most persistent nursery areas for *A. foliacea* were bordered in very small areas distributed south-eastern the Amendolara Bank and offshore Crotone. A partial overlapping between nurseries and spawning areas was detected in the GSA19 for the giant red shrimp. In fact, the highest levels of persistency for the spawning as well as nursery areas of *A. foliacea* were estimated on the upper slope bottoms distributed eastern Santa Maria di Leuca, offshore Gallipoli and Punta Stilo (GSA19_S1, Fig 2.2.5.7.5).

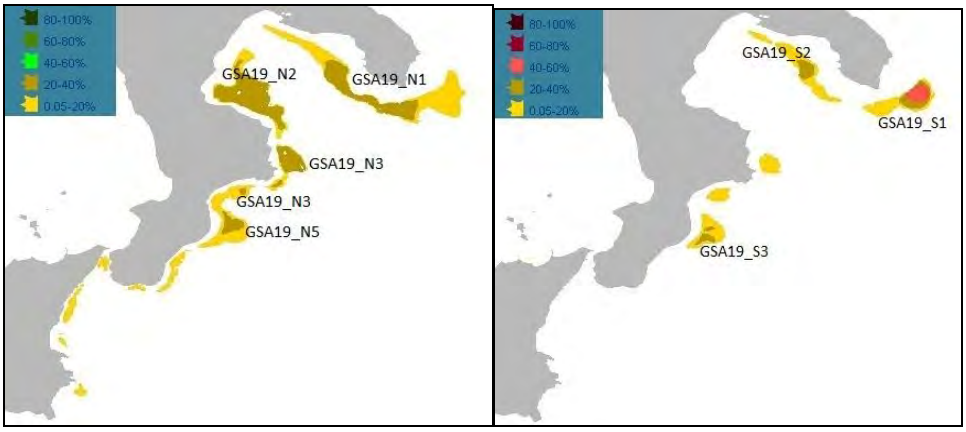


Fig 2.2.5.7.5. Position of persistent nursery (left) and spawning areas (right) of giant red shrimp in GSA19

GSA 22-23

Although giant red shrimps were collected from depths exceeding 390m in the Aegean Sea, our analysis demonstrated that the higher abundances of spawners of the species were found in the 500-700m depth range. Spawners of the species were also captured in the Ionian Sea, however the local distribution of the captures combined with the low numbers did not allow for any modeling. In the few instances that recruits of the species were captured these were distributed in depths that exceeded 250m in the Aegean and 350 in the Ionian Sea. Hence the only available distribution maps are annual bubble plot maps.

The density maps revealed a very local distribution of giant red shrimps spawners in the Aegean Sea and the most persistent area was a narrow spot in the Dodecanese island complex (Fig 2.2.5.7.6). This could be linked to the specific topographic and bathymetric conditions of the Aegean Sea which is characterized by a complex bathymetry, the existence of numerous islands and the presence of a narrow continental shelf (with the exception of its north-eastern part). It is likely that the presence of spawners in the Dodecanese region is related to the general large-scale water circulation pattern of the Aegean Sea which brings warmer and more saline waters of Levantine origin in this region. This may create conditions favouring spawning activities.

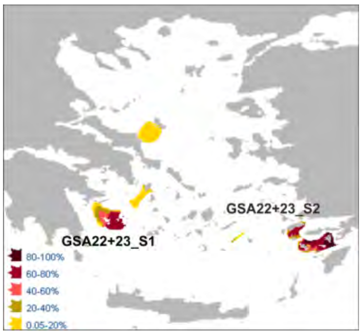


Fig 2.2.5.7.6. Position of persistent spawning areas of giant red shrimp in GSA 22_23.

Table 2.2.5.7.5. Main environmental features of the most persistent areas identified for giant red shrimp in European GSAs

GSA	**Type of area**	**Code**	**Depth range (m)**	**Description (few lines of text)**
10	nursery	GSA10_N1	526-594	The bottom is muddy with deep mud biocenosis (VP) and *Isidella elongata* facies with associated species as *Polycheles typhlops*, *Geryon longipes*, *Anamathia rissoana Echinus spp* etc. The mainstream current direction is from south to north.
10	nursery	GSA10_N2	496-646	The bottom is muddy with deep mud biocenosis (VP) and *Isidella elongata* facies with associated species as *Polycheles typhlops*, *Geryon longipes*, *Echinus spp* etc. The mainstream current direction is from south to north.
10	nursery	GSA10_N3	532-563	The bottom is muddy with deep mud biocenosis (VP) and *Isidella elongata* with associated species as *Polycheles typhlops*, *Geryon longipes*, *Bathynectes maravigna* etc. The mainstream current direction is from south to north.
11	nursery	GSA11_N1	500-550	Muddy bottoms. Biocenosis at *Isidella elongata*
11	Adult females aggregation	GSA11_S1	500-700	Muddy bottoms. Biocenosis at Isidella elongata
15+16	nursery	GSA15+16_N1	560-730	Bathyal muds, facies with *Isidella elongata*. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
15+16	nursery	GSA15+16_N2	455-640	Bathyal muds, facies with Isidella elongata. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
15+16	Adult females aggregation	GSA15+16_S1	560-730	Bathyal muds, facies with Isidella elongata. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.

15+16	Adult females aggregation	GSA15+16_S2	590-620	Bathyal muds, facies with Isidella elongata. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
18	nursery	GSA18_N1	508-567	The bottom is muddy with deep mud biocenosis (VP) with characteristic species as *Macropipus tuberculatus*, *Polycheles typhlops, Geryon longipes, Homola barbata* etc. The mainstream current direction is from south to north.
18	nursery	GSA18_N2	500-571	The bottom is muddy with deep mud biocenosis (VP) and Isidella elongata facies with associated species as *Polycheles typhlops, Geryon longipes, Bathynectes maravigna Anamathia rissoana* etc. The mainstream current direction is from south to north.
18	nursery	GSA18_N3	264-562	The bottom is muddy with deep mud biocenosis (VP) and Isidella elongata facies with associated species as *Polycheles typhlops, Geryon longipes, Bathynectes maravigna Echinus spp* etc. The mainstream current direction is from south to north.
18	Adult females aggregation	GSA18_S1	504-602	The bottom is muddy with deep mud biocenosis (VP) with caracteristic species as *Macropipus tuberculatus, Polycheles typhlops, Geryon longipes, Homola barbata* etc. The mainstream current direction is from south to north.
18	Adult females aggregation	GSA18_S2	519-575	The bottom is muddy with deep mud biocenosis (VP) with caracteristic species as *Macropipus tuberculatus, Echinus spp, Polycheles typhlops, Geryon longipes, Argobuccinum olearium* etc. The mainstream current direction is from south to north.
19	nursery	GSA19_N1	249-584	The upper slope from Santa Maria di Leuca to Gallipoli was characterized by the shelf-edge detritic and bathyal muds biocenosis.
19	nursery	GSA19_N2	265-628	The upper slope southern the Amendolara Bank until the area between Cape Trionto and Punta Alice was characterized bathyal muds biocenosis.
19	nursery	GSA19_N3	204-652	The upper slope offshore Crotone was characterized by the biocenosis of the bathyal muds.
19	nursery	GSA19_N4	117-173	The shelf break-upper slope offshore Catanzaro was characterized by the biocenosis of the terrigenous mud and shelf-edge detritic.
19	nursery	GSA19_N5	107-431	The upper slope north-eastern Punta Stilo was characterized by the terrigenous mud and bathyal muds.
19	Adult females aggregation	GSA19_S1	249-584	The shelf break and slope from Santa Maria di Leuca to Gallipoli was characterized by the shelf-edge detritic and bathyal muds biocenosis.
19	Adult females aggregation	GSA19_S2	311-689	The slope offshore Gallipoli was characterized by the bathyal muds biocenosis.
22_23	Adult females aggregation	GSA22-23_S2	250-450	Deep areas offshore Argolikos gulf. Main substrate is mud. Other environmental information is lacking.
22_23	Adult females aggregation	GSA22-23_S2	250-450	South-east Aegean Sea (Dodecanese complex). Relatively deep, saline (Levantine-origin) waters.

2.2.5.7.4 Gaps in knowledge and future actions

The biological knowledge (e.g. maturity, spawning period) about this species is available in Western Mediterranean is extremely limited. No published biological information exists for this species in the Spanish waters. In GSA 17 the giant red shrimp is almost absent and the identification by means of modeling of nursery and spawning grounds was not possible. However, this species is present and locally abundant in the Levantine Sea as demonstrated by the occurrence of trawlers from other countries exploiting the species.

2.2.5.8 Aristeus antennatus

2.2.5.8.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

In GSA 05 recruits of *A. antennatus* have been detected on the middle slope (600-750 m depth) during autumn-winter, while spawners are mainly distributed in the same fishing grounds during summer (Guijarro *et al.*, 2008).

Short spatial differences between northern and southern the Balearic Islands have been detected in the population dynamics, biology and condition of some deep water species, *A. antennatus* among them (Cartes *et al.*, 2008a, 2009; Guijarro *et al.*, 2008, 2009, 2012; Hidalgo *et al.*, 2008a, 2008b, 2009a). These differences are likely to be related to the distinct environmental conditions (hydrodynamics, water masses, geomorphology, sediment characteristics and trophic resources) and fishing impact among these areas (Cartes *et al.*, 2008b; López-Jurado *et al.*, 2008; Moranta *et al.*, 2008), located at the Balearic and Algerian sub-basins, respectively. For *A antennatus*, while in the south the population of this species is more demographically homogeneous, in the north it shows important variations, like high abundance of juveniles recruiting to fishing grounds in autumn-winter and high abundance of large mature females during summer have been shown in the north (Guijarro *et al.*, 2008). Several differences have also been found in the biology of the species, males being more abundant north than south. Also, the reproductive period started sooner in the north than in the south, and the condition of pre-spawning females was better north.

In the Balearic Islands, the recruitment of *A. antennatus* seems to be enhanced during low NAO and IDEA indices periods (Massutí *et al.*, 2008). During these periods, colder-than-normal winters generate high amounts of cold Western Mediterranean Intermediate Waters (WIW) in the Gulf of Lions, which flow southwards and reach the Balearic Islands channels in spring, increasing the productivity in the area. Both spawning stock and abundance of *A. antennatus* seem to be enhanced by high Mediterranean Oscillation index periods, which could reflect the increased presence of the saline and warm Levantine Intermediate Waters (LIW) in the Balearic Islands, extending over the fishing grounds of this species.

In GSA9 the recruits of *A. antennatus* are usually detected, both in the samples coming from surveys or from biological samplings (DCF), in a very scarce amount and it is very difficult to identify a well-defined recruitment period.

In the GSAs 10 and 18 recruits did not occur in the experimental catches, either in spring and autumn, probably because they were not accessible to the gear.

In GSA11 migration from nurseries takes place when juveniles attained a critical size between 16 and 18 cm TL at depths deeper than 500-550 m. The recruitment reaches a peak in August. The minimum size of recruit is 6.2 and 6.7 for males and females respectively.

In GSAs 15-16 recruitment of *A.antennatus* occurs from mid-summer and throughout autumn. The youngest modal group observed within the sampling area (down to 800 m) in the Strait of Sicily, has a mean length equal to 29 mm. However it is known that the youngest fraction of the species lives at depths inaccessible to trawlers.

In GSA 19 *A.antennatus* was collected from 108 to 3300 m depth. The minimum and maximum sizes were 10 and 66 mm CL. Recruitment is observed from April to September on a wide depth range, with an increasing occurrence on bottoms deeper than 800 m, where commercial trawling generally does not take place in this basin. In GSA 20 recruits enter the stock during the spring-summer period. No information is available for GSA 22_23.

Spawning

The reproductive biology of this species is fairly known in GSA 5. The reproduction period of *Aristeus antennatus* is somewhat extended, starting in spring (April), peaking in summer (July-August), when most of the females reach sexual maturity, and ending in autumn (October-November). In GSA 01 the smallest observed mature female measured 35 mm in carapace length (CL) and the smallest mature male 18 mm (CL). In GSA 06 similar trends and sizes occur. In GSA 05 *A. antennatus* spawns during June-August, with a length of first maturity at around 19 mm carapace length for males and 25 mm for females (Guijarro *et al.*, 2008). The recruitment of small individuals (20-25 mm) of this species to trawl fishing grounds has been detected from November to February.

In GSA9 the reproductive period of *Aristeus antennatus* is somewhat extended, starting in spring (April), peaking in summer (July-August), when most of the females reach sexual maturity, and ending in autumn (October-November). In the Ligurian Sea, the smallest observed mature female measured 31 mm in carapace length (CL) and the smallest mature male 20 mm (CL). In the Northern and Central Tyrrhenian, the smallest observed mature females measured, respectively, 32 mm and 24 mm. In Central Tyrrhenian Sea the size of first maturity for the females was indicated at of 27mm CL. In GSA 7 it was indicated a spawning season very similar to that reported for Ligurian and Tyrrhenian seas and a female size at first maturity (L50) of 28.8 mm CL.

In GSA10 spawning of *A. antennatus* takes place in the late spring-summer (Spedicato et al., 1999b) with a similar pattern observed in GSA18. According to the data obtained from DCR in 2008, the proportion of mature females by length class gave an estimate of maturity ogive which indicates a $L_{m50\%}$ of about 25.4 mm (±0.19 cm; MR=3.3±0.25) a value similar to that of DCF in 2010 ($L_{m50\%}$= 28.7 ±0.22; MR= 4.9 ±0.19) when the estimate was obtained using a GLM.

In GSA 11 the reproductive period starts in May, peaking in July-August, when most of the females reach sexual maturity at 24-27 mm CL. No reliable estimates of size at first maturity are available.

In the Strait of Sicily (GSA 15-16) the reproductive strategy of *A.antennatus*, is characterized by a single spawning peak in summer.

In GSA18, according to the data obtained from DCF in 2010, the proportion of mature females gave an estimate of maturity ogive which indicates a $L_{50\%}$ of about 25.6 mm (±0.19 cm; MR=4.9±0.11). This estimate was obtained using a GLM approach. In GSA19 reproductive period is extended between late spring and autumn (D'Onghia et al., 2005). The smallest recorded mature female and male were 19 and 15 mm CL. The size at maturity of females was 35 mm CL. Aggregations of potentially spawning females were localised in the GSA 19 by Lembo et al. (2000c) using geostatistical methods as co-kriging and disjunctive kriging (Isaaks and Srivastava, 1990). In GSA 20 sexually mature individuals are found during mid to late summer with large females being able to (release) leave eggs more than once in each reproductive period. No information is available for GSA 22_23.

2.2.5.8.2. Modeling approach

Identification of recruits and spawners

Tables 2.2.5.8.1 and 2.2.5.8.2 list the frequency of positive hauls and the number of blue and red shrimp specimens caught during MEDITS survey in each GSA. Recruitment and maturity sizes are indicated in Table 2.2.5.8.3.

GSAs 1-6, 5

The proportion of positive hauls is similar in the three Spanish GSAs, varying from 0.14 to 0.16 in GSA05 and from 0.08 to 0.18 in GSAs 01 and 06. The amount of specimens is highly variable ranging from 392 to 1131 in the GSA05 and from 150 to 2474 in the GSA 01and 06.

The spawning fractions of females were extracted by means of the length at first maturity (L50 or length at which 50% of the individuals are mature) and the maturity ogive (L25-75). For this purpose, data on monthly biological samplings of commercial catches, obtained within the Data Collection Framework, were used to identify the spawning periods of each species, from monthly average of the Gonadosomatic Index (GSI) and the percentage of maturing or mature individuals. Only data compiled during these spawning periods was used to calculate L50, from the logistic curve: PL= e(a+b*L)/(1+e(a+b*L)), where PL is the proportion of mature individuals for a given size class L. Logistic curves were fitted by maximizing the log-likelihood function, using Solver in EXCEL (Tokai, 1997).

GSAs 7, 8, 9

A. antennatus was practically absent GSA8 (it was caught in only two hauls in 2000). In GSA 7 the frequency of positive hauls ranged from 0.05 to 0.11 and the number of specimens caught in the different years varied from 15 to 622. In GSA9 the frequency of positive hauls ranged from 0.07 to 0.16; the number of specimens caught ranged from 131 to 1395. The presence of recruits was not significantly detected in the MEDITS catch. Thresholds of 27 and 29 mm carapace length, respectively for GSA 9 and 7, were chosen to identify spawners, corresponding to the size of first maturity indicated by literature.

Thresholds of 27 and 29 mm carapace length, respectively for GSA 7 and 9, were chosen to identify spawners, corresponding to the size of first maturity reported in literature.

GSAs 10, 11, 18, 19

The frequency of positive hauls for *A. antennatus* in GSA10 ranges between 0.08 (MEDITS 1995) and 0.29 (MEDITS 1994), with an overall catch fluctuating from a minimum of 53 (MEDITS 1995) and a maximum of 1161 (MEDITS 1997) sampled specimens.

The frequency of positive hauls for *A. antennatus* in GSA11 ranges between 0.09 (MEDITS 2004) and 0.20 (MEDITS 2001), with an overall catch fluctuating from a minimum of 351 (MEDITS 2004) and a maximum of 1536 (MEDITS 1997) sampled specimens.

The frequency of positive hauls for *A. antennatus* in GSA18 ranges between 0 (MEDITS 1994, 1995 and 2004) to 0.13 (MEDITS 2010), with a maximum overall catch of 1282 (MEDITS 2010) sampled specimens.

The higher abundance of *A. antennatus* in the North-Western Ionian Sea was recorded during MEDITS 1998 with a total of 3789 specimens collected. The lower abundance of the blue and red shrimp was recorded during MEDITS 2003 with 656 sampled specimens. The lower frequency of positive hauls for *A. antennatus* (0.21) was observed in both MEDITS 2003 and MEDITS 2004. The higher occurrence (0.46) was recorded during MEDITS 2010.

GSAs 15-16

A.antennatus is generally caught in low numbers (189 specimens as average) in GSA 15+16 and in very few hauls (9 -13% of the total hauls). However catches are restricted to the deepest bottoms (500-800 m) of the Strait of Sicily and show a rather constant spatial pattern. Specimens in the first year of life were absent from catches of MEDITS surveys in the Strait of Sicily as probably not accessible to the gear. The Lm50% of maturity ogives obtained from biological sampling of commercial catches (DCF) was equal to 31 mm and was used as threshold size to identify potential spawners.

GSA 17

The blue and red shrimp was not found in the GSA 17 during MEDITS 2002-2010.

GSAs 20, 22, 23

The data for red shrimp used within MEDISEH were obtained from the MEDITS survey. The available data for red shrimp that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 and in GSAs 22_23 the proportion of positive hauls for red shrimp was extremely low, always <6% and 2%, respectively (Table 2.5.5.1). Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates based on the aforementioned approaches, threshold values were established based on literature information and expert knowledge.

GSA 25

In GSA 25, blue and red shrimp has been observed only in MEDITS 2009 in 3 hauls with 1 specimenscollected in each haul.

Table 2.2.5.8.1. Frequency of positive MEDITS hauls (n of positive hauls/total number of hauls) for blue and red shrimp by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.10	0.00	0.10	0.29	0.17		0.00	0.36			0.11		
1995		0.09	0.00	0.07	0.08	0.11		0.00	0.31			0.12		
1996				0.09	0.20	0.14		0.06	0.42			0.18		0.01
1997		0.07	0.00	0.12	0.16	0.18		0.09	0.38			0.17		0.01
1998		0.07	0.00	0.12	0.24	0.22		0.08	0.43	0.06		0.14		0.01
1999		0.09	0.00	0.10	0.19	0.14		0.04	0.41	0.03		0.15		0.02
2000		0.07	0.00	0.08	0.27	0.19		0.04	0.39	0		0.09		0.01
2001		0.06	0.00	0.10	0.25	0.20		0.07	0.41	0.03		0.11		0.01
2002		0.06		0.09	0.23	0.17	0	0.03	0.41			0.10		
2003		0.07	0.01	0.09	0.23	0.11	0	0.01	0.21	0.03		0.15	0.09	0.01
2004		0.07	0.00	0.09	0.20	0.09	0	0.00	0.21	0		0.15	0.12	0.01
2005		0.05	0.00	0.06	0.21	0.13	0	0.01	0.31	0.06		0.06	0.12	0.02
2006		0.06	0.00	0.08	0.24	0.12	0	0.00	0.39	0.03		0.09	0.11	0.02
2007	0.14	0.07	0.00	0.08	0.26	0.13	0	0.02	0.40			0.08	0.13	
2008	0.16	0.11	0.00	0.09	0.21	0.13	0	0.02	0.34	0.03		0.12	0.08	0.01
2009	0.16	0.05	0.00	0.06	0.14	0.12	0	0.07	0.43			0.10	0.10	
2010	0.16	0.05	0.00	0.16	0.16	0.16	0	0.13	0.46			0.08	0.08	

Table 2.2.5.8.2. Number of specimens of blue and red shrimp caught during MEDITS by GSA and year.

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		622	0	592	962	1288		0	2000			150		
1995		265	0	468	53	972		0	968			1089		
1996		0		369	179	1374		112	2233	123		890		1
1997		115	0	889	1161	1536		1233	1532	107		882		5
1998		129	0	493	518	1520		210	3789			756		1
1999		86	0	562	432	765		207	2692	26		830		39
2000		111	6	450	503	990		29	3297			2474		38
2001		155	0	225	806	1090		62	1889	10		1136		18
2002		213		139	243	707	0	55	1262			974		
2003		189	10	231	374	573	0	1	656	125		1097	60	13
2004		223	0	355	291	351	0	0	1904	19		908	155	10
2005		58	8	131	440	540	0	4	1638			674	274	25
2006		15	0	194	508	539	0	0	2526	178		1449	320	10
2007	392	89	0	227	299	506	0	134	2001	123		533	187	
2008	1131	314	0	514	257	437	0	4	1074	107		1323	145	40
2009	644	75	0	171	425	483	0	964	3644			846	264	
2010	400	141	0	1395	232	678	0	1282	3117			382	109	

Table 2.2.5.8.3. Recruitment and spawning size identification for modeling purposes

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (CL mm)**	**Data source**	**Method used**	**Mean maturity length (mm) /Maturity stage**
5, 1-6	2000-2010	-	-	-	DCF	Fixed threshold length (L50)	22.8
7	1994-2010	-	-	-	MEDITS-DCF	Fixed threshold length (L50)	27
8	1994-2010	-	-	-	MEDITS-DCF	-	-
9	1994-2010	-	-	-	MEDITS-DCF	Fixed threshold length (L_{50})	29
10	1994-2010	--	--	--	Biological sampling	Maturity ogive	26
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya	22.8	MEDITS	Fixed threshold length (L_{50})	26
15+16	2003-2010				DCF	Fixed threshold length (L_{50})	31
18	1994-2010	--	--	--	Biological sampling	Maturity ogive	26

		Recruits			Spawners		
GSA	Sampling years	Data source	Method used	Mean threshold length (CL mm)	Data source	Method used	Mean maturity length (mm) /Maturity stage
19	1994-2010	--	--	--	MEDITS	Fixed threshold length (L_{50})	28
20	1998-2008	MEDITS	Bhattacharya	26	MEDITS	Fixed threshold length (L_{50})	31
22-23	1996-2008	MEDITS	Bhattacharya	20	MEDITS	Fixed threshold length (L_{50})	33

Mapping of density and identification of hot spot areas

A summary of the spatial models implemented for mapping recruits and adults/spawners of blue and red shrimp is provided in Table 2.2.5.8.4. No modeling has been attempted for the blue and red shrimp in **GSA 7,8, 9, 17, 20, 22-23** and **25** due to lack of suffiecient data.

GSAs 1-6

The adult aggregations and recruits were modeled using GAMs. Two models were developed independently, one for presence/absence data, and another for standardized abundances restricted to presence data only. Bottom temperature and salinity were not significant and both the final presence/absence and given presence models, included depth, the interaction between longitude and latitude and year as significant factors. Each model explained 50 and 52% of the total variance, respectively. Lastly, it must be pointed out the very low correlation between the mean annual number of spawners (n/km^2), estimated from the samples and from the model of abundance predictions for red shrimp spawners (0.12). Although fishery-independent information provides high quality and useful data, the results for those species like red shrimp, with seasonal and small-scale temporal variability in the population dynamics and catchability, must be taken carefully (Guijarro *et al.*, 2011).

GSA 5

The recruits of this species were not modeled due to the mismatch between the sampling period and the time of the year that the recruits can be found (spawning occurs in summer, after the survey). The spawners of GSA 05 were also not modeled because, although the amount of individuals per haul was high, the proportion of positive hauls was too low.

GSAs 15-16

The spawners of *A.antennatus* were modeled in GSA 15+16 using a GLM with spatial component i.e. a simple spatial model with no trend. The model goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km. The persistence was obtained as the rate of years in which a point was a hot spot. Recruits of *A.antennatus* were not detected by MEDITS trawl survey because this fraction of the population is inaccessible to the gear. Hence no modeling work was possible for the juvenile fraction of the population.

GSAs 10, 11, 18, 19

In GSAs 10-11-18-19 annual abundance values were predicted by mean a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeed, ordinary kriging was applied on real abundance values. For modelling, the R MEFH MEDISEH routine 2.0 was used. The density hot spots were found using the local G statistic. Only spawners could be modelled, as recruits are not accessible to the sampling gear, given the maximum depth explored in MEDITS (800 m depth).

Table 2.2.5.8.4. Spatial models implemented for mapping recruits and adults/spawners of blue and red shrimp. CV= Cross-validation Index

Life Stage	Gsa	Depth Range	Period	Model Type	Covariates	Explained Variance (%)	Goodness of fit (R^2)
spawners	10	200-800	1994:2010	Gaussian GAM	Depth	3.56	0.04
				Binomial GAM	Depth	47.57	0.49
				Ordinary Kriging			
spawners	11	200-800	1994:2004 2006:2010	Ordinary Kriging			
spawners	18	200-800	1996:1998, 2000, 2001 2009, 2010	Ordinary Kriging			
spawners	19	200-800	1994:2010	Ordinary Kriging			
Spawner females	01, 06	400-820	Spawner females	Pres./Abs.	Year, (Lon,Lat), depth	50.2	0.69
				Abundance	Year, (Lon, Lat), depth	51.9	
Spawners	15+16	500-800	2003-2010	GLM with spatial component	-		CV=0.97, 0.48

2.2.5.8.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.8.5 summarizes the main environmental features of the most persistent areas identified for blue and red shrimp in European GSAs. For details see at http://mareaproject.net/mediseh/viewer/med.html.

GSAs 1-6

According to the models, the adult aggregations present a marked increasing trend in both presence and abundance in relation to depth. The mean annual abundance showed frequent oscillations, without a clear trend and a maximum in 2000. The predictions showed that the largest areas where adult aggregations are present include the slope bottoms of the gulfs of Vera and Almería in the GSA 01, and the slope bottoms from Barcelona to Cape Creus in the GSA 06. No differences in the geographic distribution pattern depending on their annual abundance have been observed. A large persistency density hot-spot was detected, connecting the northern and southern parts of the GSAs 01 and 06, and a small one located in the vicinity of the Blanes canyon, in the northern part of the GSA 06.

The areas with the highest abundance are located in the vicinity of submarine canyons. This species is characterized by spatiotemporal movements related to the geographic structure of submarine canyons (Tobar and Sardá, 1987; Demestre and Martín, 1993). Since Sardà *et al.* (2009), the bottom trawl fisheries of this species are based in areas on the open slope outside the canyon, areas known locally as ‘‘baranas”. Fishing occurs in these areas from late winter to early summer, and fishing along the canyon walls from the mid-canyon to the canyon head, known locally as the “Sot-Través” fishing ground, occurs mainly from late summer to mid-winter (Sardà et al., 1994; Sardà and Cartes, 1997; Tudela et al., 2003).

In the GSA 01 and 06, a large persistent density hot-spot for spawners was detected, connecting the northern and southern parts of the GSAs 01 and 06, and a small one located in the vicinity of the Blanes canyon, in the northern part of the GSA 06 (Fig. 2.2.5.8.1).

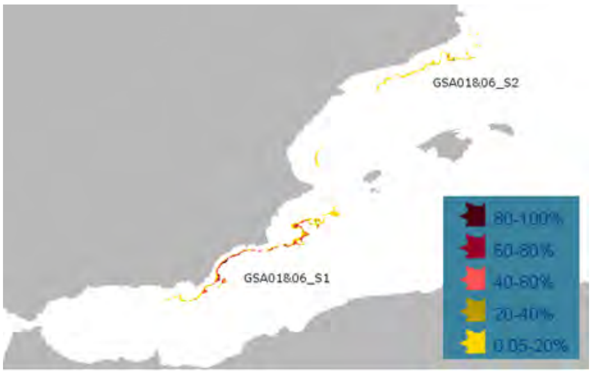


Fig. 2.2.5.8.1. Position of persistent spawning areas of blue and red shrimp in GSAs 1 and 6

GSA 10

Hot spots of spawner aggregations were estimated with a high level of persistence (40-60%) off Licosa promontory (GSA10_S1) and Capri island (GSA10_S2) at down 500 m depth in the northern part of the central-southern Tyrrhenian sea (Fig. 2.2.5.8.2.). The spawning areas are characterised by muddy bottom with deep mud biocenosis (VP) and *Gryphus vitreus* and *Isidella elongata* facies. The mainstream current direction of LIW is from south to north.

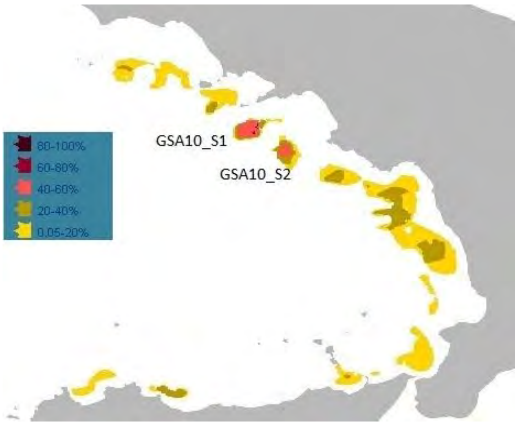


Fig. 2.2.5.8.2. Position of persistent spawning areas of blue and red shrimp in GSA 10

GSA 11

Spawning areas with high level of persistence (> 60%) are found in Sardinian seas both in western and eastern coasts at depth greater than 500 m, where the bottoms are mainly characterized by muddy sediments. Zone of high concentration of mature specimens with a slightly lower level of persistence (40-60 %) where found also along the northern coast at the same depth (Fig. 2.2.5.8.3).

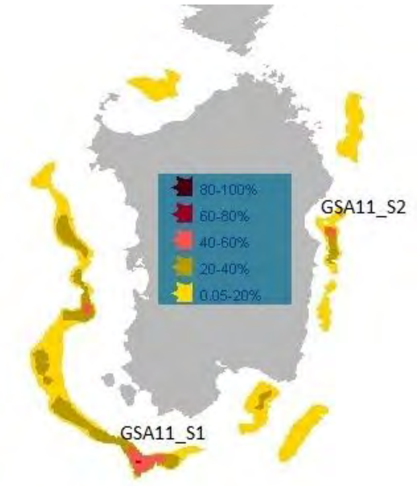


Fig. 2.2.5.8.3. Position of persistent spawning areas of blue and red shrimp in GSA 11

GSA 18

The only very high persistent (80-100%) hot spot of *A. antennatus* spawning aggregation was localized along the western border of the South Adriatic pit down 500 m depth (Fig. 2.2.5.8.4). The grounds are characterised by muddy bottom with deep mud biocenosis (VP) and Isidella elongata facies. The mainstream current direction is from north to south. The abundance of this species has increased in this basin in very recent time.

Fig. 2.2.5.8.4. Position of persistent spawning areas of blue and red shrimp in GSA 18

GSA 19

The main spawning areas of the blue and red shrimp in the North-Western Ionian Sea (GSA19) were frequently observed on the slope grounds along the coast from Santa Maria di Leuca to Taranto (GSA19_S1), from Crotone to Cape Rizzuto (GSA19_S2) as well as offshore Punta Stilo and Cape Spartivento (GSA19_S3). These are the largest spawning areas on the slope bottoms down to 800 m of depth with the highest persistency (60-80%). In addition, other smaller areas showing remarkable persistency levels were observed offshore Ugento, Porto Cesareo, Torre Ovo, in the vicinity of GSA19_S1, and Crotone in the vicinity of GSA19_S2 (Fig. 2.2.5.8.5).

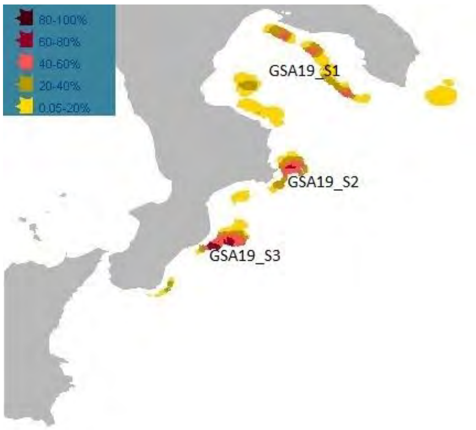


Fig. 2.2.5.8.5. Position of persistent spawning areas of blue and red shrimp in GSA 19.

GSA 15-16

Bathyal muds (facies with *Isidella elongata*) represent the preferential habitat for spawners of *A.antennatus*. Persistent density hotspots of mature individuals have been identified in the deep basin to the west of Malta (GSA15+16_S2 and GSA15+16_S3) and to the west of the Adventure Bank (GSA15+16_S1). All the spawning areas (including the less persistent areas) are restricted to depths between 580 m and 700 m and are located next to deep trenches (1200-1650 m) thus substantiating the hypothesis that the whole bathymetric distribution of the species extends well below 1000 m. Recruits of this species inhabit depths inaccessible to trawlers and the species undertakes ontogenetic migrations to shallower grounds (500-700 m) to spawn (Fig. 2.2.5.8.6).

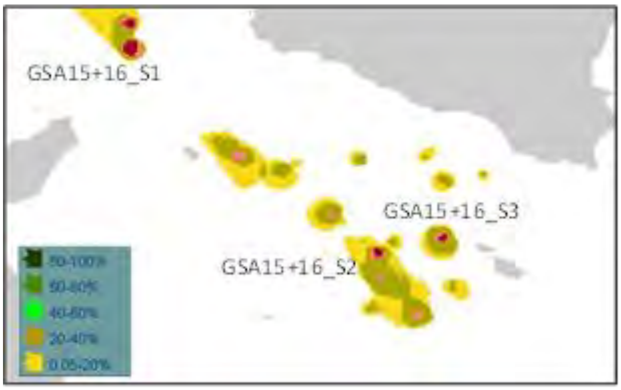


Fig. 2.2.5.8.6. Position of persistent spawning areas of blue and red shrimp in GSA 15-16

Table 2.2.5.8.5. Main environmental features of the most persistent areas identified for blue and red shrimp in GSA 15-16

GSA	Type of area	Code	Depth range	Description (few lines of text)
01 and 06	Adult females aggregation	GSA01_06_S1	500-800	Persistent hotspot connecting the northern part of the GSA 01 and the Southern part of the GSA06 Middle slope
01 and 06	Adult females aggregation	GSA01_06_S2	500-800	In the vicinity of the Blanes canyon. Middle slope

10	Adult females aggregation	GSA10_S1	564-664	The bottom is muddy with deep mud biocenosis (VP) and *Gryphus vitreus* facies with associated species as *Macropipus tuberculatus, Polycheles typhlops*, *Geryon longipes Anamathia rissoana Echinus spp* etc. The mainstream current direction is from south to north.
10	Adult females aggregation	GSA10_S2	563-642	The bottom is muddy with deep mud biocenosis (VP) and *Isidella elongata* facies with associated species as *Polycheles typhlops*, *Geryon longipes*, *Anamathia rissoana Echinus spp* etc. The mainstream current direction is from south to north.
11	Adult females aggregation	GSA11_S1	500-700	Muddy bottoms. Biocenosis at *Isidella elongata*
11	Adult females aggregation	GSA11_S2	500-700	Muddy bottoms. Biocenosis at *Isidella elongata*
15+16	Adult females aggregation	GSA15+16_S1	610-670	Bathyal muds, facies with *Isidella elongata*. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
15+16	Adult females aggregation	GSA15+16_S2	635-700	Bathyal muds, facies with *Isidella elongata.* This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
15+16	Adult females aggregation	GSA15+16_S3	580-670	Bathyal muds, facies with Isidella elongata. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
18	Adult females aggregation	GSA18_S1	505-563	The bottom is muddy with deep mud biocenosis (VP) and *Isidella elongata* facies with associated species as *Polycheles typhlops*, *Geryon longipes*, *Bathynectes maravigna Echinus spp* etc. The mainstream current direction is from north to south.
19	Adult females aggregation	GSA19_S1	501-772	The slope grounds from Santa Maria di Leuca to Taranto were characterized by the bathyal muds biocenosis.
19	Adult females aggregation	GSA19_S2	502-779	The slope offshore Crotone was characterized by the bathyal muds biocenosis.
19	Adult females aggregation	GSA19_S3	501-767	The slope grounds from Punta Stilo to Roccella Ionica were characterized by the bathyal muds biocenosis.

2.2.5.8.4 Gaps in knowledge and future actions

In GSA 17 and 25 the blue and red shrimp is not present. According to the data available in the GSA05 the recruitment of *Aristeus antennatus* would require sampling in late autumn-winter (Guijarro *et al.,* 2008). Although fishery-independent information (e.g. surveys) provides high quality and useful data, the results for those species like *A. antennatus*, with seasonal and small-scale temporal variability in the population dynamics and catchability, must be taken with caution (Guijarro *et al.*, 2011). More hauls are needed to obtain adequate data to model spawners' distribution in GSA 05.

2.2.5.9 Parapenaeus longirostris

2.2.5.9.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

In the Spanish Mediterranean (GSAs 1-6) the recruits of this species are detected during summer, with 0-age individuals showing sizes below 15 mm of carapace length (García-Rodríguez et al., 2008).

In GSA9 the specimens smaller than 20 mm CL are caught in depths shallower than 250 m. Individuals with 21-30 mm CL are collected mostly between 250 and 350 m depth, while the largest specimens mainly occur at greater depths. The presence of recruits throughout the year confirms that reproductive activity is almost continuous, although the largest recruitment seems to occur from July to October. Studies in the area demonstrated climate-related changes in recruitment success seem to be the key process driving the dynamics of this species in the GSA 09 (Tyrrhenian-Ligurian Sea). In GSA 7 the species is at very low abundance.

In GSA10 areas with significant aggregation of deep water pink shrimp recruits were mainly localised off Cape Bonifati, using geostatistical methods (Lembo et al., 2000b) and data from autumn surveys carried out along the Italian coasts (GRU.N.D. surveys; Relini, 2000). Using MEDITS data, significant nuclei of P. longirostris recruits, with a threshold of 610 N/km^2, were located in late spring-early summer northern off Procida and Ischia Island, off Tropea (Calabria coasts) and Cefalù (North Sicily). In these areas the probability of finding a nursery reached about 90% (Lembo et al., 2010). Recruitment follows a quasi continuous pattern with main peaks in spring and autumn. Recruits mainly occur between 100 and 200 m depth. Size of recruits ranged between 14 mm and 19 mm CL.

In GSA11 the small specimens are mostly found at depths between 100 and 200 m during spring time. The area with higher persistence was localised offshore Capo Pecora, though nuclei of recruits' aggregation were also identified off-shore Capo caccia, Cagliari and Orosei Gulf.

In the Strait of Sicily (GSAs 15-16), the young of the year (carapace length (CL) < 18 mm) appear all year around but the peak of recruitment is in autumn. Two stable nursery areas are identified: one along the 200 m isobath in the waters off the central coast of Sicily, the other one located on Malta Bank east to northeast of Malta, at a depth range of 200-400m.

In GSA 17 juveniles were found throughout the distribution grounds of the species (Manfredi, 2011).

In the Eastern Mediterranean recruits have been found, depending on the study area, during the whole year. The range of their carapace length varied from 7 to 20 mm. Bottom settlement occurs at around 100 m depth, although they can be detected in deeper depths, up to 300 m.

In GSA18 nursery of P. longirostris were localised south of Manfredonia Gulf, offshore the coast between Monopoli and Brindisi and along the border of Otranto Channel (Lembo et al., 2010). Recruitment follows a quasi continuous pattern with main peaks in spring and autumn. Recruits of deep-water rose shrimps mainly occur between 100 and 200 m depth. Recruitment size ranges between 16 mm and 20 mm CL.

In GSA 19 the deep-water rose shrimp was collected at depths ranging from 18 to 711. The minimum and maximum sizes were 5 and 49 mm CL. Mature individuals ranged between 11 and 19 mm CL. Nursery areas of P. longirostris were frequently detected on the shelf and shelf break between Otranto and Santa Maria di Leuca, offshore Torre Ovo, around the Amendolara Bank, in the Gulf of Squillace, offshore Punta Stilo and Siracusa. However, the more persistent nursery area was identified on the shelf between Otranto and Santa Maria di Leuca.

Spawning

In GSA 5 spawning takes place all year around with two peaks, one in spring-summer and another in autumn (Guijarro et al., 2009). The length at first maturity of females of this species is 28 mm of carapace length (Guijarro et al., 2009).

In GSA9 ripe females were found throughout the year with two maxima of activity, one in spring and another at the beginning of autumn. The smallest females found with ripe ovaries measured 16 mm CL; the size at onset of sexual maturity ranges from 20 to 24 mm CL. In GSA 7 the size at first maturity ranges between 29.5 and 27.0 mm CL.

In GSA10, according to the data obtained from DCR in 2008, the maturity ogive was obtained from a maximum likelihood procedure. The fitting of the curve was fairly good, however the estimates of the size at first maturity L50% (18.7 cm ±0.06 cm) and of the maturity range (0.31 cm ±0.09 cm) seem underestimated if compared with literature values (average of the smallest females 24 mm CL). Similar estimates were obtained in DCF 2009 (L50%= 18.5 ±0.05; MR= 1.5 ±0.06) and 2010 (L50%= 18.6 ±0.15; MR= 1.27 ±0.22) when a GLM approach was used.

In GSA 11 the reproductive period lasts all year with two peaks in April June and September–February respectively. Length at first maturity of females is reached at about 25 mm of CL. Mature females of the deep-water pink shrimp are observed in the GSA 15+16 throughout the year with two maturity peaks, one extending from November to February and another one in April. Estimates of length at maturity (Lm50%) in GSA 15+16 are within the range 21.5-24 mm CL for females and 15-19 mm CL for males. Two stable spawning areas are identified, one on the southeastern side of Adventure Bank, located between the shelf break and the upper slope, and one on Malta Bank lying in the north-eastern boundary of GSA 15, partly overlapping with the nursery ground.

It is important to consider that the spawning ground of the population identified in GSA 17 is only a fraction of a bigger population living in the south Adriatic Sea.

In GSA18, according to the data obtained from DCR in 2009, the maturity ogive was obtained from a maximum likelihood. The fitting of the curve was fairly good, however the estimates of the size at first maturity L50% (18.4 cm ±0.04 cm) and of the maturity range (1 cm ±0.05 mm) seem underestimated if compared with literature values (average of the smallest females 24 mm CL). Slightly higher estimates were obtained in DCF 2010 (L50%= 20.3 ±0.11; MR= 2.5 ±0.13) when a GLM approach was used.

In GSA 19 the deep-water rose shrimp showed an extended reproductive period between late spring and autumn. The highest percentage of mature females was recorded during autumn. The smallest mature female and male were 13 mm CL. The size at first maturity of females was 26 mm CL. Up to date, no spawning areas were detected for *P. longirostris* in the basin, however 2 aggregation areas for adults specimens were detected offshore Gallipoli and Roccella Ionica.

In Aegean Sea mature (GSAs 22-23) females occur during the whole year with two main spawning peaks: late spring and autumn - winter.

2.2.5.9.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.9.1 and 2.2.5.9.2 list the frequency of positive hauls and the number of blue and red shrimp specimens caught during MEDITS in each GSA. Recruitment and maturity sizer are indicated in Table 2.2.5.9.3.

GSA 1-6, 5

In the GSA 05 data are available from 2007 to 2010 and from 1994 to 2010 in GSAs 01 and 06. The amount of positive hauls is low in the three Spanish GSAs, varying from 0.10 to 0.16 in the GSA 05 and from 0.11 to 0.32 in the GSA 01 and 06. The amount of specimens is highly variable ranging from 27 to 244 in the GSA 05 and from 44 to 2371 in the GSA 01 and 06.

Following the protocol developed in the R_RSI_MEDISEH script, we applied the Bhattacharya's method to extract the first modal component of the length-frequency distribution of *P. longirostris*, on a yearly basis. The mean length of the first modal component plus the standard deviation was applied as a threshold value of total length. This threshold and the swept area of each haul were used to calculate the standardized abundance index of recruits (n/km^2). If differences in the length frequencies between GSAs were observed, the method was applied separately in each GSA.

The spawning fractions of females were extracted by means of the length at first maturity (L50 or length at which 50% of the individuals are mature) obtained from published literature.

GSA 7, 8, 9

In GSA7 *P .longirostris* was rarely caught (frequency of positive hauls from 0.04 to 0.15, except in 2010, with 0.28). In GSA8 the frequency of positive hauls ranged from 0.14 to 0.55, while in GSA9 it varied from 0.35 to 0.68, showing a clear increasing temporal trend.

The number of specimens caught in the different years in GSA7 was scarce; in GSA 8 it ranged from 17 to 238. Only in GSA9the catches of this species were abundant; they ranged from 541 to 8247 specimens, showing a clear temporal trend.

Only in GSA9 it was possible to observe the presence of recruits, whereas in GSAs 7 and 8 this demographic fraction was negligible. Therefore, the identification of recruits was performed only in GSA9, using the Bhatthacharya approach. The cutoff size resulted ranged from 13.3 to 18.7 mm CL.

Females greater than 25 mm CL were selected as spawners in the three GSAs, according to the maturity size of the species reported in literature for GSA9.

GSAs 10, 11, 18, 19

The frequency of positive hauls for *P. longirostris* in GSA10 ranged between 0.47 (MEDITS 1996) and 0.74 (MEDITS 2008), with an overall catch fluctuating from a minimum of 830 (MEDITS 1994) and a maximum of 6251 (MEDITS 2005) sampled specimens. The frequency of positive hauls for *P. longirostris* in GSA11 ranged between 0.19 (MEDITS 1994) and 0.40 (MEDITS 1999), with an overall catch fluctuating from a minimum of 349 (MEDITS 1995) and a maximum of 1604 (MEDITS 1998) sampled specimens. The frequency of positive hauls for *P. longirostris* in GSA18 ranged between 0.13 (MEDITS 1994 and 1995) and 0.88 (MEDITS 2005), with an overall catch fluctuating from a minimum of 69 (MEDITS 1994) and a maximum of 7990 (MEDITS 2005) sampled specimens. The overall catch of deep-water rose shrimp in the North-Western Ionian Sea varied between 2154 and 9953 specimens collected during MEDITS 2000 and MEDITS 2009, respectively. The frequency of positive hauls of *P. longirostris* in the GSA19 fluctuated from a minimum and a maximum value of 0.28 and 0.57, respectively.

In GSAs 10, 11, 18 and 19, the recruitment has been identified in an annual basis according to ability of the survey to intercept the phenomenon. The threshold to separate the recruits has been generally estimated as the mean length of the first modal component + 2* sd (in some cases +1* sd) using the Bhattacharya's method and the Routine R_RSI, specifically developed for the Mediseh project. In some cases an empirical value was used, when separate modes in the distributions could not be identified.

To identify the adults or potential spawners, an average of the parameters of the maturity ogive among the years from the MEDITS survey and/or from biological samplings of DCR and DCF has been used in GSAs 10 and 18, selecting those better fitting to the model. An empirical cut-off value of 26 mm CL was adopted for GSA19 and 25 mm for GSA11.

GSA 15-16

P.longirostris is among the most abundant species in the Strait of Sicily. Catches during MEDITS surveys were significant both in terms of abundance (between 10987 and 40689 total number of specimens) and spatial coverage (67% of positive hauls on average). Recruits of P. longirostris were identified using the Bhattacharya approach (mean length of the first modal component + 1sd). The cutoff size selected was between 17 and 21 mm CL. The spawning fraction of the population was identified using the Lm50% estimate of maturity ogives for females (23 mm CL) obtained from biological sampling of commercial catches (DCF).

GSA 17

In GSA 17 MEDITS data deep-water rose shrimp is quite abundant with usually more than 30% of positive hauls and an average of almost 3,000 specimens collected each year. The approach employed to detect the recruits was the Bhattacharya, which identified threshold sizes comprised between 1.4-1.8 cm of carapace length. The threshold length (L50 = 2.4 cm) used to detect the spawners was based on Relini et al., (1999).

GSA 20, 22-23

In Greek GSAs the available data for deep water rose shrimp that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 and in GSAs 22_23 the proportion of positive hauls for deep water rose shrimp ranged from 50-70%, with fluctuating catches in each GSA. Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards. The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates following the aforementioned approaches, threshold values were established based on literature information and expert knowledge.

Table 2.2.5.9.1. Frequency of positive MEDITS hauls (n of positive hauls/total number of hauls) for deep-water rose shrimp by GSA and year.

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.04	0.19	0.39	0.48	0.19		0.13	0.53			0.11		
1995		0.06	0.14	0.35	0.48	0.21		0.13	0.41			0.20		
1996				0.36	0.47	0.24		0.45	0.46			0.17		0.55
1997		0.00	0.31	0.46	0.52	0.24		0.46	0.57			0.11		0.52
1998		0.04	0.22	0.50	0.56	0.37		0.53	0.43	0.63		0.20		0.56
1999		0.09	0.35	0.54	0.60	0.40		0.48	0.28	0.63		0.25		0.59
2000		0.09	0.59	0.58	0.65	0.35		0.56	0.34	0.59		0.27		0.58
2001		0.08	0.45	0.52	0.67	0.30		0.73	0.31	0.59		0.24		0.55
2002		0.08		0.52	0.53	0.20	0.39	0.78	0.39			0.24		
2003		0.08	0.30	0.52	0.63	0.35	0.35	0.74	0.37	0.69		0.19	0.65	0.61
2004		0.15	0.36	0.58	0.60	0.29	0.35	0.87	0.30	0.66		0.23	0.71	0.53
2005		0.06	0.52	0.60	0.73	0.24	0.41	0.88	0.33	0.63	0.56	0.18	0.71	0.59
2006		0.07	0.52	0.50	0.69	0.26	0.41	0.80	0.34	0.63	0.36	0.20	0.72	0.59
2007	0.12	0.03	0.55	0.62	0.59	0.24	0.30	0.68	0.46		0.36	0.15	0.55	
2008	0.10	0.04	0.36	0.55	0.74	0.25	0.29	0.64	0.44	0.56	0.19	0.16	0.65	0.6
2009	0.16	0.08	0.45	0.64	0.70	0.26	0.23	0.74	0.47		0.48	0.32	0.70	

	GSA												
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
2010	0.14	0.28	0.45	0.68	0.63	0.25	0.25	0.63	0.56		0.41	0.19	0.67	

Table 2.2.5.9.2. Number of specimens caught during MEDITS by GSA and year.

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		7	28	541	830	415		69	3652			601		
1995		7	62	746	1405	349		131	5483			2815		
1996		0		575	906	508		6863	3780			5785		24767
1997		0	17	1274	2391	1216		2839	5261			7460		18985
1998		3	64	3821	3488	1604		4058	7407	1227		18171		16543
1999		30	106	5702	5813	1581		1733	2959	1901		8561		26989
2000		28	241	3482	5020	1128		2136	2154	2249		18227		23196
2001		27	149	1616	3574	1072		3832	2264	1939		14720		19127
2002		8		1759	2139	766	4822	2967	3840			11780		
2003		23	58	1658	2912	1267	5898	4171	5494	3372		2079	18355	31845
2004		82	132	2831	2955	839	3168	4746	4388	4225		6635	40689	28648
2005		30	113	3334	6251	559	3455	7990	4744	7276	579	2188	18360	27930
2006		27	140	3355	6203	890	3627	3992	5836	3238	173	3779	40516	36540
2007	27	14	88	1520	1526	373	2412	1809	4102		49	3094	10987	
2008	208	12	219	4136	3210	431	1700	4965	7135	3829	189	4165	31704	16561
2009	150	49	168	3612	2994	701	745	6539	9953		427	20124	47174	
2010	244	101	238	8274	4762	933	1052	4589	9125		134	10118	29366	

Table 2.2.5.9.3. Recruitment and spawning size identification for modeling purposes.

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (CL mm)**	**Data source**	**Method used**	**Mean maturity length (CL mm) /Maturity stage**
05	1994-2010	MEDITS from GSAs 01 and 06	Bhattacharya	11.4	Guijarro *et al.* (2009)	Fixed threshold length (L_{50})	28.5
01	1994-2000, 2002,2004, 2007, 2009-2010	MEDITS	Bhattacharya	14.1	Guijarro *et al.* (2009)	Fixed threshold length (L_{50})	28.5
06	1995, 2009	MEDITS	Bhattacharya	13.5	Guijarro *et al.* (2009)	Fixed threshold length (L_{50})	28.5
7	1994-2010	No recruits were present in the catches			DCF/MEDITS	Fixed threshold length (L_{50})	25

		Recruits			Spawners		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (CL mm)**	**Data source**	**Method used**	**Mean maturity length (CL mm) /Maturity stage**
8	1994-2010	No recruits were present in the catches			DCF/MEDITS	Fixed threshold length (L_{50})	25
9	1994-2010	DCF/MEDITS	Bhattacharya	Fixed threshold length (L_{50})	DCF/MEDITS	Fixed threshold length (L_{50})	25
10	1994-2010	MEDITS	Cut-off size calculated as average of Bhattacharya mean length from the years 1994, 1997, 1999, 2000, 2003, 2004	14.5	MEDITS and biological sampling	Maturity ogive	18
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya	16.2	MEDITS	Fixed threshold length (L50)	25
15+16	2003-2010			19.5	DCF	Fixed threshold length (L50)	23
17	2002-2010	MEDITS	Bhattacharya	16	Relini et al., 1999	Fixed threshold length (L50)	24
18	1994-2010	MEDITS	Cut-off size calculated as average of Bhattacharya mean length from the years 1994, 1997, 1999, 2000, 2003, 2004 from GSA 10	14.5	MEDITS and biological sampling	Maturity ogive	18
19	1994-2010	MEDITS	Bhattacharya	20	MEDITS	Fixed threshold length (L50)	26
20	1998-2008	MEDITS	Bhattacharya	10	MEDITS	Fixed threshold length (L50)	19

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (CL mm)**	**Data source**	**Method used**	**Mean maturity length (CL mm) /Maturity stage**
22_23	1996-2008	MEDITS	Bhattacharya	10	MEDITS	Fixed threshold length (L50)	19
25	2005-2010	MEDITS	Bhattacharya	12	MEDITS	Maturity stage	

Mapping of density and identification of hot spot areas

A summary of the spatial models implemented for mapping recruits and adults/spawners of blue and red shrimp is provided in Table 2.2.5.9.4

GSAs 1-6

The adult aggregations and recruits were modeled using GAMs. Two models were implemented independently, one for presence/absence data, and another for standardized abundances restricted to presence data only.

The final presence/absence model for recruits included depth, the interaction between longitude and latitude and year as significant factors, whereas the final abundance restricted to presence samples model included only year and depth. These models explained 29 and 32% of the total variance, respectively. The very low abundance of recruits northwards 39ºN, restricted the models southwards this latitude. The predictions showed that recruits are predicted to be mostly located in the GSA 01, around cape Gata. Similarly to spawners, recruits showed very low abundance during some periods (e.g. 2003-2008). The bathymetric distribution was different depending on the model, presence/absence showing a maximum at 150-250 m, while the highest abundance was observed at the shallowest depth surveyed up to 200 m, with a decreasing trend below this depth. Both the final presence/absence and abundance models for spawners included depth, interaction between longitude and latitude and year as significant factors, these models explaining 46 and 41% of the total variance, respectively.

GSA 5

In the GSA05, the recruits and the spawners of *P. longirostris* were not modeled due to the low amount of individuals captured. In the GSA 05, a clear decreasing trend in its abundance has been observed over the last years. Large fluctuations observed may be due not only to environmental conditions that greatly affect this short life span and fast growing species, but also to the different exploitation rates over the years.

GSA 7, 8, 9

It was possible to apply the modeling approach to map distribution of recruits and spawners only in GSA9, while for GSA7 and GSA8, due to the low catches, bubble plot maps were used to show the distribution of spawners.

The modeling approach used to map recruits in GSA 9 was s a simplified Bayesian kriging with the INLA approach which uses the Matèrn function. The period covered was 1996-2010.

Spawners in GSA 9 were modelled using GAM with spatial component, fixed intercept, year effect and smooth function on the bottom stepness as covariate for the period 1994-2010. A spherical covariance function was applied in most of the years.

GSA 10

In GSA10-11-18-19 annual abundance values were predicted by means of a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not perform well, ordinary kriging was applied on real abundance values. The analysed period was from 1994 to 2010. The models goodness-of fit was measured by the cross-validation index. The density hot spots were found using the local G statistic.

GSA 15-16

Recruit distribution of *P.longirostris* was modeled in GSA 15+16 using a GLM with spatial component and a linear trend on the covariate Distance from the coast. Both the intercept and the spatial component were supposed to change each year. The spawners were modeled in GSA 15+16 using a GLM with spatial component and a second order trend on the covariate Distance from the coast. Both the intercept and the spatial component were supposed to change each year.

The models goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km. The persistence was obtained as the rate of years in which a point was a hot spot.

GSA 17

Modeling approaches employed to identify nursery and spawning grounds of deep-water rose shrimp in GSA 17 were the zero-Inflated Generalized Additive Model (Liu and Chan, 2010) and local G statistic (Getis and Ord, 1992), respectively to define the spatial distribution and the hot spots, considered as the place where high values of densities cluster together. The covariates employed to identify the spatial patterns of recruits and spawners of deep-water rose shrimp were year (as factor), latitude, longitude and depth.

The diagnostics of the ZIGAM model employed for recruits and spawners of deep-water rose shrimp in GSA 17 (Table 2.5.1.4) show a better fitting for recruits, although the model results seems appropriate also for the spawners.

GSA 20, 22-23

Generalized Additive Models were employed to model the distribution of red and blue shrimp in GSA 22_23 and GSA 20. The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots.

In GSA 22-23 the analysed period was from 1996-2008 and the depth distribution of red and blue shrimp recruits and adults was very similar and ranged from 45 - 730 m. In GSA 20 the analysed period was from 1998-2008 and the depth distribution of red and blue shrimp adults ranged from 65 - 620 m. No modeling could be applied for recruits in GSA 20 due to the low number and the local distribution of of specimens caught.

GSA 25

In GSA 25, attempts of modeling have been undertook for recruits and spawners of deep water rose shrimp, but as is possible to observe in ANNEX 2, both geo-statistical and GAM methods did not provide any appropriate result. The few positive hauls in each annual survey and their relatively high distance did not allow to implement any reasonable model (no spatial covariance can be estimated).

Table 2.2.5.9.4. Model developed in EU GSAs for mapping recruits and spawners of deep-water rose shrimp. CV=Cross Validation Index.

Life stage	GSA	Depth range (m)	Period	Model type	Covariates	% Deviance explained	Goodness of fit (R^2)

<table>
<tr><th>Life stage</th><th>GSA</th><th>Depth range (m)</th><th>Period</th><th>Model type</th><th>Covariates</th><th colspan="2">% Deviance explained</th><th colspan="2">Goodness of fit (R^2)</th></tr>
<tr><td rowspan="2">Recruits</td><td rowspan="2">01, 06</td><td rowspan="2">25-600</td><td rowspan="2">1995-2004, 2006-2007, 2009-2010</td><td>Pres./Abs.</td><td>Year, (Lon, Lat), depth</td><td colspan="2">29</td><td colspan="2" rowspan="2">0.21</td></tr>
<tr><td>Abundance</td><td>Year, depth</td><td colspan="2">31.8</td></tr>
<tr><td rowspan="2">Spawners females</td><td rowspan="2">01, 06</td><td rowspan="2">50-600</td><td rowspan="2">1994-2010</td><td>Pres./Abs.</td><td>Year, (Lon, Lat), depth</td><td colspan="2">46.4</td><td colspan="2" rowspan="2">0.48</td></tr>
<tr><td>Abundance</td><td>Year, (Lon, Lat), depth</td><td colspan="2">41.3</td></tr>
<tr><td rowspan="3">Recruits</td><td rowspan="3">10</td><td rowspan="3">10-500</td><td rowspan="3">1994-2010</td><td>Gaussian GAM</td><td>Depth</td><td colspan="2">26.1</td><td colspan="2">0.23</td></tr>
<tr><td>Binomial GAM</td><td>Depth</td><td colspan="2">30.7</td><td colspan="2">0.34</td></tr>
<tr><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td>Spawners</td><td>10</td><td>10-800</td><td>1994-2010</td><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Recruits</td><td rowspan="3">11</td><td rowspan="3">10-800</td><td rowspan="3">1995-2010</td><td>Gaussian GAM</td><td>Depth</td><td colspan="2">31.6</td><td colspan="2">0.2</td></tr>
<tr><td>Binomial GAM</td><td>Depth</td><td colspan="2">28.1</td><td colspan="2">0.18</td></tr>
<tr><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Spawners</td><td rowspan="3">11</td><td rowspan="3">10-800</td><td rowspan="3">1994-2010</td><td>Gaussian GAM</td><td>Depth</td><td colspan="2">0.56</td><td colspan="2">0.06</td></tr>
<tr><td>Binomial GAM</td><td>Depth</td><td colspan="2">50.4</td><td colspan="2">0.55</td></tr>
<tr><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td>Recruits</td><td>18</td><td>10-800</td><td>1996-2010</td><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Spawners</td><td rowspan="3">18</td><td rowspan="3">10-800</td><td rowspan="3">1996-2010</td><td>Gaussian GAM</td><td>Depth</td><td colspan="2">12.3</td><td colspan="2">0.1</td></tr>
<tr><td>Binomial GAM</td><td>Depth</td><td colspan="2">15.7</td><td colspan="2">0.18</td></tr>
<tr><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Recruits</td><td rowspan="3">19</td><td rowspan="3">10-800</td><td rowspan="3">1996-2010</td><td>Gaussian GAM</td><td>Depth</td><td colspan="2">17.9</td><td colspan="2">0.15</td></tr>
<tr><td>Binomial GAM</td><td>Depth</td><td colspan="2">52.8</td><td colspan="2">0.52</td></tr>
<tr><td>Ordinary Kriging</td><td colspan="5"></td></tr>
<tr><td>Spawners</td><td>19</td><td>10-800</td><td>1994-2010</td><td>Ordinary Kriging</td><td colspan="5">Depth</td></tr>
<tr><td>Recruits</td><td>9</td><td>40-700</td><td>1994-2010</td><td>Bayesian kriging</td><td></td><td colspan="2"></td><td colspan="2">CV=0.49
0.87</td></tr>
<tr><td>Spawners</td><td>9</td><td>40-700</td><td>1994-2010</td><td>GAM</td><td>Latitude, slope</td><td colspan="2"></td><td colspan="2">CV=1.02
0.43</td></tr>
<tr><td>Recruits</td><td>15+16</td><td></td><td>2003-2010</td><td>GLM with spatial component</td><td>Year, Distance from the coast</td><td colspan="2"></td><td colspan="2">CV=1.202
0.532</td></tr>
<tr><td>Spawners</td><td>15+16</td><td>500-800</td><td>2003-2010</td><td>GLM with spatial component</td><td>Year, Distance from the coast</td><td colspan="2"></td><td colspan="2">CV=0.999
0.648</td></tr>
<tr><td rowspan="2">Spawners</td><td rowspan="2">17</td><td rowspan="2">10-600</td><td rowspan="2">2002-10</td><td rowspan="2">ZIGAM</td><td rowspan="2">Year, Lon, Lat, depth</td><td>LR</td><td>GAM</td><td>LR</td><td>GAM</td></tr>
<tr><td>58.9</td><td>67.3</td><td>0.43</td><td>0.54</td></tr>
<tr><td rowspan="2">Recruits</td><td rowspan="2">17</td><td rowspan="2">10-600</td><td rowspan="2">2002-10</td><td rowspan="2">ZIGAM</td><td rowspan="2">Year, Lon, Lat, depth</td><td>LR</td><td>GAM</td><td>LR</td><td>GAM</td></tr>
<tr><td>63.9</td><td>57.3</td><td>0.49</td><td>0.64</td></tr>
<tr><td>Recruits</td><td>22_23</td><td>45-730</td><td>1996-2008</td><td>GAM (delta lognormal)</td><td>Year, Lon, Lat, depth</td><td colspan="2">32.3</td><td colspan="2">0.24</td></tr>
<tr><td>Spawners</td><td>22_23</td><td>45-715</td><td>1996-2008</td><td>GAM(delta lognormal)</td><td>Year, Lon, Lat, depth</td><td colspan="2">63.0</td><td colspan="2">0.58</td></tr>
</table>

Life stage	GSA	Depth range (m)	Period	Model type	Covariates	% Deviance explained	Goodness of fit (R^2)
Spawners	20	65-620	1998-2008	GAM(delta lognormal)	Year, Lon, Lat, depth	71.7	0.64

*Cross-validation Index

2.2.5.9.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.9.5 summarizes the main environmental features of the most persistent areas identified for deep-sea pink shrimp in European GSAs. For further details see at http://mareaproject.net/mediseh/viewer/med.html.

GSA 1-6, 5

Persistent density hot-spots for recruits were detected in the GSA 01, around Cape Gata, in the Gulf of Almeria and in some parts of the Gulf of Vera, the higher persistence being found in the Gulf of Almeria (Fig. 2.2.5.9.1). Regarding spawners, a large persistent density hot-spot was detected, covering almost the entire GSA 01 (Fig. 2.2.5.9.1).

The predictions showed that adult aggregations are predicted to be mainly located in the GSA 01 and the southern part of the GSA 06, from cape Palos to cap La Nao, with the highest abundance in the upper slope, between 200 and 400 m depth. It must be pointed out the very low abundance of spawners during some years (e.g. 1995, 2003, 2006 and 2007), probably due to environmental factors conditioning the high inter-annual variability in the population dynamics of this species

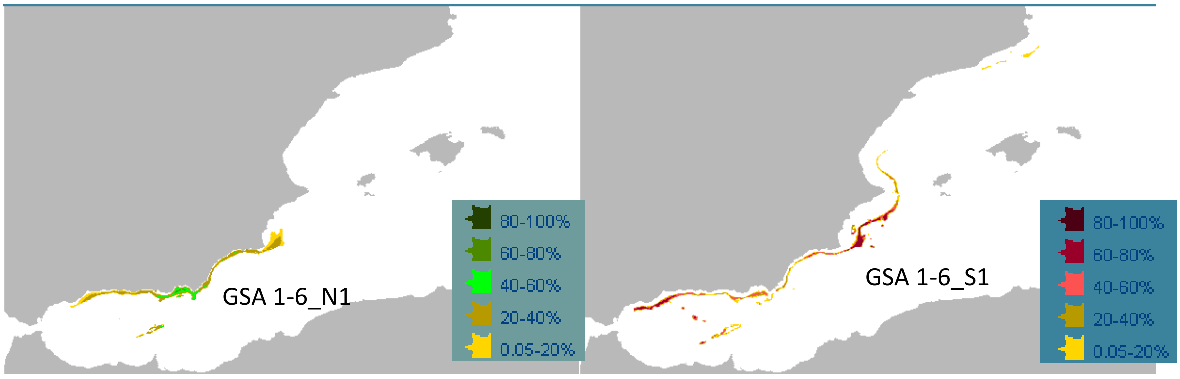


Fig. 2.2.5.9.1. Position of persistent nursery (left) and spawning areas (right) of deep-sea pink shrimp in GSAs 1-6.

GSA 9

In GSA9, nurseries of *P. longirostris* with the highest values of temporal persistency and recruit density were located south of the Isle of Elba (northern and central Tyrrhenian Sea), at depths ranging from 120 to 200 m (Fig. 2.2.5.9.2). These areas are often characterized by facies of the crinoid *Leptometra phalangium*. Recruits are also associated with juveniles of other commercial species, such as *Merluccius merluccius, Trisopterus minutus capelanus, Illex coindetii*.

Three main spawning areas have been detected in GSA9; as for the nursery areas, they were present south of the Elba Island. These areas occupy larger surface than the nursery areas along the shelf break and at the beginning of the continental slope (from 150 to 300 m depth). Other smaller high density patches of spawners are located north to Elba Island and in front of Latium coasts (Fig. 2.2.5.9.2).

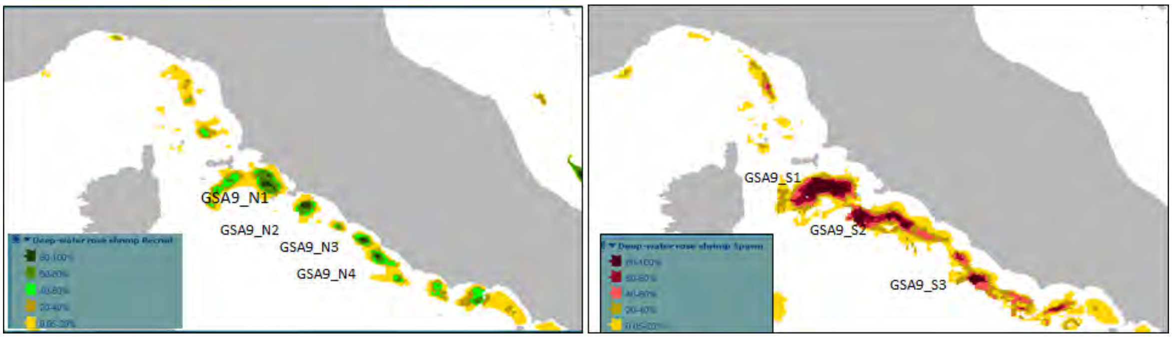


Fig. 2.2.5.9.2. Position of persistent nursery (left) and spawning areas (right) of deep-sea pink shrimp in GSA 9.

GSA 10

In the GSA10 the more persistent nurseries were localized in the Salerno Gulf (GSA10_N1) and in the Castellammare Gulf (GSA10_N2). These areas were also in overlap with spawning grounds (GSA10_S1; GSA10_S8). Spawning grounds were however more diffuse in the GSA, with other locations in which adult specimens potentially mature were persistently localized. These sites were off Capo Bonifati (GSA10_S3), a place already identified in previous studies (Lembo et al., 1999), in the Sant'Eufemia Gulf (GSA10_S4) and in the Patti Gulf (GSA10_S5, Fig. 2.2.5.9.3). In general the grounds are characterised by coastal terrigenous muds (VTC) and detritic bottom (DL) biocoenosis, depending on the zone and depth, inhabited from the shallower facies of Leptometra phalangium (along the shelf) and the deepest facies of Funiculina quadrangularis (along the slope). The direction of the mainstream current is parallel to the coast from south to north.

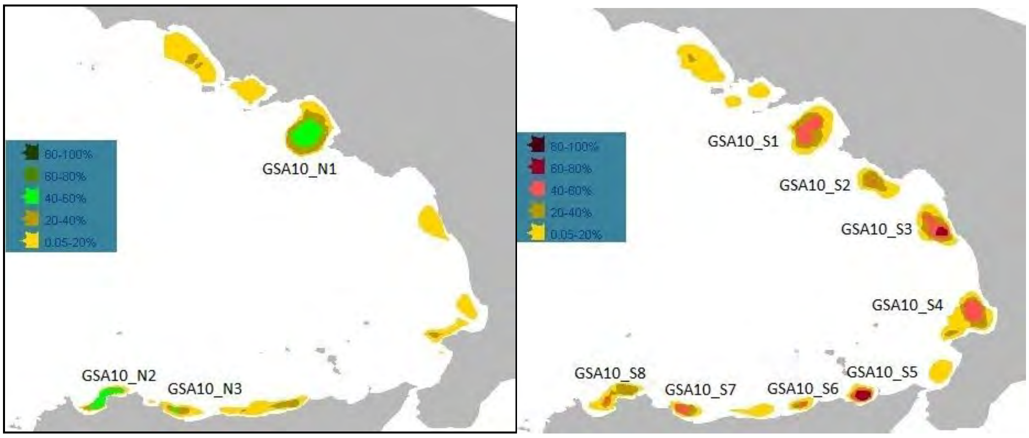


Fig. 2.2.5.9.3. Position of persistent nursery (left) and spawning areas (right) of deep-sea pink shrimp in GSA10.

GSA 11

Zone of high concentration of juveniles are mainly found in the south western coast of Sardinia (level of persistence 60-80 %) at 100-300 m depth, mainly 100-200 m (Fig. 2.2.5.9.4). The biocenosis prevalently present in these bottoms is the one of the crinoid *Leptometra phalangium*. A marked spawning area (level of persistence 80-100 %) is found in the southwestern coast of Sardinia at depth comprised around 200-550 m. Typical Biocenosis of bathyal mud characterizes this area.

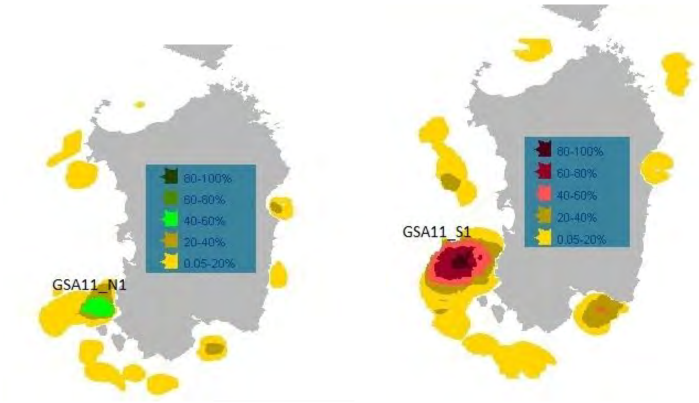


Fig. 2.2.5.9.4. Position of persistent nursery (left) and spawning areas (right) of deep-sea pink shrimp in GSA11

GSAs 15-16

Several persistent nursery areas of *P.longirostris* are observed on muddy bottoms of the outer shelf (up to 200 m), whereas spawning areas are located on adjacent and deeper bottoms (200-400 m). The distribution pattern of the persistent nurseries resembles the one observed for the nurseries of *M.merluccius*. Similarly to hake, nurseries are located to the east of the Adventure Bank (GSA15+16_N1), along the central southern coast of Sicily (GSA15+16_N2 and GSA15+16_N2), and east of Malta Bank at the border of the GSA 15 (GSA15+16_N4), always in correspondence of key hydrographic structures which act as enrichment, concentration and retention mechanisms (Fig. 2.2.5.9.5). On the other hand, the spawning grounds of the deep-water pink shrimp seem to be limited to one area east of the Adventure Bank (GSA15+16_S1 partially overlapped to the GSA15+16_N1) as well as to the area east of Malta Bank (GSA15+16_S2 partially overlapped to the GSA15+16_N4). Again in analogy to the hake case, GSA15+16_S2 and GSA15+16_N4 extend well beyond the eastern border of GSA 15 (area not covered in the present project) as reported in a previous study (Fig. 2.2.5.9.5)

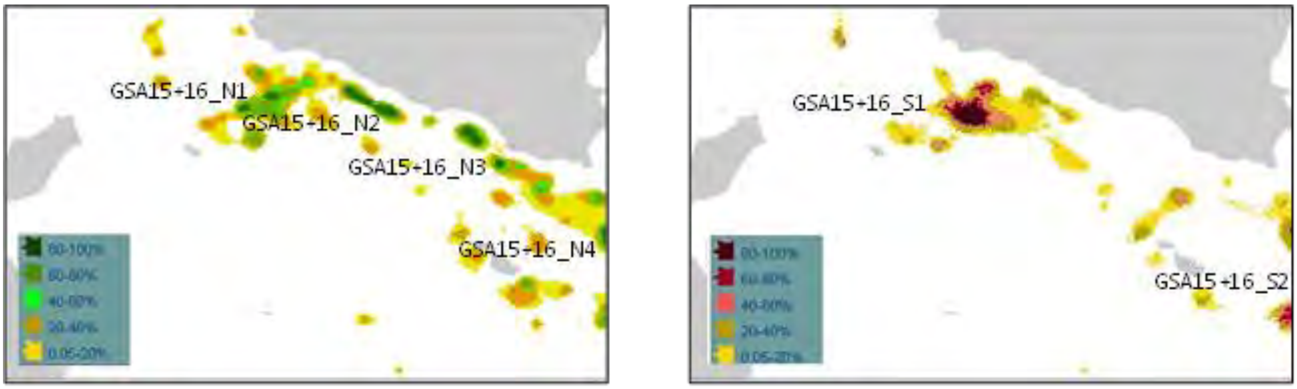


Fig. 2.2.5.9.5. Position of persistent nursery (left) and spawning areas (right) of deep-sea pink shrimp in GSA 15+16

GSA 17

The area of persistency identified for the recruits of deep-water rose shrimp in GSA 17 are essentially three. They are comprised between 100 and 400 m. R1 is located easthwards the Pomo/Jabuka Pit, R2 is located from southwards the Pomo/Jabuka Pit area to the limit of GSA17 and R3 extends 85 nm along parallel 45.5 N. R2 and R3 are connected with the nursery areas defined in the GSA18 (Fig. 2.2.5.9.6). The oceanographic features of these areas are characterized by deep water formed in the northern Adriatic region, cool and relatively fresh and water with higher temperature and salinity from the southern Adriatic. Vertical mixing between water masses is an extremely powerful dynamical process in the basin. The sediments present in these areas are constituted by recent mud; most of it is deposited in the basins of the Central Adriatic with a maximum accumulation rate for the Holocene on the average circa ½ mm per year. The area has been reported to be characterized by facies and associations with *Thenea muricata, Brissopsis lyrifera, Funiculina quadrangularis and Isidella elongate* (Gamulin-Brida, 1967.)

The area of persistency identified for the spawners of deep-water rose shrimp in GSA 17 is comprised between 100 and 200 m, located in the south-eastern side of the GSA in front of Croatian waters. The area is quite small and is connected with the spawning ground observed in GSA 18 with the same oceanographic and biotic features.

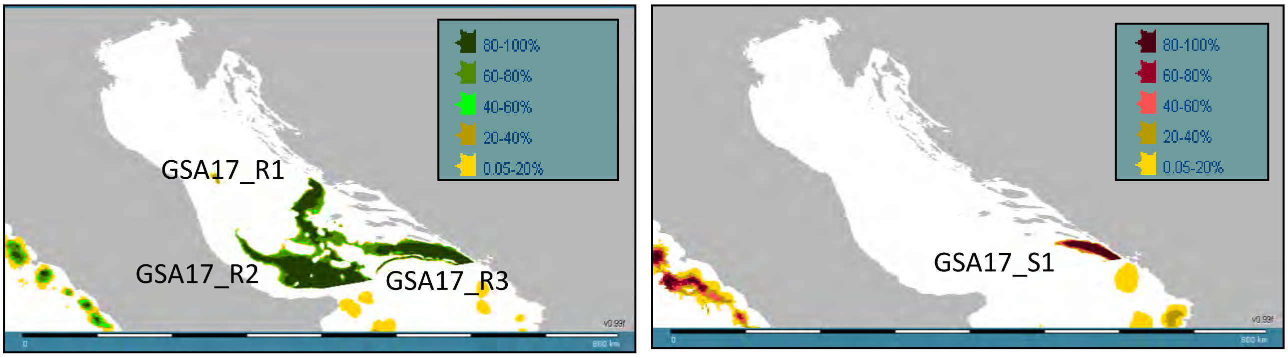


Fig. 2.2.5.9.6. Position of persistent nursery (left) and spawning areas (right) of deep-sea pink shrimp in GSA 17

GSA 18

Nursery areas, but especially adult aggregations of females are mainly located in the eastern part of the GSA18, along the Albania coast, where a persistent spawning ground is localized (GSA18_S1, Fig. 2.2.5.9.7). Details of the environmental characterization of the nursery grounds and adult aggregations are reported in details in the table 2.2.5.9.5. Warmer and saltier waters flowing in the eastern side are a favorable environmental condition for the preferential distribution of this species (Abellò et al., 2002).

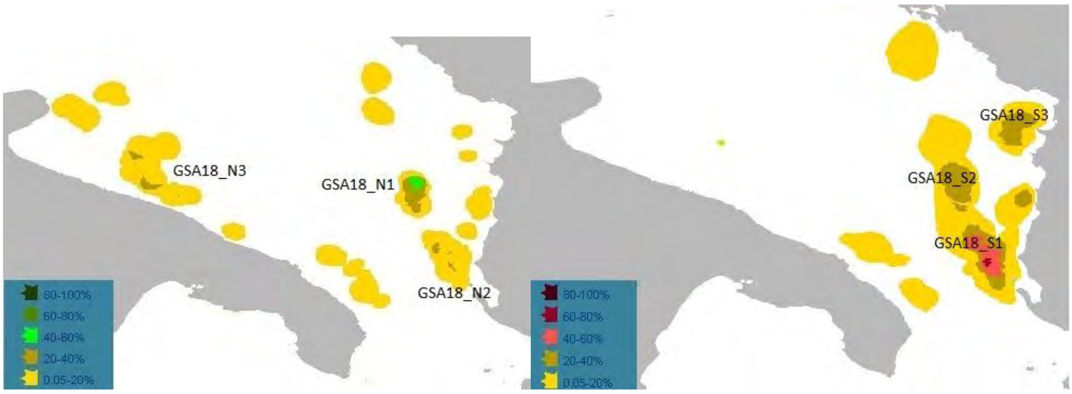


Fig. 2.2.5.9.7. Position of persistent nursery (left) and spawning areas (right) of deep-sea pink shrimp in

GSA 19

The nursery areas of *P. longirostris* in the GSA19 were mainly observed on the shelf and shelf break in the Gulf of Squillace and from Catania to Cape Passero (Fig. 2.2.5.9.8). The more persistent nursery areas were distributed on the shelf offshore Catanzaro, the shelf break-upper slope between Siracusa and Cape Passero. The spawning areas were distributed on deeper grounds compared to the nursery areas. In fact, the highest levels of persistency were detected for on the shelf break-upper slope south-eastern Santa Maria di Leuca, as well as offshore Gallipoli and Torre Ovo, eastern the Amendolara Bank, in the Gulf of Squillace and between Siracusa and Cape Passero.

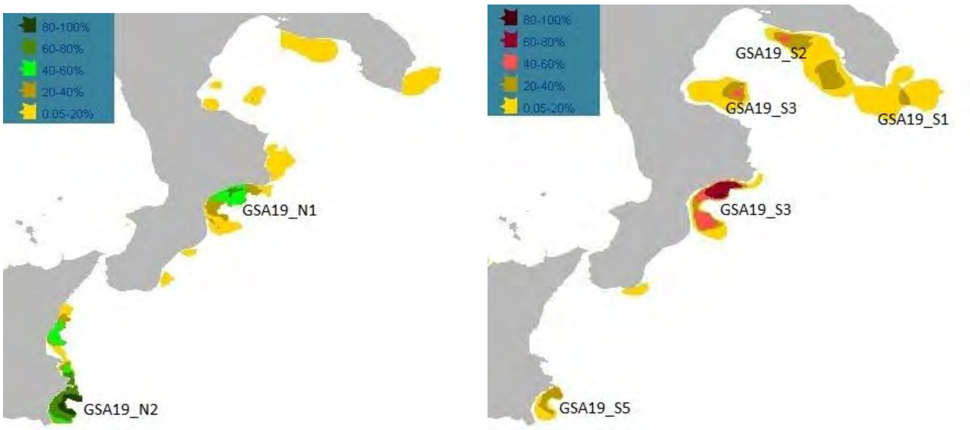


Fig. 2.2.5.9.8. Position of persistent nursery (left) and spawning areas (right) of deep-sea pink shrimp in GSA 19.

GSA 20, 22-23

The results of our analysis regarding the depth distribution of the deep water rose shrimp showed that the recruits of the species in GSAs 22_23 can be found in depths from 50 – 730 m. No areas with persistency over 80% were identified for recruits in the Aegean Sea. The areas with high persistency values were in deep areas in the west-central Aegean, in the Cretan shelf and in the Thracian Sea (north Aegean Sea, Fig. 2.2.5.9.9). Regarding the Ionian Sea no modeling could be applied due to the low number of specimens captured.

Regarding spawners of the deep water rose shrimp, the most persistent hot spots were identified in deep areas of the Cretan shelf and up to depths of 400m in that area. Less persistent areas were found in the south- east Aegean Sea and in the North Aegean. In the Ionian (GSA 20) the most persistent areas were identified at the southest part (relatively deep waters) of the surveyed area and in the central part of the surveyed area at depths not exceeding 250m between continental Greece and the island of Kefalonia (Fig. 2.2.5.9.10).

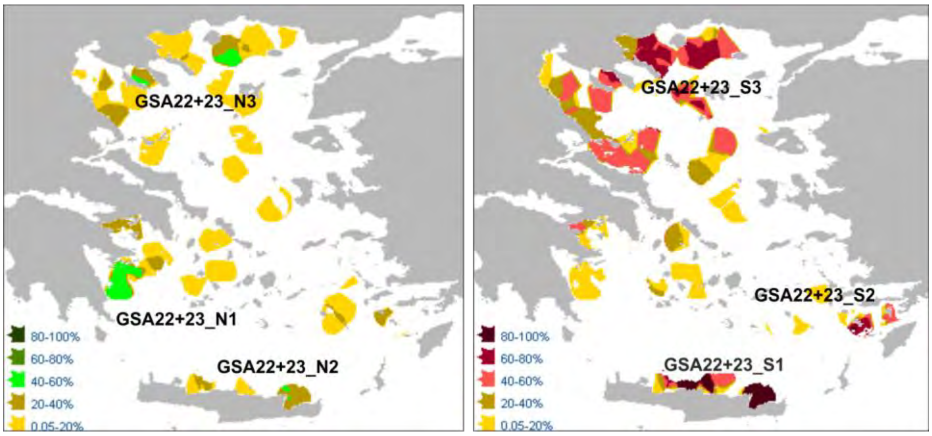


Fig 2.2.5.9.9. Position of persistent spawning areas of deep-sea pink shrimp in GSA 22-23.

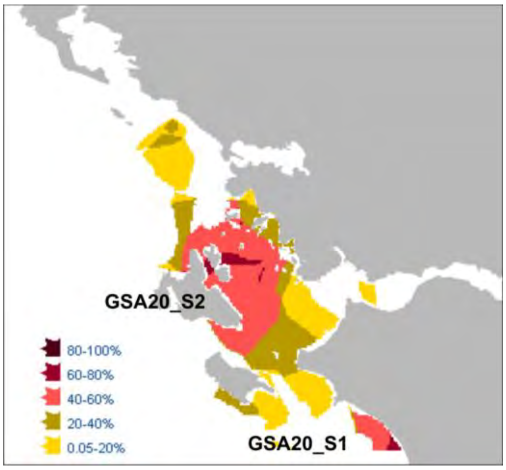


Fig. 2.2.5.9.10. Position of persistent spawning areas of deep-sea pink shrimp in GSA 20.

Table 2.2.5.9.5. Main environmental features of the most persistent areas identified for deep-sea pink shrimp in European GSAs

GSA	Type of area	Code	Depth range	Description
01	nursery	GSA01 and 06_N1	around 250 m	Around Cape of Gata in the Gulf of Almeria and some parts of Gulf of Vera Shelf break
01 and 06	Adult females aggregation	GSA01 and 06_S1	250-800 m	Big area covering almost all the GSA01 and the South of the GSA06 Shelf break-Upper slope
9	Nursery	GSA9_N1	90-120 m	Outer shelf close to Giglio Island, on a dense facies of *Leptometra phalangium* and high density of European hake juveniles.
9	Nursery	GSA9_N2	100-120 m	The area is located south of Giannutri Island
9	Nursery	GSA9_N3	100-130 m	Outer shelf North of Fiumicino under the influence of eutrophic Tevere freshwater input.
9	Nursery	GSA9_N4	90-115	Outer shelf South of Fiumicino under the influence of eutrophic Tevere freshwater input.
9	Adult females aggregation	GSA9_S1	200-400	Upper slope under the influence of Levantine saltier waterswith high values of persistence of spawners. Main associated species are *M. merluccius, Illex coindetii and Trisopterus minutus capelanus*.
9	Adult females aggregation	GSA9_S2	220-350	Wide areas of the North Turscany upper slope under the influence of Levantine waters and antyciclonic gyre, causing upwelling off-shore Bonifacio mouth.
9	Adult females aggregation	GSA9_S3	400-650	Middle slope of the Latium coasts.
10	nursery	GSA10_N1	77-125	The bottoms inside the Gulf of Salerno are characterized by coastal terrigenous muds (VTC) and detritic bottom (DL) biocoenosis inhabited from the shallower facies of *Leptometra phalangium* (along the shelf). The direction of the main current is parallel to the coast from south to north.
10	nursery	GSA10_N2	77-125	The bottom inside and outside of Castellamare Gulf is muddy with coastal terrigenous muds biocenosis (VTC). The characteristic species are *Alcyonium palmatum, Astropecten spp, Stichopus regalis*. The main current is from from east to west during the sampling period (spring).

GSA	Type of area	Code	Depth range	Description
10	nursery	GSA10_N3	115-139	The bottom is muddy characterized by coastal detritic biocenosis (DC) with an asteroids facies (*Astropecten irregularis, Astropecten bispinosus, Tethyaster subinermis*) associated with species as *Alcyonium palmatum, Suberites dumuncula, Stichopus regalis* etc. The main current is from east to west.
10	Adult females aggregation	GSA10_S1	158-366	The bottoms inside the Gulf of Salerno are characterized from coastal terrigenous muds (VTC) and detritic bottom (DL) biocoenosis inhabited from the shallower facies of *Leptometra phalangium* (along the shelf) and the deepest facies of *Funiculina quadrangularis* (along the slope). The main current is parallel to the coast from south to north.
10	Adult females aggregation	GSA10_S2	264-368	The bottom is muddy with detritic bottom (DL) biocoenosis with facies of crinoides Leptometra phalangium and associated species as *Cidaris cidaris, Stichopus regalis, Tethyaster subinermis* etc. The main current is parallel to the coast from south to north.
10	Adult females aggregation	GSA10_S3	123-359	The bottom is muddy with detritic bottom (DL) biocoenosis and facies of crinoides Leptometra phalangium and associated species as *Cidaris cidaris, Stichopus regalis, Tethyaster subinermis* etc. The main current is parallel to the coast from south to north.
10	Adult females aggregation	GSA10_S4	295-416	The bottom is muddy with deep muddy biocenosis (VP) and facies of Funiculina quadrangularis along the slope. The associated species are *Echinus spp, Actinauge richardi, Luidia sarsi* etc. The main current is parallel to the coast from south to north.
10	Adult females aggregation	GSA10_S5	235-444	The bottom is muddy with deep muddy biocenosis (VP) and facies of Funiculina quadrangularis along the slope. The associated species are *Echinus spp, Actinauge richardi, Luidia sarsi* etc. The main current is from east to west.
10	Adult females aggregation	GSA10_S6	107-120	The bottom is muddy characterized by the detritic bottom biocenosis (DL) with pennatulaceans facies (*Pteroides spinosus, Pennatula rubra* etc.) and associated species as *Galeodea echinophora, Stichopus regalis, Latrilia elegans*, etc. The main current is from east to west.
10	Adult females aggregation	GSA10_S7	114-337	The bottom is muddy characterized by coastal detritic biocenosis (DC) with an asteroids facies (*Astropecten irregularis, Astropecten bispinosus, Tethyaster subinermis*) associated with species as *Alcyonium palmatum, Suberites dumuncula, Stichopus regalis* etc. The main current is from east to west.
10	Adult females aggregation	GSA10_S8	107-621	The bottom is muddy characterized by the detritic bottom biocenosis (DL). The characteristic species are *Alcyonium palmatum, Astropecten spp, Stichopus regalis*. The main currents is from east to west.
11	nursery	GSA11_N1	100-300	The biocenosis prevalently present in these bottoms are those of the crinoid *Leptometra phalangium*
11	Adult females aggregation	GSA11_S1	200-550	Biocenosis of bathyal mud
15+16	nursery	GSA15-16_N1	130-200	Bathyal muds, facies with Funiculina quadrangularis The area is characterized by permanent upwelling and by the presence of a large cyclonic vortex, called Adventure Bank Vortex (ABV), a dominant feature linked to the meanders of Atlantic Ionian Stream (AIS) (flowing eastward up to 100 m depth). The mean value of SST observed in late spring-early summer changes from 21.5 to 21.7 when moving southwestward.

GSA	Type of area	Code	Depth range	Description
15+16	nursery	GSA15-16_N2	80-140	Bathyal muds. The area is characterized by permanent upwelling and by the presence of a 'stagnant point' (still water), where the AIS impinges the shore on the eastern side of the Adventure Bank. The mean value of SST observed in late spring-early summer changes from 21.4 to 21.7 when moving eastward
15+16	nursery	GSA15-16_N3	70-170	Bathyal muds, facies with Funiculina quadrangularis The main mesoscale oceanographic feature is a pronounced anticyclonic meander (Maltese Channel Crest-MCC) where the AIS detaches from the coast. The mean value of SST observed in late spring-early summer changes from 21.8 °C to 22.4 °C when moving southeastward
15+16	nursery	GSA15-16_N4	140-170	Bathyal muds, facies with *Funiculina quadrangularis* Persistent mesoscale structures in the area are the cyclonic Ionian Shelf Break Vortex (IBV) and the temperature and salinity fronts over the Ionian slope (Ionian Slope Front, ISF) located at the eastern boundary of IBV. The mean value of SST observed in late spring-early summer changes from 22.8 °C to 23 °C when moving southward.
15+16	Adult females aggregation	GSA15-16_S1	250-400	Bathyal muds, facies with sandy and gravel bottom. The area is characterized by permanent upwelling and by the presence of a large cyclonic vortex, called Adventure Bank Vortex (ABV), a dominant feature linked to the meanders of Atlantic Ionian Stream (AIS) (flowing eastward up to 100 m depth). The mean value of SST observed in late spring-early summer is 21.6-21.8 °C.
15+16	Adult females aggregation	GSA15-16_S2	220-250	Bathyal muds, facies with sandy and gravel bottom. Persistent mesoscale structures in the area are the cyclonic Ionian Shelf Break Vortex (IBV) and the temperature and salinity fronts over the Ionian slope (Ionian Slope Front, ISF) located at the eastern boundary of IBV. The mean value of SST observed in late spring-early summer changes from 22.8 °C to 23 °C when moving southward.
17	nursery	GSA17_R1	100-400	- muddy-sediments - mix of water masses - deep sea communities
17	nursery	GSA17_R2	100-150	- muddy-sediments - mix of water masses - deep sea communities
17	nursery	GSA17_R3	100-400	- muddy-sediments - mix of water masses - deep sea communities
17	Adult females aggregation	GSA17_S1	100-200	- look at GSA 18 section
18	nursery	GSA18_N1	269-301	The bottom is muddy characterized by the deep mud biocenosis (VP) with species as *Munida intermedia, Cidaris cidaris, Echinus spp, Macropipus tuberculatus* etc. and detritic bottom biocenosis (DL) with hidroids facies (*Nemertesia antennina, Lytocarpia myriophyllum*) and associated species as *Astropecten spp, Scaphander lignarius, Stichopus regalis Tethyaster subinermis* etc. The main current is from south to north.
18	nursery	GSA18_N2	153-322	The muddy bottoms are characterized by coastal terrigenous muds (VTC) biocenosis (*Alcyonium palmatum, Astropecten spp, Stichopus regalis Pennatula phosphorea* etc.) and the detritic bottom biocenosis (DL) inhabited by typical species as *Nemertesia antennina, Cidaris cidaris, Tetyiaster subinermis*. The main current is from north to south).

GSA	Type of area	Code	Depth range	Description
18	nursery	GSA18_N3	105-117	The bottom is muddy characterized by detritic coastal biocenosis (DC) with the characteristic species as *Alcyonium palmatum, Suberites dumuncula, Pennatula rubra Astropecte irregularis, Macropipus depurator* on the tanatocenosis of *Neopycnodonte cochlear*. The main current is from north to south).
18	Adult females aggregation	GSA18_S1	108-587	The sandy-muddy bottoms are characterized by coastal terrigenous muds (VTC) biocenosis (*Alcyonium palmatum*, *Astropecten spp*, *Stichopus regalis Pennatula phosphorea* etc.) and the detritic bottom biocenosis (DL) inhabited by typical species as *Nemertesia antennina, Cidaris cidaris, Tetyiaster subinermis.* Moreover it is possible to recognize in the area the deep mud biocenosis (VP) with characteristic species as *Munida intermedia, Macropipus tuberculatus, Polycheles typhlops, Geryon longipes* etc. The main current is from north to south).
18	Adult females aggregation	GSA18_S2	269-310	The bottom is muddy characterized by the deep mud biocenosis (VP) with characterized species as *Munida intermedia, Cidaris cidaris, Echinus spp, Macropipus tuberculatus* etc. and detritic bottom biocenosis (DL) with hidroids facies (*Nemertesia antennina, Lytocarpia myriophyllum*) and associated species as *Astropecten spp, Scaphander lignarius, Stichopus regalis Tethyaster subinermis* etc. The main current is from north to south).
18	Adult females aggregation	GSA18_S3	40-100	The bottom is muddy with coastal terrigenous muds biocenosis (VTC) with characteristic species as *Astropecten irregularis Stichopus regalis, Alcyonium palmatum Pteria hirundo, Turritella communis, Dorippe lanata* etc. The main current is from north to south).
19	nursery	GSA19_N1	117-173	The shelf offshore Catanzaro was characterized by the biocenosis of the terrigenous mud and shelf-edge detritic.
19	nursery	GSA19_N2	121-441	The shelf and shelf break-upper slope from Siracusa to Cape Passero was characterized by the terrigenous mud and bathyal muds biocenosis.
19	Adult females aggregation	GSA19_S1	264-346	The shelf break-upper slope south-eastern Santa Maria di Leuca was characterized by the biocenosis of the shelf-edge detritic and bathyal muds.
19	Adult females aggregation	GSA19_S2	313-378	The shelf break-upper slope offshore Gallipoli and Torre Ovo was characterized by the bathyal muds biocenosis.
19	Adult females aggregation	GSA19_S3	302-407	The upper slope eastern the Amendolara Bank was characterized by the bathyal muds biocenosis.
19	Adult females aggregation	GSA19_S4	107-431	The shelf break-upper slope in the Gulf of Squillace was characterized by the shelf-edge detritic and bathyal muds biocenosis.
19	Adult females aggregation	GSA19_S5	212-441	The shelf break-upper slope from Siracusa to Cape Passero was characterized by the shelf-edge detritic and bathyal muds biocenosis.
22_23	Adult females aggregation	GSA22-23_S1	50-400	Deep areas of the Cretan shelf (south Aegean). Main sediment type: mud
20	Adult females	GSA20_S1	50-400	Relatively deep area in the western coast of Peloponnesos. Substrate information not available.

GSA	Type of area	Code	Depth range	Description
	aggregation			
20	Adult females aggregation	GSA20_S2	50-250	Relatively shallow area in the part between continental Greece and the Ionian islands. Substrate information not available.
22_23	nursery	GSA22-23_N1	50-700	Off-coast deep areas of Argolikos gulf (western Aegean Sea). Main sediment type is mud but additional environmental characteristics of the area are largely lacking
22_23	nursery	GSA22-23_N2	100-300	Deep areas of the Cretan shelf (south Aegean). Main sediment type: mud
22_23	nursery	GSA22-23_N3	100-200	Deep areas of the Cretan shelf (south Aegean). Main sediment type: mud. Environmental characteristics are unavailable.
22_23	Adult females aggregation	GSA22-23_S1	50-400	Deep areas of the Cretan shelf (south Aegean). Main sediment type: mud. Environmental characteristics are unavailable.
22_23	Adult females aggregation	GSA22-23_S2	100-450	South-east Aegean Sea (Dodecanese complex). Relatively deep, saline (Levantine-origin) waters. Substrate information not available.
22_23	Adult females aggregation	GSA22-23_S3	250-650	Deep areas of the North Aegean Sea. Largely influenced by the inflow of Black Sea waters from the Dardanelles straits into the Aegean Sea. Main sediment type: mud

2.2.5.9.4 Gaps in knowledge and future actions

In the GSA05, the recruits and the spawners of *P. longirostris* were not modeled due to the low amount of individuals captured. There is a good amount of knowledge on the biology of the species in GSA 9. The dynamics of recruitment however needs to be better understood. Recruits are poorly caught during MEDITS, also due to the low catchability of the trawl net even with the small mesh size adopted during the survey.The impossibility to map recruits and spawners in GSA7 and GSA8 was due to the low abundance of the species in these areas. More investigations about the role of environmental preferences of the species would be required. No major gaps in the data of GSA 17 were identified. There is a good amount of knowledge on the biology of the species in GSA 10, 18 and 19, though more investigations about the role of environmental preferences of the species would be required. n GSA 20 and 22-23 nursery areas cannot be identified with precision as the timing of the MEDITS survey (June) does not allow for captures of deep water rose shrimp recruits, hence information is largely lacking.

Apart from the sediment type, environmental information for several small hot-spot areas is generally lacking in GSAs 22, 23 and 20. Although the large scale oceanographic features have been described, information at the local scale is poor and the prevailing environmental conditions in the identified hot-spot areas are hardly known. Nursery areas could not be fully identified due to the timing of the MEDITS survey (June). The spawning season is only partially covered by the survey; thus important spawning hot-spot areas may have not been identified. No information is available in GSA 25.

2.2.5.10 Nephrops norvegicus

2.2.5.10.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized. We should note that in GSA 25 Norway lobster was never caught during MEDITS.

Recruitment

Norway lobster is a mud-burrowing species that prefers sediments with mud mixed with silt and clay in variable proportions. In GSA 01 and 06 the highest abundances, both in numbers of individuals and in biomass, are located in the 200-500 m depth stratum (Abelló *et al.*, 2002). Recruitment takes places in spring-summer and autumn.

In GSA9 recruitment takes place in spring-summer and in autumn; recruits peak in abundance between 300 and 400 m depth over the upper slope and appear to move slightly deeper when they reach 30 mm carapace length.

In the GSA10 nursery areas of *N. norvegicus* were located in the Gaeta Gulf, off Cape Bonifati and in the Sant'Eufemia Gulf (Lembo et al., 2010). Recruitment follows a quasi continuous pattern with highly occurrence during the autumn season down to 300 m depth (Abelló *et al*., 2002); the size of recruits is around 30 mm CL.

Actually, there is little information regarding the recruitment of Norway lobster in GSA 11, though some nuclei with a higher density of Norway lobster recruits were identified along the souther-western side of the GSA at depth greater than 200 m.

In GSA18 higher abundance of Norway lobster were localized offshore Molfetta and Brindisi, along the centra-western side of the GSA (Lembo et al., 2010) . Recruitment follows a quasi continuous pattern and the size of recruits ranges between 17 mm and 27 mm CL (AA.VV. 2002).

In the North-Western Ionian Sea *N. norvegicus* was collected at depths from 43 to 908 m. The minimum and maximum sizes recorded in the GSA19 were 7 and 83 mm CL. The Norway lobster is a seasonal iteroparous. The recruitment occurred in autumn although the smallest individuals of *N. norvegicus* were captured in spring. The sizes of recruitment ranged between 12 and 26 mm CL. In the GSA19 the main aggregation areas for juveniles of *N. norvegicus* were frequently detected on the slope from 450 to 700 m between Gallipoli and Taranto, southern the Amendolara Bank and offshore Punta Stilo.

Recruitment of *N. norvegicus* occurs more or less continuously in the Strait of Sicily (GSAs 15-16) even though a stronger recruitment pulse is detected in autumn. The mean size of the first Gaussian component from the catch (about 22 mm CL) is well below the estimated size at 50% maturity, suggesting a precocious recruitment to the fishery. Recruitment follows an almost continuous pattern in GSA 17.

The recruitment period of the Norway lobster in the E. Mediterranean (GSA 20, 22-23) is also very long. Recruits have been found during winter, summer and spring, mainly in September. The length of the recruits ranged from 15-25 mm CL for males and 11-20 mm CL for females. The depth zones in which they found ranged from the shallower (~150-200 m) to the deeper ones (500-700 m).

Spawning

Females reach maturity at 29-30 mm CL in NW Mediterranean (GSAs 1-6, Abelló et al., 2002).

In GSA9 females mature at 30-33 mm CL o 35 mm CL; reproduction peak is between spring and summer, and females with external eggs are observed in autumn-winter. Maturity and fecundity of Norway lobster have been studied in the GSA 10 using trawl-survey data (1994-2004) collected in a ten years period (Carbonara et al., 2006). The maturity cycle is completed from late-spring summer through autumn, while ovigerous females are mainly found in late summer-early autumn season. The smallest ovigerous female was 23.5 mm carapace length. Length at first maturity was within 30.6-34.8 mm, depending on the year. The lower value was similar to findings in other Mediterranean areas (29.9 mm-32.1 mm). In Sardinian seas (GSA 11), a reproductive peak is observed in June, but the reproductive season ranges between April and

September. The breeding season lasts from September to January. The size at the onset of maturity of females is 33.5 mm of carapace length. The minimum size of ovigerous female is 28.5 mm of CL.

Norway lobster females in the Strait of Sicily (GSAs 15-16) undergo ovary ripening mainly in spring and spawn in summer-autumn, averaging a size at onset of maturity around 31 mm CL (which should correspond to an age of 4-5 years from hatching).

In GSA 17 *N. norvegicus* spawns once a year presenting a peak for females with mature ovaries in spring or at the beginning of summer. The size of mature females is quite different in different parts of the Adriatic (Pomo/Jabuka Pit and off Ancona) (Froglia and Gramitto, 1981), although berried females were found also in autumn, up to late spring (Vrgoc et al., 2004). Also differences in growth parameters among settlements in different areas have been observed (Froglia and Gramitto, 1981; Froglia and Gramitto, 1988; Vrgoč et al., 2004).

In GSA 18 the maturity cycle is completed from late-spring summer through autumn, when ovigerous females are also found. The size at first maturity estimated in SAMED (2002) using a logistic was 25.2 mm carapace length. According to the data obtained from DCR in 2008 (period 2006-2008), the proportion of mature females by length class gave an estimate of maturity ogive which indicates a L50% of about 24.5 cm (±0.08 mm; MR= 3.6 ±0.11) a value similar to DCF in 2009 (L50%= 24.2 ± 0.04; MR= 2.1 ± 0.05) using a maximum likelihood approach as well and to 2010 (L50%= 23.3 ± 0.04; MR= 1.9 ± 0.06) when the estimate was obtained using a GLM.

In the GSA 19 the females of Norway lobster bearing mature ovary presented a maximum in summer, while berried females were only observed during autumn (Capezzuto et al., 2009). The smallest mature female and male recorded in the North-Western Ionian Sea were 19 and 27 mm CL, respectively. Up to date, no spawning areas were detected for *N. norvegicus* in the basin.

The smallest mature female in Greek waters (GSAs 20, 22-23) ranged from 19 to 28 mm CL and that of the ovigerous females from 23 to 29 mm CL. The CL50%has been estimated at the range of 26,5-36 mm for the mature females and from 29,5 to 32 mm for the ovigerous females.

2.2.5.10.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.10.1 and 2.2.5.10.2 list the frequency of positive hauls and the number of blue and red shrimp specimens caught during MEDITS in each GSA. Recruitment and maturity sizer are indicated in Table 2.2.5.10.3.

GSAs 1-6, 5

The propostion of positive hauls is a bit lower in the GSA 05 than in the other Spanish GSAs, varying from 0.12 to 0.22 in the GSA 05 and from 0.17 to 0.35 in the GSA 01 and 06. The amount of specimens is highly variable in GSAs 01 and 06 but a bit more stable in the GSA 05, ranging from 239 to 563 in the GSA 05 and from 233 to 2977 in the GSA 01 and 06 (Table 2.5.11.1).

The length distribution and the amount of individuals per length-class did not allow computing Bhattacharya's method to obtain a threshold value and thus bibliographic information was used. The mean length of the first modal component plus the standard deviation was applied as a threshold value of total length. This threshold and the swept area of each haul were used to calculate the standardized abundance index of recruits (n/km^2). The spawning fractions of females were extracted by means of the length at first maturity (L50 or length at which 50% of the individuals are mature) obtained from published literature.

GSAs 7, 8, 9

In GSA7 the occurrence of *N. norvegicus* was rather low: the frequency of positive hauls ranged from 0.13 to 0.31. In GSA8 and GSA9 the species was more frequent; the occurrences ranged from 0.50 to 0.57 and from 0.42 to 0.51 in the two areas, respectively. The catches were more abundant in GSA9 (from 1317 to 3227 specimens) than in the other two GSAs.

A noticeable presence of recruits was recorded only in GSA9 (all years), even though with low density values, without evident temporal trends. According to previous knowlege, a cutoff size of 20 mm CL, was chosen to select recruits. Maturity ogives were used to select the cutoff size to identify spawners. A mean value of the L50 sizes was used in the three GSAs: 27 mm for GSA7, 30 mm for GSA 8 and 9. Spawners were detected in most on the years in the two French GSAs, in all the years in GSA9. No temporal trends were detected.

GSAs 10, 18-19

The frequency of positive hauls for *N. norvegicus* in GSA10 ranges between 0.14 (MEDITS 2002) and 0.47 (MEDITS 2006), with an overall catch fluctuating from a minimum of 32 (MEDITS 2002) and a maximum of 335 (MEDITS 1999) sampled specimens. The frequency of positive hauls for *N. norvegicus* in GSA11 ranges between 0.23 (MEDITS 2002) and 0.33 (MEDITS 1996, 1997 and 1998), with an overall catch fluctuating from a minimum of 319 (MEDITS 2002) and a maximum of 933 (MEDITS 1996) sampled specimens. The frequency of positive hauls for *N. norvegicus* in GSA18 ranges from 0.19 (MEDITS 2007) and 0.49 (MEDITS 1996), with an overall catch fluctuating from a minimum of 171 (MEDITS 1994) and a maximum of 888 (MEDITS 2009) sampled specimens. The number of specimens of *N. norvegicus* collected in the GSA19 fluctuated between 119 (MEDITS 2004) and 1042 (MEDITS 2000). The frequency of positive hauls for the Norway lobster in the North-Western Ionian Sea oscillated between 0.17 and 0.43.

GSA 15-16

N.norvegicus was abundant and widely distributed in the bathyal grounds of the GSA 15+16. The percentage of positive hauls was consistent throughout the time series and equal to 46% on average, whilst the total number of specimens caught ranged between 1021 and 3509. The cutoff size used for identifying recruits was the Lm25% (26 mm CL) of maturity ogive based on biological sampling of commercial catches (DCF). On the other hand, the Lm50% (31 mm CL) of maturity ogive for females was chosen to estimate the spawning fraction of the population

GSA 17

GSA 17 MEDITS data are available for the period 2002-2010. The period 1994-2001 has been excluded from the analyses because data of the eastern side of the basin were not available. In GSA 17 MEDITS data Norway lobster is quite abundant with more than 25% of positive hauls and an average of more than 700 specimens collected each year. The threshold sizes to detect recruits (carapace length ≤ 2 cm) and spawners (carapace length ≥ 2.6 cm) has been derived respectively from Piccinetti et al. (2012) and Vrgoč et al (2004).

GSA 20, 22-23

The available data for Norway lobster in Greek waters that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 and in GSAs 22_23 the proportion of positive hauls for Norway lobster ranged from 6-25% and 22-36%, respectively (Table 2.5.5.1). Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates based on the aforementioned approaches, threshold values were established based on literature information and expert knowledge

Table 2.2.5.10.1. Frequency of positive MEDITS hauls (n of positive hauls/total number of hauls) for Norway lobster by GSA and year

GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.13	0.52	0.41	0.36	0.26		0.29	0.35			0.28		
1995		0.18	0.50	0.40	0.38	0.25		0.33	0.35			0.30		
1996				0.43	0.29	0.33		0.49	0.32			0.26		0.36
1997		0.20	0.77	0.44	0.34	0.33		0.40	0.36			0.23		0.33
1998		0.18	0.57	0.45	0.41	0.33		0.38	0.43	0.22		0.17		0.32
1999		0.16	0.57	0.44	0.42	0.24		0.34	0.32	0.16		0.24		0.36
2000		0.19	0.68	0.42	0.32	0.26		0.29	0.41	0.19		0.25		0.28
2001		0.23	0.59	0.45	0.35	0.26		0.30	0.28	0.25		0.29		0.31
2002		0.23		0.47	0.14	0.23	0.35	0.32	0.17			0.25		
2003		0.19	0.57	0.42	0.34	0.27	0.36	0.28	0.30	0.16		0.25	0.45	0.22
2004		0.19	0.55	0.44	0.34	0.26	0.41	0.37	0.20	0.13		0.35	0.49	0.24
2005		0.15	0.52	0.43	0.43	0.26	0.32	0.27	0.30	0.13		0.25	0.40	0.26
2006		0.31	0.57	0.43	0.47	0.29	0.37	0.24	0.33	0.19		0.31	0.45	0.25
2007	0.12	0.24	0.55	0.47	0.41	0.30	0.29	0.19	0.34			0.31	0.45	
2008	0.18	0.28	0.56	0.51	0.43	0.28	0.29	0.27	0.36	0.06		0.26	0.50	0.24
2009	0.20	0.23	0.55	0.42	0.33	0.28	0.31	0.34	0.31			0.32	0.47	
2010	0.22	0.22	0.55	0.47	0.39	0.32	0.25	0.33	0.31			0.29	0.49	

Table 2.2.5.10.2. Number of specimens of Norway lobster caught during MEDITS by GSA and year.

GSA														
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		506	684	1317	172	444		171	350			526		
1995		871	706	1676	191	928		347	250			993		
1996		0		2414	118	933		760	191	175		973		265
1997		458	545	2036	214	464		399	270	40		893		733
1998		297	1378	2697	323	538		374	434	48		233		365
1999		452	539	2108	335	422		374	317	141		476		330
2000		460	637	2864	225	568		363	1042			1081		252
2001		415	1262	3227	229	365		545	267	54		2977		187
2002		781		1373	32	319	497	209	210	46		1576		
2003		319	757	2269	93	615	1169	257	227	24		1439	1021	540
2004		321	825	1791	218	511	745	301	119	29		2057	1732	526
2005		327	639	1328	292	490	1030	306	278			568	1641	1130
2006		376	695	1725	179	635	1225	331	515	8		1075	2420	522
2007	563	430	690	2443	138	704	546	190	246	175		758	3085	
2008	562	438	817	2280	144	722	533	469	234	40		494	3509	351
2009	239	594	802	2848	94	602	414	888	153			1683	3455	
2010	414	345	742	1830	148	610	266	554	124			661	2265	

Table 2.2.5.10.3. Recruitment and spawning size identification for modeling purposes.

	Recruits	**Spawners**

GSA	Sampling years	Data source	Method used	Mean threshold length (CL mm)	Data source)	Method used	Mean maturity length (cm) /Maturity stage
5, 1-6		Orsi-Relini et al., 1998; Mytilineou et al., 1998		13	Orsi-Relini et al., 1998	Fixed threshold length (L50)	30
7	1994-2010	DCF/MEDITS	Maturity ogives	27	DCF/MEDITS	Maturity ogives	27
8	1994-2010	DCF/MEDITS	Maturity ogives	30	DCF/MEDITS	Maturity ogives	30
9	1994-2010	DCF/MEDITS	Fixed	20	DCF/MEDITS	Maturity ogives	30
10	1994-2010	MEDITS	L25 of the maturity ogive	27	MEDITS and biological sampling	Maturity ogive	29
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya	25	MEDITS	Fixed threshold length (L50)	33
15+16	2003-2010	DCF	Fixed threshold length (Lm25%)	26	DCF	Fixed threshold length (L50)	31
17	2002-2010	Piccinetti et al., 2012	Fixed threshold length	20	Vrgoc et al., 2004	Fixed threshold length (L50)	26
18	1994-2010	MEDITS	L25 of the maturity ogive	23	MEDITS and biological sampling	Maturity ogive	25
19	1994-2010	MEDITS	fixed	20	MEDITS	fixed	29
20	1998-2008	MEDITS	Bhattacharya	25	MEDITS	Fixed threshold length (L50)	32
22_23	1996-2008	MEDITS	Bhattacharya	20	MEDITS	Fixed threshold length (L50)	31

Mapping of density and identification of hot spot areas

A summary of the spatial models implemented for mapping recruits and adults/spawners of blue and red shrimp is provided in Table 2.2.5.10.4.

GSAs 1-6

The adult aggregations and recruits were modeled using GAM. Two models were developed independently, one for presence/absence data, and another for standardized abundances restricted to presence data only. The final presence/absence model for adult aggregations included depth and the interaction between longitude and latitude, whereas the final abundance restricted to given presence model included year, depth and the interaction between longitude and latitude as significant factors. These models explained 58 and 36% of the total variance, respectively. Recruits were not modeled due to the low amount of individuals captured.

GSA 5

Recruits and spawners in GSAs 05 were not modeled due to the low amount of individuals captured.

GSAs 7, 8, 9

Recruits have been observed only in GSA9; anyway, due to the low number of specimens observed, the modeling approach failed to identify hot spot areas and only bubble plots showing observed density values were produced. Areas of aggregation of adults were identified both in GSAs 7 and 9. In GSA 7 adults were modeled using a GAM with spatial component, a fixed intercept and a smooth effect on the covariate Longitude. The whole MEDITS time series was used (1994-2010). The covariance functions were both exponential and spherical depending on the year. In GSA 9 it was used a GLM with spatial component and an exponential covariance function.

GSA 10, 11, 18, 19

In GSA10-11-18-19 annual abundace values were predicted by mean a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging was applied on real abundance values. In GSA10 and 18 the positive hauls for recruits were scattered thus resulting in poor modeling. MEDITS time series from 1994 to 2010 was used. The density hot spots were found using the local G statistic.

GSAs 15-16

Recruit distribution of *N.norvegicus* was modeled in GSA 15-16 using a GLM with spatial component. Both the intercept and the spatial component were allowed to change each year. The spawners were modeled in GSA 15-16 using a GAM with spatial component, a fixed intercept and a smooth effect on the covariate Longitude. The spatial component was allowed to change in an annual basis. The models goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km. The persistence was obtained as the rate of years in which a point was a hot spot.

GSA 17

Modeling approaches employed to identify nursery and spawning grounds of Norway lobster in GSA 17 were the zero-Inflated Generalized Additive Model (Liu and Chan, 2010) and local G statistic (Getis and Ord, 1992), respectively to define the spatial distribution and the hot spots, considered as the place where high values of densities cluster together. The covariates employed to identify the spatial patterns of recruits and spawners of Norway lobster were year (as factor), latitude, longitude and depth. The diagnostics of the ZIGAM model employed for recruits and spawners of Norway lobster in GSA 17 (Table 2.5.1.4) show a better fit for recruits, although the model results seems appropriate also for the spawners.

Generalized Additive Models were employed to model the distribution of spawners of Norway lobster in GSA 22_23. The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots.

The period analysed was from 1996-2008 and from 1998-2008 for GSA 20 and GSAs 22_23, respectively. The depth distribution of thornback ray spawners was found to range between 47 - 655 m in GSAs 22_23.

Table 2.2.5.10.4. Modeling applied in EU GSAs for mapping Norway lobster. CV=Cross Validation Index

Life Stage	GSA	Depth Range m	Period	Model Type	Covariates	Explained Deviance (%)	Goodness of fit (R^2)
Spawners	9	300-700	1994-2010	GLM with spatial component			CV=0.99 0.60
Spawners	7		1994-2010	GAM with spatial component	*Longitude*		CV=1.02 0.28
Spawners females	22_23	47-655	1996-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	48.8	0.42
Spawner females	01, 06	50-820	1994-2010	Pres./Abs.	(Lon, Lat), depth	58.1	0.68
				Abundance	Year, (Lon, Lat), depth	35.5	
Recruits	15+16	200-700	2003-2010	GLM with spatial component			CV=0.991 0.500
Spawners	15+16	200-700	2003-2010	GAM with spatial component	*Longitude*		CV=1.063 0.513
Spawners	17	10-600	2002-10	ZIGAM	(Year), (Lon, Lat), (depth)	LR GAM 31.5 31.2	LR GAM 0.32 0.25
Recruits	17	10-600	2002-10	ZIGAM	(Year), (Lon, Lat), (depth)	LR GAM 53.9 67.3	LR GAM 0.43 0.54
Recruits	11	200-800	1994:2001 2003:2010	--	--	--	--
				--	--	--	--
				Ordinary Kriging (*)			
Recruits	19	10-800	1994:2010	--	--	--	--
				--	--	--	--
				Ordinary Kriging			
Spawners	10	200-800	1994:2010	Gaussian GAM	Depth	8.36	0.07
				Binomial GAM	Depth	13.42	0.14
				Ordinary Kriging			
Spawners	11	200-800	1994:2010	Gaussian GAM	Depth	17.84	0.13
				Binomial GAM	Depth	22.29	0.23
				Ordinary Kriging			
Spawners	18	10-800	1996:2010	--	--	--	--
				--	--	--	--
				Ordinary Kriging			
Spawners	19	10-800	1994:2010	Gaussian GAM	Depth	16.6	0.1
				Binomial GAM	Depth	24.7	0.2
				Ordinary Kriging			

**Cross-validation index*

2.2.5.10.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.10.5 summarizes the main environmental features of the most persistent areas identified for deep-sea pink shrimp in European GSAs

GSAs 1-6

The predictions showed that spawners are mainly located in the GSA 06, from cape Salou to cape Creus, with the highest abundance in the upper slope, at around 400 m depth. During the years with high abundance (e.g. 2003 and 2007), this area seems to be enlarged southwards, up to cape Palos, covering the whole GSA 06. A large persistency density hot-spot was detected, covering almost the entire upper slope of the GSA 06 (Figure 2.2.5.10.1).

As in other crustacean decapods, several studies have shown the influence of environmental factors on the population dynamics of this species. Since Maynou and Sardà (1997), grain size of sediment and, to a lesser extent, redox potential determine relative growth and morphometrical differences in the *Nephrops norvegicus* populations of the north-western Mediterranean. Temperature plays a minor role, explaining only the advancement of sexual maturation in females of the slope.

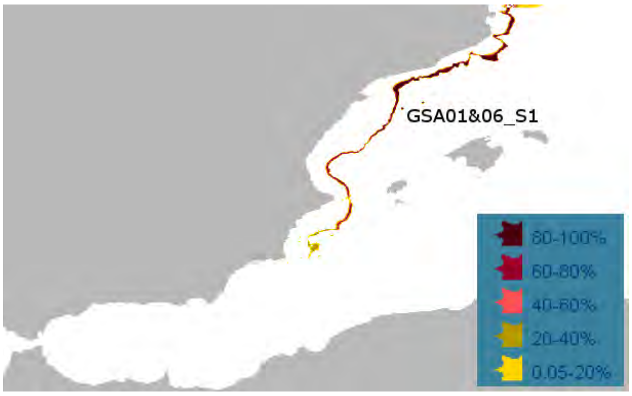


Fig. 2.2.5.10.1. Position of persistent spawning areas of Norway lobster in GSA 01 and 06

GSA 7

The results on the modeling approach indicated the occurrence of small persistent areas of concentration of spawners occurring between upper and middle slope in a wide depth range (300-700 m, Fig.2.2.5.10.2). The slope of the Gulf of Lions is characterized by the occurrence of canyons where sediment transport occurs. In the Eastern part of the Gulf due to the effect of winds and Eckman transport upwelling may occur. The western part is generally affected by downwelling features.

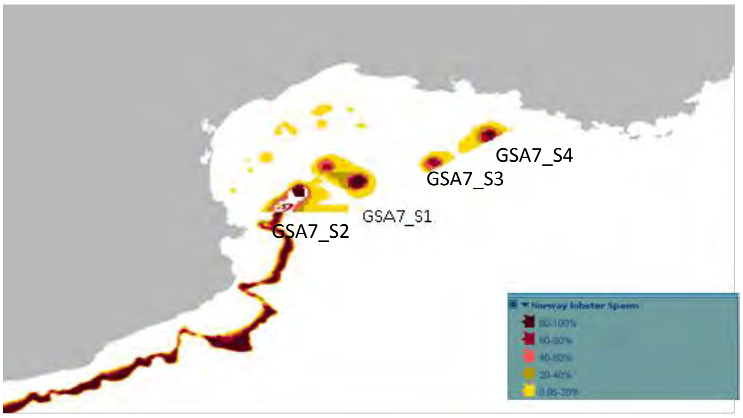


Fig. 2.2.5.10.2. Position of persistent spawning areas of Norway lobster in GSA 7

GSA 9

Spawners of Norway lobster are concentrated in two large areas with high persistency and density values, one at the north and another at the south of Elba Island. The first area is notably larger than the first. Both areas are located from 300 to 500 m depth (300-500 the first and 300-450 the second) and characterized by muddy bottoms (Fig.2.2.5.10.3). The most important co-occuring species are *Gadiculus a. argenteus, Phycis blennoides, Micromersistius poutassou, Macropipus tuberculatus* in both areas, *Parapenaeus longirostris* mostly in the southern area.

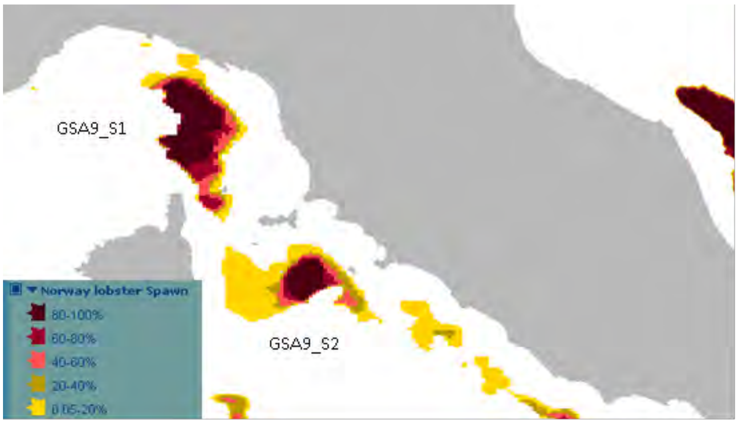


Fig. 2.2.5.10.3. Position of persistent spawning areas of Norway lobster in GSA 9

GSA 10

In the GSA 10 a highly persistent and wide hot spot of adult aggregation was found in the northernmost part of the GSA in the Gaeta Gulf (GSA10_S1; 80-100%) down 300 m depth and another smaller off Napoli Gulf (GSA10_S1; 80-100% Fig.2.2.5.10.4). Both areas are characterised by muddy bottoms with deep mud biocenosis (VP) and *Gryphus vitreus* facies with caracteristic species as *Munida intermedia*, *Macropipus tuberculatus*, *Echinus melo*, *Actinauge richardi* etc. The mainstream current direction is from south to north.

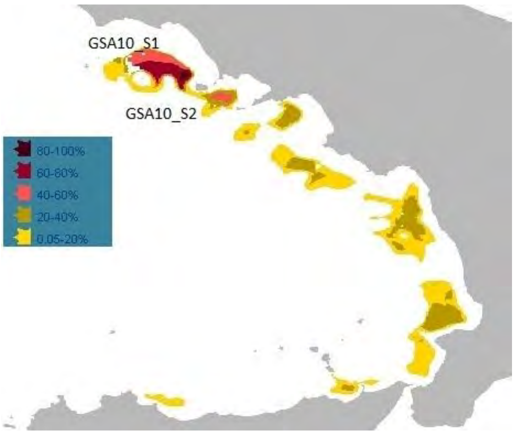


Fig. 2.2.5.10.4. Position of persistent spawning areas of Norway lobster in GSA 10

GSA 11

Nursery areas are mainly found in the north-eastern coast of Sardinia at depth between 400-600 m (Fig. 2.2.5.10.5). These areas are characterized by the presence of bathyal mud. Spawning areas (level of persistence 60-80%) are found in the central western, northern and north-eastern coasts of the island mainly at depths comprised between 350-650 m (Fig. 2.2.5.10.5). The Biocenosis found in these beds is dominated by *Funiculina quadrangularis* and at deeper levels by *Isidella elongata.*

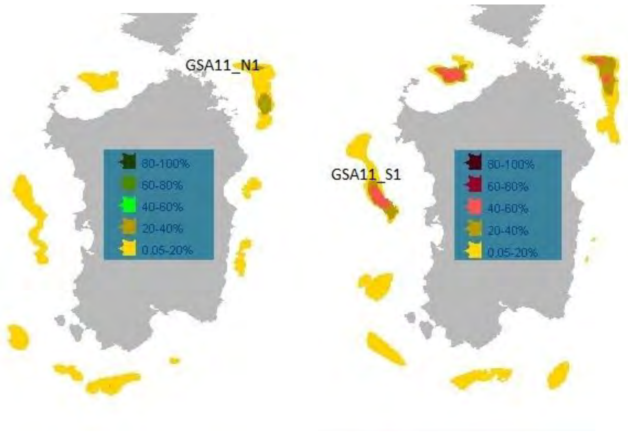


Fig. 2.2.5.10.5. Position of persistent spawning areas of Norway lobster in GSA 11

GSA 15-16

Recruits of Norway lobster in the Strait of Sicily are distributed on muddy bottoms of the upper slope between 250 and 500 m depth. Persistency analysis of density hotspots showed the presence of two large nurseries located in the northwest sector of the Strait of Sicily, to the west (GSA15+16_N1) as well as to the east (GSA15+16_N2) of the Adventure Bank at about 300-450 m depth (Fig. 2.2.5.10.6). No stable recruitment area is identified in the easternmost part of the Strait, although high concentrations of immature specimens have been described in a previous study to the north of Gozo and to the south/southwest of Malta. Conversely persistent spawning areas have been identified in the southeast sector of the Strait, next the extreme south border of GSA 16 (GSA15+16_S1) and the south border of GSA15 (GSA15+16_S2, Fig. 2.2.5.10.6). However there is also evidence of concentration areas of spawners, albeit not much persistent, in the bathyial basin to the northwest of Malta and to the west of the Adventure Bank, (the latter co-occurrent with a nursery ground). On the whole, the spatial pattern of spawning and recruitment of the species is not very clear and deserves further investigation.

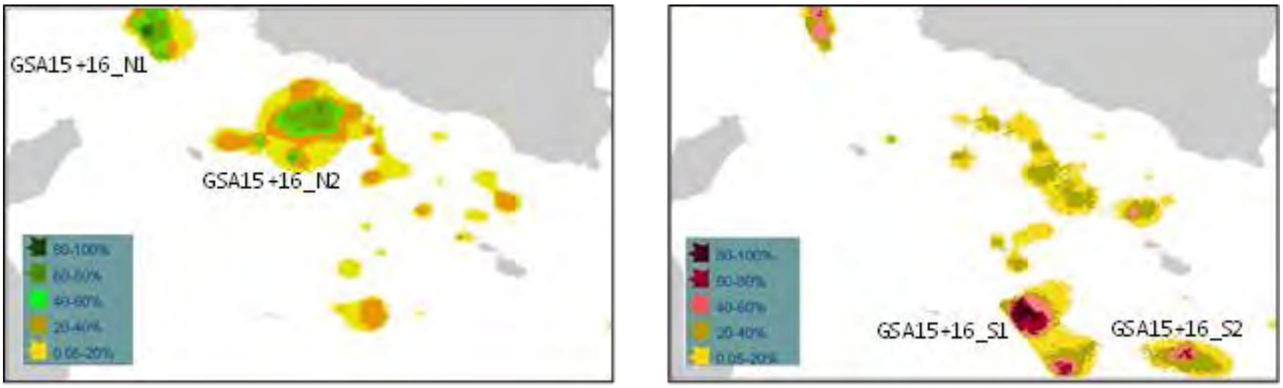


Fig. 2.2.5.10.6. Position of persistent nursery (left) and spawning areas (right) of Norway lobster in GSA 15-16

GSA 17

The area of persistency identified for the recruits of Norway lobster in GSA 17 is identified between 100-270 m depth, located close just to the Pomo/Jabuka Pit area (Fig. 2.2.5.10.7). However, it is important to clarify that the specimens inhabiting this area are not proper recruits but probably a subpopulation of individuals showing smaller size patterns. It is well known that marked differences exist, primarily in length frequencies among the settlements south of Ancona and the Pomo/Jabuka Pit (Froglia and Gramitto, 1981, Froglia and Gramitto, 1988, IMBC et al., 1994), as well as among the settlements in the northern Adriatic channels and the Pomo/Jabuka Pit (Karlovac, 1953; Crnković, 1964, Crnković, 1965, Crnković, 1970; Jukić, 1974; Županović and Jardas, 1989). Froglia and Gramitto (1981) discussed these discrepancies as the consequence of the difference in ecological factors that dramatically depress growth of *N. norvegicus* and other benthic decapods in the Pomo/Jabuka Pit. Similarly, Mantovani and Scali (1992), using genetic analysis, found that differences between Norway lobster off Ancona and the Pomo/Jabuka Pit did not surpass those at the population level. The differences are probably only a consequence of different environments, considering that although the muddy sediments of Pomo/Jabuka Pit are ideal for the burrowing behavior of the species they are also characterized by a very low input of fresh organic matter with low fluxes of all nutrients that could determine slower growth rate. Bottom water masses of the Pomo pit are only periodically renewed by the oxygen-rich dense waters formed in the eutrophic coastal regions of the North Adriatic and flowing into the basin (Gramitto and Froglia, 1988). A mesoscale experiment carried out in fall 1988 showed a large gyre in the area which may prevent larval dispersion (Paschini et al., 1993). The area has been reported to be characterized by conspicuous numbers of benthic scavengers (e.g. Natatolana borealis) and other crustaceans as Munida intermedia, Munida rugosa (Froglia and Gramitto, 1998).

Four areas of persistency have been identified for the spawners of Norway lobster in GSA 17. S1 is the same area identified for the so called recruits in the Pomo/Jabuka Pit (Fig. 2.2.5.10.7). S2 is located between 60 and 100 m depth along the western side between Conero and Gargano promontories. S3 is located in the eastern side representing an important fishing ground in the Velebit Channel, Kvarner and Kvarnerić region, as also observed by Crnković, (1965). S4 is located in the southern portion of the GSA 17 from 200 to 600m depth, and is probably connected with spawning grounds observed in GSA 18.

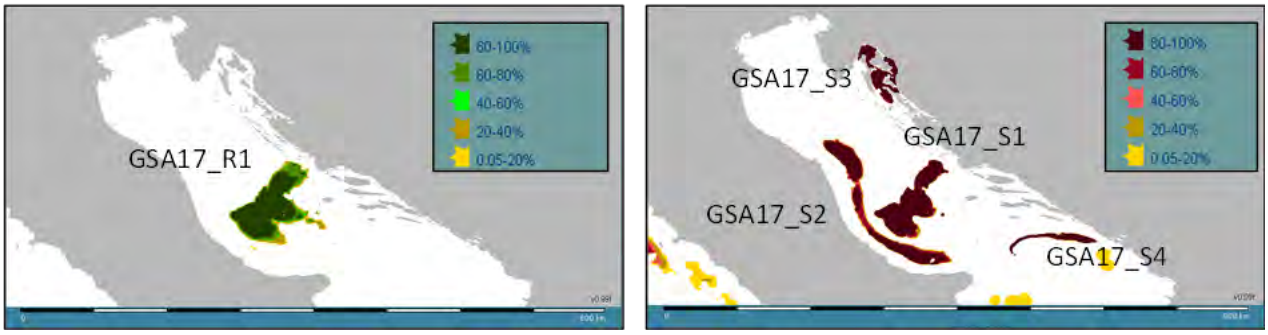


Fig. 2.2.5.10.7. Position of persistent nursery (left) and spawning areas (right) of Norway lobster in GSA 17.

GSA 18

In the South Adriatic highly persistent (60-80% probability) hot spots of Norway lobster adult females are found in the Otranto channel, along the border of the South Adriatic pit, both on the eastern (GSA18_S1) and western side (GSA18_S2 and GSA18_S3) down 200 m depth (Fig. 2.2.5.10.8). The main aggregation is characterised by muddy bottoms with deep mud biocenosis (VP) and caracteristic species as *Macropipus tuberculatus, Munida intermedia*, *Echinus spp* etc. The mainstream current direction is from south to north.

Fig. 2.2.5.10.8. Position of persistent spawning areas of Norway lobster in GSA 18

GSA 19

The nursery areas of the Norway lobster in the GSA19 were observed from Santa Maria di Leuca to Taranto along the Apulian coasts (GSA19_N1) and south-eastern the Amendolara Bank along the Calabrian coasts (GSA19_N2, Fig. 2.2.5.10.9). In particular, the main nursery areas with the highest persistency levels were estimated on the shelf break and slope offshore Gallipoli and Torre Ovo (GSA19_N1). A partial overlapping between nursery and spawning areas was generally detected in the GSA19 for the Norway lobster. In fact, the highest levels of persistency were observed on the shelf between Otranto and Santa Maria di Leuca as well as on the slope offshore Gallipoli-Torre Ovo (GSA19_S1) and eastern the Amendolara Bank (GSA19_S3). The more persistent spawning area was observed offshore Punta Stilo (GSA19_S3, Fig. 2.2.5.10.9).

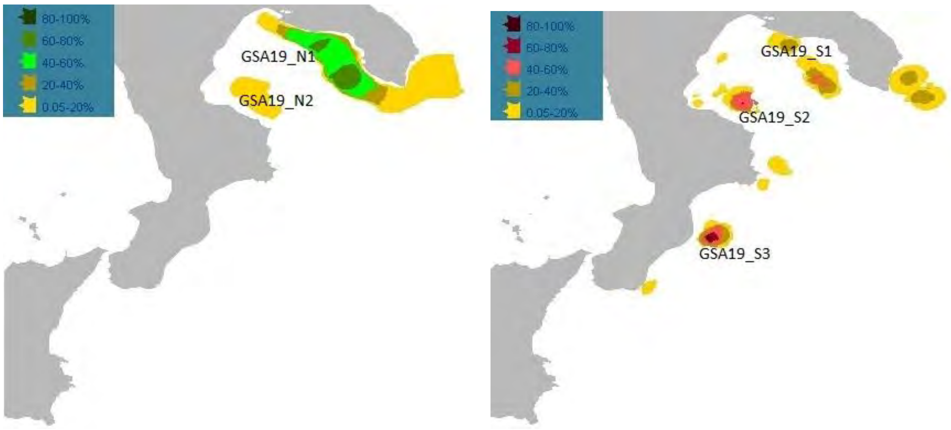


Fig. 2.2.5.10.9. Position of persistent nursery (left) and spawning areas (right) of Norway lobster in GSA 19.

GSA 20, 22-23

The depth distribution of Norway lobster extends from 47-655m in the Aegean Sea according to MEDITS catches. However, the higher abundances of the spawners of the species were found in the 300-500m depth zone. The captured recruits of the species in the Aegean Sea were very limited to allow for modeling procedures. Norway lobsters (spawners and recruits) were also captured in the Ionian Sea, however the local distribution of the captures combined with the low numbers did not allow for any modeling. Hence the only available distribution maps for the Ionian Sea are annual bubble plot maps. The density maps revealed a distribution ground mainly located around the Sporades island complex in the north part of the central Aegean Sea (Fig. 2.2.5.10.10). No modeling was applied for recruits in GSA 20 and GSA 22_23 due to the low number and the very local distribution of specimens caught. The same was situation occurred for spawners in GSA 20.

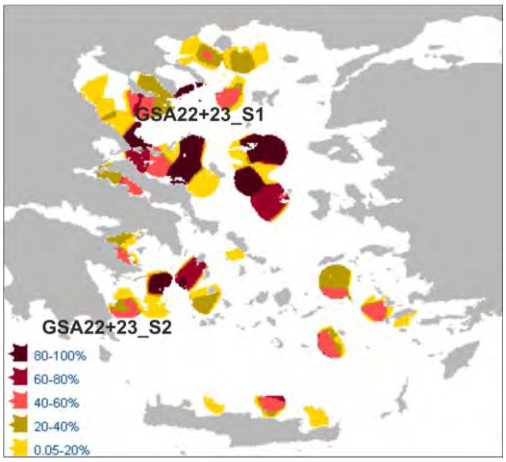


Fig. 2.2.5.10.10. Position of persistent spawning areas of Norway lobster in GSA 22_23.

Table 2.2.5.10.5. Environmental characteristics on nurseries and spawning grounds for Norway lobster.

GSA	Type of area	Code	Depth range	Description (few lines of text)
01 and 06	Adults density aggregation	GSA1-6_S1	300-500	Big area covering almost all the upper slope of the GSA06
7	Adults density aggregation	GSA7_S1	350-600	Bathyal muds in the central –western part of the Gulf. Occurrence of canyons and downwellings. Winter Intermediate Waters (WIW) produced in winter mix with the underlying Levantine Intermediate Waters (LIW).
7	Adults density aggregation	GSA7_S2	350-700	Bathyal muds in the western part of the Gulf. Occurrence of canyons and downwellings. Winter Intermediate Waters (WIW) produced in winter mix with the underlying Levantine Intermediate Waters (LIW).
7	Adults density aggregation	GSA7_S3	430-700	Bathyal muds in the eastern part of the Gulf. Occurrence of canyons and upwellings.
7	Adults density aggregation	GSA7_S4	300-700	Bathyal muds in the eastern part of the Gulf. Occurrence of canyons and upwellings.
9	Adults density aggregation	GSA9_S1	380-660 m	Bathyal muds of Ligurian Sea.
9	Adults density aggregation	GSA9_S2	360-600 m	Bathyal muds of Northern Tyrrhenian Sea. Wind-induced cyclonic gyre with well-defined meanders close to this area, produce upwelling in winter-spring.
10	Adults density aggregation	GSA10_S1	316-588	The bottom is muddy with deep mud biocenosis (VP) with caracteristic species as *Munida intermedia*, *Macropipus tuberculatus*, *Echinus melo*, *Actinauge richardi* etc. The mainstream current direction is from south to north.
10	Adults density aggregation	GSA10_S2	408-454	The bottom is muddy with deep bathyal biocenosis (VP) and *Gryphus vitreus* facies with associated species as *Macropipus tuberculatus, Polycheles typhlops*, *Geryon longipes Anamathia rissoana Echinus spp* etc. The mainstream current direction is from south to north.
11	nursery	GSA11_N_9	400-600 m	Bathyal mud
11	Adults density aggregation	GSA11_S_16	350-650 m	Biocenosis of *Funiculina quadrangularis* and at deeper levels that of *Isidella elongata*
11	Adults density aggregation	GSA11_S_17	350-650 m	Biocenosis of *Funiculina quadrangularis* and at deeper levels that of *Isidella elongata*

11	Adults density aggregation	GSA11_S_18	350-650 m	Biocenosis of *Funiculina quadrangularis* and at deeper levels that of *Isidella elongata*
15+16	nursery	GSA15+16_N1	320-480	Bathyal muds. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep Waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
15+16	nursery	GSA15+16_N2	300-420	Bathyal muds, facies with sandy and gravel bottom. This area is under the dominant influx of two major water masses, the superficial inflow of the Atlantic Ionian Stream (AIS) (up to 100m depth) and the deep counterflow of the Levantine Intermediate Water (LIW) (core depth between about 200 m and 600 m) bringing salty and warm waters. The mean value of SST observed in late spring-early summer is 21.7 °C.
15+16	Adults density aggregation	GSA15+16_S1	370-620	Bathyal muds. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep Waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
15+16	Adults density aggregation	GSA15+16_S2	530-570	Bathyal muds, facies with Isidella elongate. This area is under the dominant influx of the Levantine Intermediate Water (LIW) and the Eastern Deep waters which flow westward along the Sicilian slope. The LIW flows in two veins through the Strait, in a depth range of 200 to 600 m, salinity 38.74- 38.75 % and temperature 14.0-14.18 °C.
17	nursery	GSA17_R1	100-270	- muddy-sediments - water masses periodically renewed - scavengers communities (especially crustaceans)
17	Adults density aggregation	GSA17_S1	100-270	- muddy sediments - water masses periodically renewed - scavengers communities (especially crustaceans)
17	Adults density aggregation	GSA17_S2	60-100	- sand-muddy sediments - policheates
17	Adults density aggregation	GSA17_S3	30-100	- Croatian channels.
17	Adults density aggregation	GSA17_S4	200-600	- Connection with GSA 18
18	Adults density aggregation	GSA18_S1	269-310	The bottom is muddy with deep mud biocenosis (VP) with caracteristic species as *Macropipus tuberculatus, Munida intermedia*, *Echinus spp* etc. The mainstream current direction is from south to north.
18	Adults density	GSA18_S2	263-594	The bottom is muddy characterized by the detritic bottom biocenosis (DL) with hidroids facies (*Lytocarpia myriophyllum*, *Nemertesia antennina*) and associated

	aggregation			specie as *Galeodea spp*, *Astropecten irregularis*, *Monodaeus couchii*, *Goneplax rhomboids* etc. The mainstream current direction is from north to south.
18	Adults density aggregation	GSA18_S3	318-557	The bottom is muddy with deep mud biocenosis (VP) with caracteristic species as *Macropipus tuberculatus, Polycheles typhlops*, *Munida intermedia*, *Echinus spp* etc. The mainstream current direction is from north to south.
19	nursery	GSA19_N1	249-774	The shelf break and slope offshore Gallipoli and Torre Ovo were characterized by the shelf-edge detritic and bathyal muds biocenosis.
19	nursery	GSA19_N2	302-610	The slope eastern the Amendolara Bank was characterized by the bathyal muds biocenosis.
19	Adults density aggregation	GSA19_S1	307-774	The slope offshore Gallipoli was characterized by the bathyal muds biocenosis.
19	Adults density aggregation	GSA19_S2	302-610	The slope eastern the Amendolara Bank was characterized by the bathyal muds biocenosis.
19	Adults density aggregation	GSA19_S3	506-634	The slope grounds eastern Punta Stilo were characterized by the bathyal muds biocenosis.
22_23	Adults density aggregation	GSA22-23_S1	150-450	Deep areas of the northwest Aegean Sea (mainly the Sporades Island complex). Main sediment type: mud
22_23	Adults density aggregation	GSA22-23_S2	150-350	Deep areas of the western part of the Aegean Sea. Main sediment type: mud

2.2.5.10.4 Gaps in knowledge and future actions

Recruitment processes are still poorly understood in the Mediterranean. The available information on the biology of the species in GSAs 22, 23 and 20 is scarce and it is unknown to what extent the MEDITS survey overlaps with the species reproductive cycle. Hence findings should be faced with caution as may not be representative of the real situation. Moreover, information on the environmental characteristics of the identified hot-spot areas is rather poor, especially concerning the prevailing local oceanographic features. Nursery areas could not be identified which is largely due to the timing of the MEDITS survey (June), which does not allow adequate captures of juveniles.

2.2.5.11 Eledone cirrhosa

2.2.5.11.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized. In GSA 25 based on the available MEDITS data the horned octopus is absent.

Recruitment

The horned octopus, *Eledone cirrhosa*, is a typical soft bottom species, present in a wide bathymetric range, generally up to 700 m depth (Relini et al., 1999), even though the higher abundance is observed from 100 to 150 m depth in GSA 06 and GSA 01 (Gil de Sola, 1992). Very little is known about the biology and ecology of *E. cirrhosa* in the Mediterranean Sea although few papers can be found from the Adriatic waters. It reproduces from March to August; the abundance decreasing in autumn probably following the spawning death (Casali et al., 1998). The proportion of small individuals (below 60 mm ML) is higher in autumn (Pastorelli et al., 1998). Length at first maturity was estimated in 90 and 110 mm ML for males and females respectively (Soro and Piccinetti, 1989). In GSA 9, during the MEDITS period (spring-beginning of summer), size frequency distributions clearly show two components, even though with different amplitude: recruits with modal length from 30 to 40 mm ML and adults with modal lengths from 80 to 90 mm ML. Trawl net recruitment in GSA9 is concentrated mainly in spring summer. In GSA10 horned octopus recruitment follows a discrete pattern with peak in June-July. Recruits of horned octopus mainly occur between 100 and 200 m depth and recruit size ranges between 36 mm and 50 mm (Dorsal Mantle Length; DML). Higher concentrations of *E. cirrhosa* were localized between Procida Island and Volturno river within 50-100 m depth (Lembo et al., 2010). In GSA11 recruitment of *E. cirrhosa* mainly occurs in summer. In GSA18 recruitment follows a discrete pattern with peak in June-July. Recruits of horned octopus mainly occur between 100 and 200 m depth with aggregations in the central-northern part of the South Adriatic. In the GSA19 horned octopus was collected at depths from 15 to 650 m. The minimum and maximum sizes were 17 and 185 mm DML, respectively. The presence of *E. cirrhosa* recruits mostly occurred during spring (Tursi et al., 1995). The sizes of recruitment ranged between 32 and 58 mm DML. The main aggregation area for juveniles of *E. cirrhosa* was frequently detected on the shelf around the Amendolara Bank. Up to date no nursery areas were localised for the horned octopus in the basin. The recruitment signal of horned octopus in the Strait of Sicily is detected in spring. The mean length of the first modal component is about 30 mm mantle length (ML). Small concentrations of recruits are observed along the eastern edge of the Adventure Bank between 150 and 250 m depth. In GSA 17, recruitment of *E. cirrhosa* peaks in summer. In Greek seas recruitment seems to be closely related with oceanographic features, varying even between neighboring geographic areas. Recruits (ML<50mm) have been collected in different areas of the Aegean Sea (GSA 22-23), mainly during early autumn.

Spawning

The horned octopus spawns from March to August. Its abundance decreases in autumn probably following spawning death (Casali et al., 1998). The proportion of small individuals (below 60 mm ML) is higher in autumn (Pastorelli et al., 1998). Length at first maturity was estimated in 90 and 110 mm ML for males and females respectively (Soro and Piccinetti Manfrin, 1989). Males mature at smaller size than females.

In GSA9 the spawning peak corresponds to the summer period; maturity size of 82 mm ML females and 76 mm ML for males was reported. It seems that there are bathymetric migrations linked to spawning: increased presence of females with mature gonads was reported in GSA9 at depth greater than 300 m. Reports of post spawning or spent specimens are very rare.

In GSA10, in spring-summer the occurrence of mature or maturing individuals of horned octopus was higher. A proxy of size at first maturity for females was estimated in the SAMED project using the average length at stage 2 that indicates an average length of about 8.8 cm. According to the data obtained from DCR in 2008, the maturity ogive was obtained from a maximum likelihood procedure. The fitting of the curve was good resulting into $L_{50\%}$ (9.1 cm ±0.11 cm) and of the maturity range (0.9 cm ±0.11 cm). Similar estimates were obtained in DCF 2009 ($L_{50\%}$= 9.0 ±0.26; MR= 1.1 ±0.30) and slightly lower in 2010 ($L_{50\%}$= 8.2 ±0.36; MR= 0.92 ±0.65) when a GLM approach was used (Donnaloia et al., 2010). Spawning aggregations were not localized in this GSA in past studies.

In GSA11 sexual maturity of *E. cirrhosa* is in spring. Fully mature males are found from 5.5 to 13 cm of total mantle length (ML) while females from 6.5 and 17 cm ML. High concentrations of mature specimens are found at depth greater than 300 m.

In GSA18, sexual maturation of semelparous horned octopus occurs early in males (from November) than in females (April). The peak of spawning takes place in summer (89-100% from June to August for females; 74-97% from March to August for males), while during autumn there are few mature and large specimens defined as "late spawner". According to the data obtained from DCR in 2008, the maturity ogive was obtained from a maximum likelihood procedure. The fitting of the curve was good with the following results: $L_{50\%}$ (9.7 cm ±0.06 cm) and of the maturity range (1.5 cm ±0.07 cm). Similar estimates were obtained in DCF 2009 ($L_{50\%}$= 10.8 ±0.16; MR= 1.7 ±0.17) and 2010 ($L_{50\%}$= 10.5 ±0.1; MR= 2.16 ±0.12) when a GLM approach was used. Spawning aggregations were not localized in this GSA in past studies.

The horned octopus displays seasonal sexual maturity and spawning covers a quite long period between spring and summer-early autumn. The smallest mature female and male recorded in the North-Western Ionian Sea (GSA19) were 25 mm DML. Up to date, no discrete persistent spawning areas were detected for *E. cirrhosa* in the GSA19. The spawning season of *Eledone cirrhosa* in the Strait of Sicily (GSAs 15-16) is spring-summer. In North Aegean Sea (GSA 22) the lower ML50 observed for both sexes during early autumn indicates that peak of spawning period for this species occurs in this period. The annual variation of ML50 within the same season among years, might be related to the variable oceanographic conditions affecting species' recruitment and growth, maturation process and spawning intensity.

2.2.5.11.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.11.1 and 2.2.5.11.2 list the frequency of positive hauls and the number of blue and red shrimp specimens caught during MEDITS in each GSA. Recruitment and maturity sizes are indicated in Table 2.2.5.11.3.

GSAs 1-6, 5

The proportion of positive hauls is similar in the three Spanish GSAs, varying from 0.48 to 0.76 in the GSA05 and from 0.33 to 0.62 in the GSA 01 and 06. The amount of specimens is highly variable ranging from 83 to 180 in the GSA05 and from 90 to 866 in the GSA 01 and 06 (Table 2.5.12.2).

Due to the low amount of individuals the Bhattacharya's method was not applicable to extract the first modal component of the length-frequency distribution of *E. cirrhosa.* In the absence of bibliographic information of this species, the minimum threshold applied in all the Mediterranean GSAs was applied as a threshold value of total length. This threshold and the swept area of each haul were used to calculate the standardized abundance index of recruits (n/km^2).

In order to extract the spawners' fraction, females with maturity stage III (mature) were considered for modeling due to the lack of any other biological information or literature concerning this issue.

GSAs 7, 8, 9

E. cirrhosa was caught in the majority of the hauls carried out in GSA7; the frequency of positive hauls ranged from 0.63 in 1994 to 0.91 in 1995. The number of specimens caught in the different years was between 194 in 2001 to 1292 in 1995. In GSA8 the occurrence of the species ranged from 5 to 77% of the hauls performed each year; the number of specimens caught was very low, from 2 in 2010 to 83 in 1995. In GSA9 the frequency of positive hauls ranged from 0.53 to 0.74; the number of specimens caught showed a temporal decreasing trend, from 1216 in 1994 to 374 in 2010.

In GSA9, MEDITS catch is dominated by adults, being the recruits (cutoff size from 30 to 41 mm ML, estimated through Bhatthacharya method) the minor fraction of the catch. In GSA7, due to a more successful reproduction, the recruits are the dominating populatfraction, but they displayed greater sizes (estimated cut off from 50 to 60 mm ML) than in GSA9. Female spawners were identified using a cutoff size of 90 mm ML in the three GSAs. Almost all of the adult females caught during the MEDITS had mature gonads.

GSAs 10, 11, 18, 19

The frequency of positive hauls for *E. cirrhosa* in GSA10 ranges between 0.25 (MEDITS 1999) and 0.53 (MEDITS 2008), with an overall catch fluctuating from a minimum of 99 (MEDITS 1999) and a maximum of 208 (MEDITS 1995) sampled specimens. The frequency of positive hauls for *E. cirrhosa* in GSA11 ranges between 0.50 (MEDITS 2007) and 0.77 (MEDITS 2006 and 2010), with an overall catch fluctuating from a minimum of 313 (MEDITS 2007) and a maximum of 1193 (MEDITS 2006) sampled specimens. The frequency of positive hauls for *E. cirrhosa* in GSA18 ranges between 0.26 (MEDITS 2008) and 0.56 (MEDITS 2009), with an overall catch fluctuating from a minimum of 70 (MEDITS 1995) and a maximum of 434 (MEDITS 1994) sampled specimens. The catch of the horned octopus was generally negligible in the GSA19 with the number of collected specimens oscillating between 6 and 203 during MEDITS 1994 and MEDITS 2004, respectively. The frequency of positive hauls of *E. cirrhosa* in the GSA19 fluctuated from a minimum and a maximum value of 0.07 and 0.30, respectively.

In GSAs 10, 11 and 18, the recruits have been identified annually depending on the ability of the survey to intercept the phenomenon. The threshold to separate the recruits has been generally estimated as the mean length of the first modal component + 2* sd using the Bhattacharya's method and the R_RSI_MEDISEH routine, specifically developed for the Mediseh project. In the case of GSA19 an empirical value was adopted as threshold size, generally derived from other research studies carried out in the area.

To identify the adults or potential spawners, an average of the parameters of the maturity ogive among the years from the MEDITS survey and/or from biological samplings of DCR and DCF has been used in GSAs 10 and 18, selecting those better fitting to the model. In GSA11 the parameters from the maturity ogives estimated on MEDITS data was used. In GSA19 the empirical threshold value adopted was 80 mm DML.

GSAs 15-16

Catches of horned octopus were very sparse in GSA 15+16 throughout the time series. The frequency of positive hauls was 0.21 on average. The total number of specimens was comprised between 60 and 199. The cutoff size of recruits was estimated using the Bhattacharya approach as the mean length of the first modal component + 2sd. It ranged from 41 to 60 mm ML. Recruits weren't detected in two years (2006 and 2010). The spawning fraction of the population was identified using the ML 50% estimate (105 mm ML) of maturity ogive for females obtained from biological sampling of commercial catches (DCF).

GSA 17

GSA 17 MEDITS data are available for the period 2002-2010. The period 1994-2001 has been excluded from the analyses because data of the eastern side of the basin were not available. In GSA 17 MEDITS data horned octopus is quite abundant with more than 25% of positive hauls and an average of more than 300 specimens collected each year. The approach employed to detect the recruits was the Bhattacharya, which identified threshold sizes comprised between 3.4-4.7 cm of mantle length. The threshold sizes utilized to identify the spawners, estimated from the maturity ogives in each year, were comprised between 6.3-6.5 cm of mantle length.

GSAs 20, 22, 23

The data for horned octopus used in the present work were obtained from the MEDITS survey. The available data for horned octopus that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 and in GSAs 22_23 the proportion of positive hauls for horned octopus ranged from 6-25% and from 22-36%, respectively (Table 2.5.5.1). Data from the MEDITS surveys accomplished before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards.

The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, whereas data did not allow defining estimates based on the aforementioned approaches, threshold values were established based on literature information and expert knowledge.

Table 2.2.5.11.1. Frequency of positive MEDITS hauls (n of positive hauls/total number of hauls) for horned octopus by GSA and year

	GSA												
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.63	0.57	0.67	0.46	0.61		0.53	0.07			0.51		
1995		0.91	0.68	0.71	0.48	0.61		0.28	0.08			0.52		
1996				0.73	0.46	0.65		0.44	0.15			0.49		0.36
1997		0.69	0.77	0.69	0.41	0.68		0.46	0.24			0.53		0.33
1998		0.73	0.61	0.68	0.40	0.68		0.39	0.27	0.22		0.57		0.32
1999		0.89	0.61	0.62	0.25	0.69		0.27	0.15	0.16		0.43		0.36
2000		0.76	0.41	0.74	0.47	0.70		0.46	0.20	0.19		0.45		0.28
2001		0.67	0.41	0.61	0.39	0.76		0.39	0.28	0.25		0.40		0.31
2002		0.90		0.71	0.44	0.58	0.29	0.36	0.29			0.48		
2003		0.74	0.57	0.73	0.47	0.76	0.39	0.41	0.26	0.16		0.50	0.21	0.22
2004		0.76	0.32	0.70	0.39	0.67	0.33	0.38	0.24	0.13		0.62	0.21	0.24
2005		0.89	0.30	0.68	0.49	0.66	0.33	0.36	0.30	0.13		0.59	0.21	0.26
2006		0.84	0.52	0.76	0.40	0.77	0.41	0.32	0.23	0.19		0.60	0.13	0.25
2007	0.58	0.87	0.40	0.53	0.50	0.50	0.43	0.29	0.29			0.49	0.23	
2008	0.48	0.66	0.48	0.64	0.53	0.74	0.38	0.26	0.23	0.06		0.33	0.21	0.24
2009	0.76	0.84	0.18	0.70	0.43	0.73	0.32	0.56	0.26			0.43	0.25	
2010	0.66	0.79	0.05	0.66	0.43	0.77	0.29	0.54	0.26			0.54	0.23	

Table 2.2.5.11.2. Number of specimens of horned octopus caught during MEDITS by GSA and year.

	GSA												
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		370	24	1216	155	541		434	6			320		
1995		1292	83	1165	208	553		70	22			441		
1996		0		1051	166	576		216	28	175		277		265
1997		480	20	1019	146	665		180	85	40		298		733
1998		436	34	852	170	636		262	69	48		429		365
1999		764	35	674	99	660		77	41	141		166		330
2000		456	34	842	169	657		269	35			439		252
2001		194	15	798	257	838		133	46	54		286		187
2002		505		1140	155	761	205	215	91	46		462		
2003		356	51	729	204	633	355	113	86	24		320	95	540
2004		429	13	578	100	585	247	103	203	29		717	116	526
2005		520	26	500	109	721	333	152	87			570	166	1130
2006		476	40	613	154	1193	496	187	38	8		866	60	522
2007	139	319	22	295	155	313	524	196	46	175		237	199	
2008	83	256	25	506	136	693	528	132	38	40		90	144	351
2009	180	391	11	485	125	477	183	313	77			395	192	
2010	156	402	2	374	115	776	230	177	53			166	125	

Table 2.2.5.11.3. Recruitment and spawning size identification for modeling purposes.

		Recruits			**Spawners**		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (ML mm)**	**Data source**	**Method used**	**Mean maturity length (ML mm) /Maturity stage**
5, 1-6	1994-2010	MEDITS of all GSAs	Fixed threshold length	30	MEDITS	Maturity stage	3
7	1994-2010	DCF/MEDITS	Bhattacharya	50	DCF/MEDITS	Fixed threshold	90
8	1994-2010	-	-	-	DCF/MEDITS	Fixed threshold	90
9	1994-2010	DCF/MEDITS	Bhattacharya	35	DCF/MEDITS	Fixed threshold	90
10	1994-2010	MEDITS	Bhattacharya	45	Biological sampling	Maturity ogive	88
11	1994-2010	MEDITS	Fixed threshold length / Bhattacharya	37.6	MEDITS	Fixed threshold length (L50)	60
18	1994-2010	MEDITS	Bhattacharya	53	Biological sampling	Maturity ogive	103
19	1994-2010	MEDITS	fixed	50	MEDITS	fixed	80
15+16	2003-2010	MEDITS	Bhattacharya	48	DCF	Fixed threshold length (L50)	105
17	2002-2010	MEDITS	Bhattacharya	43	MEDITS	Maturity ogive	69
20	1998-2008	MEDITS	Bhattacharya	40	MEDITS	Fixed threshold length (L50)	50
22_23	1996-2008	MEDITS	Bhattacharya	40	MEDITS	Fixed threshold length (L50)	50

Mapping of density and identification of hot spot areas

A summary of the spatial models implemented for mapping recruits and adults/spawners of horned octopus is provided in Table 2.2.5.11.4.

GSAs 1-6

The spawners of this species were modeled using GAM. Two models were conducted independently, one for presence/absence data, and another for standardized abundances restricted to presence data only.

The recruits were not modeled because of the mismatch between the sampling period and the time of the year that recruits can be found (spawning occurs in summer, after the MEDITS survey).

The final presence/absence model for spawners included the factors depth, interaction between longitude and latitude and year, whereas the final abundance restricted to presence samples model included depth and year as significant factors. These models explained 17 and 24% of the total variance, respectively.

GSA 7, 8, 9

A generalized additive model (GAM) was used to model horned octopus recruits in GSAs 7 and 9 adding a spatial term with a spherical covariance function and the intercept changing for each year. The covariates used in the GAM models were sampling year, distance from the shore and bottom steepness (GSA 9). Spawners in GSA 9 were modelled using a Bayesian kriging with INLA software/approach which use the Matèrn spatial function. The prior distribution was defined through an estimation chain in which the parameters estimated in a generic year j are used to define the prior distribution for the year j+1.

GSA 10, 11, 18, 19

In GSAs 10-11-18-19 annual abundance values were predicted by mean a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging was applied on raw abundance values.

GSAs 15-16

Total catches of *E. cirrhosa* were generally low in the Strait of Sicily and variable from year to year. Once juveniles and spawners were disaggregated from the population fraction, data were too sparse and inadequate to perform spatial analysis.

GSAs 17

Modeling approaches employed to identify nursery and spawning grounds of horned octopus in GSA 17 were the zero-Inflated Generalized Additive Model (Liu and Chan, 2010) and local G statistic (Getis and Ord, 1992), respectively to define the spatial distribution and the hot spots, considered as the place where high values of densities cluster together. The covariates employed to identify the spatial patterns of recruits and spawners of horned octopus were year (as factor), latitude, longitude and depth. The diagnostics of the ZIGAM model employed for recruits and spawners of horned octopus in GSA 17 (table 2.5.1.4) show good model fit both for recruits and spawners.

GSA 22-23

Generalized Additive Models were employed to model the distribution of horned octopus in GSA 22_23. The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots. The period analysed was from 1996-2008 for GSA 22_23. The depth distribution of horned octopus ranged from 45 - 515 m and 35 - 523 m for recruits and spawners, respectively.

Table 2.2.5.11.4. Spatial models implemented for mapping recruits and adults/spawners of horned octopus. CV= *cross validation index*

Life stage	**GSA**	**Depth range (m)**	**Period**	**Model type**	**Covariates**	**% dev. expl.**		**Goodness of fit (R^2)**	
Spawner females	01, 06	25-620	2002-2010	Pres./Abs.	Year, (Lon, Lat), depth	17.3		0.16	
				Abundance	Year, depth	23.8			
Recruits	7		1994-2009	GAM	Year, distance from the shore, slope			CV=1.0 0.51*	
Recruits	9		1994-2010	GAM	Year, distance from the shore, slope			C.V=1.0, 0.38*	
Spawner females	9		1995-2010	Bayesian kriging (INLA)	Year, Lon, Lat, slope	0.54		0.94*	
Spawner females	17	5-600	2002-10	ZIGAM	(Year) + s(Lon, Lat) + s(dept)	LR	GAM	LR	GAM
						51.2	42.7	0.53	0.39
Recruits	17	5-600	2002-10	ZIGAM	(Year) + s(Lon, Lat) + s(dept)	LR	GAM	LR	GAM
						40.8	52.7	0.38	0.47
Recruits	22_23	45-515	1998-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	47.9		0.40	
Spawners females	22_23	35-523	1998-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	45.0		0.40	
Recruits	10	10-800	1994:2010	Gaussian GAM	Depth	35.87		0.3	
				Binomial GAM	Depth	27.88		0.23	
				Ordinary Kriging					
Recruits	11	10-800	1994:2010	Gaussian GAM	Depth	15.11		0.12	
				Binomial GAM	Depth	23.41		0.28	
				Ordinary Kriging (*)					
Recruits	18	10-800	1996:2010	Gaussian GAM	Depth	24.25		0.18	
				Binomial GAM	Depth	19.55		0.14	
				Ordinary Kriging					
Recruits	19	10-400	1999:2010	Gaussian GAM	Depth	32.7		0.2	
				Binomial GAM	Depth	11.2		0.1	
				IDW (*)					

Life stage	GSA	Depth range (m)	Period	Model type	Covariates	% dev. expl.	Goodness of fit (R^2)
Spawner females	10	10-800	1994:2010	Gaussian GAM	Depth	15.39	0.13
				Binomial GAM	Depth	21.17	0.21
				Ordinary Kriging			
Spawner females	11	10-800	2007:2010	Gaussian GAM	Depth	32.72	031
				Binomial GAM	Depth	15.48	0.17
				Ordinary Kriging			
Spawner females	18	10-800	1996:2010	Gaussian GAM	Depth	12.94	0.12
				Binomial GAM	Depth	24.72	0.23
				Ordinary Kriging			
Spawner females	19	10-400	1997:2000 2002:2004 2006:2010	Gaussian GAM	Depth	43.7	0.4
				Binomial GAM	Depth	8.5	0.1
				IDW			

2.2.5.11.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.11.5 summarizes the main environmental features of the most persistent areas identified for horned octopus in European GSAs. For details see at http://mareaproject.net/mediseh/viewer/med.html.

GSA 6

Model output showed that the highest abundance of mature horned octopus is predicted to be located in the northernmost part of the GSA 06. In this area, a traditional bottom trawl fishery targeted the juveniles of this species was developed until recently (Gil de Sola, 1992). During the years of high abundance (e.g. 2005, 2007 and 2010) this area seems to expand southwards, covering the whole GSA 06 and even the GSA 01. This could be in agreement with the reported positive effect of river discharges on the abundance and condition of this species in the western Mediterranean (Lloret *et al.*, 2001; Quetglas *et al.*, 2011). The bathymetric distribution was different depending on the model, presence/absence showing a maximum at 200-350 m, while the highest abundance was observed at the shallowest depth surveyed. However no persistent density hot-spots were identified.

GSA 7

In GSA 7 it was possible to map only the presence of recruits. A wide area with high persistency values was evidenced, corresponding to the cetral-western portion of the Gulf of Lions, located from 100 to 200 m depth.

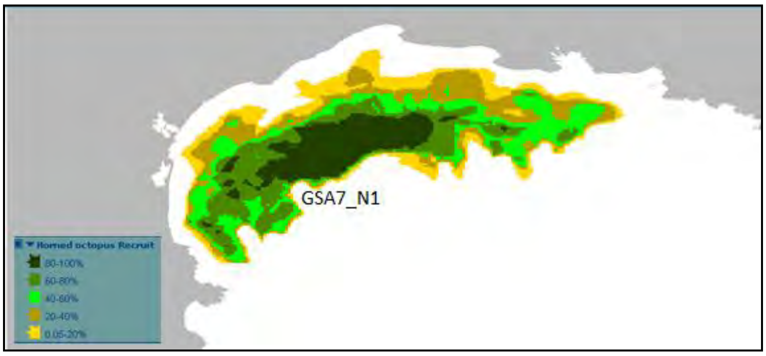


Fig. 2.2.5.11.1. Position of persistent nursery (left) of horned octopus in GSA 7

GSA 9

Several hot spot areas with high persistency values of recruits were detected in GSA9. They were distributed both to the north and to the south of Elba Island and were located mainly on muddy and detritic bottoms on the outher shelf and upper part of the slope, mostly between 100 and 180m depth (Fig. 2.2.5.11.2).

As concerns spawners, evident persistency hot spot areas were not evidenced. The area with the highest persistency values is located in the North Tyrrhenian between Elba and Giglio Islands. It seems that Eledone spawn in a wide depth range between 100 and 450 m depth (Fig. 2.2.5.11.2).

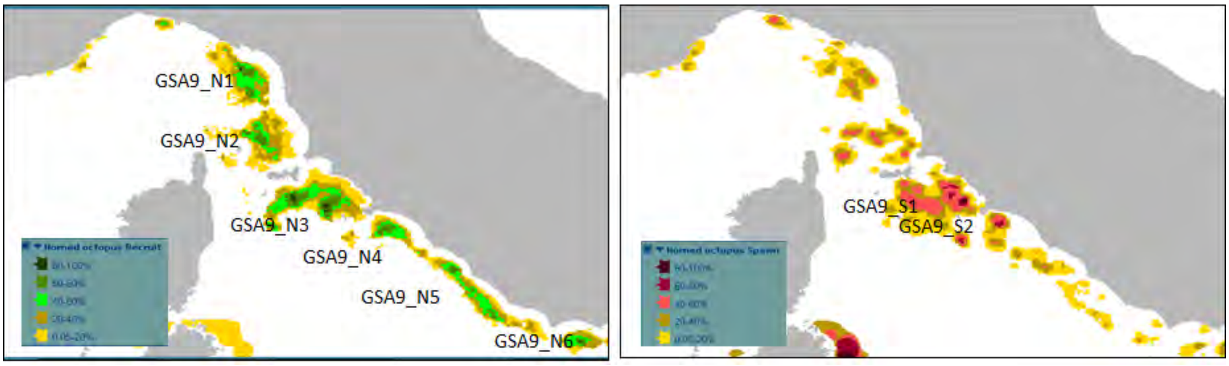


Fig. 2.2.5.11.2. Position of persistent nursery (left) and spawning areas (right) of horned octopus in GSA 9

GSA 10

In GSA10 hot spots of recruit aggregations of horned octopus were mainly localized in the northern side, where a wide nursery with a level of persistence as high as 80-100% (GSA10_N1) was localized in the Gaeta Gulf. Other two relevant hot spots were identified in the Napoli (GSA10_N2) and Salerno (GSA10_N3) Gulfs, along the mainland coasts. In the northern Sicily a nursery with a persistence level of 40-60% was localized in Palermo Gulf (GSA10_N4, Fig. 2.2.5.11.3). Likewise 4 adult aggregations were identified with a high level of persistence (up to 60-80%) and almost in overlapping with the nursery areas, except for the hot spot GSA10_S4, which was located in the Castellammare Gulf (Fig. 2.2.5.11.3). The nursery grounds are characterized by sandy-muddy bottoms, colonized by coastal terrigenous muds (VTC) biocenosis. The main current direction is from south to north on the mainland and from west to east along the coasts of northern Sicily.

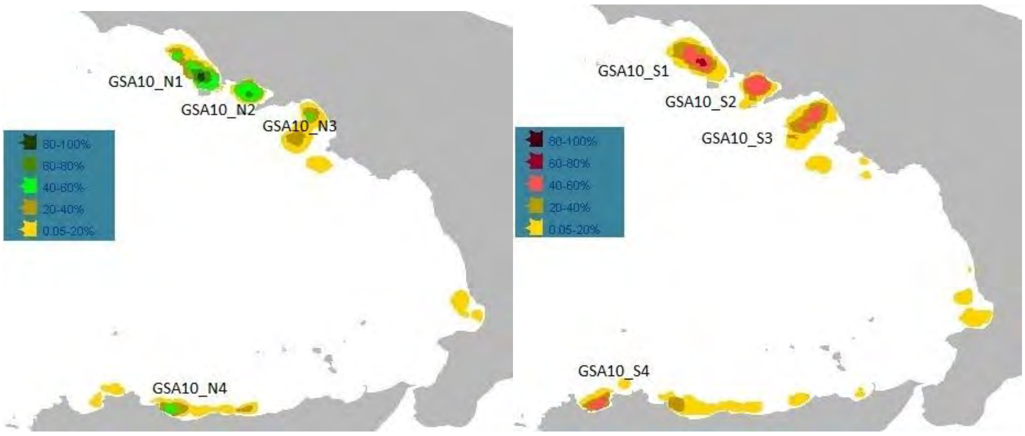


Fig. 2.2.5.11.3. Position of persistent nursery (left) and spawning areas (right) of horned octopus in GSA10

GSA 11

Nursery areas of the horned octopus (level of persistence 40-60 %) are mainly found on the western (GSA11_N1) and northern coasts (GSA11_N2) of Sardinian seas at depth comprised between 100-200 m (Fig. 2.2.5.11.4). The bottoms are mainly characterized by a biocenosis of Detrictic, (facies at *Leptometra phalangium*). Other macrobenthic organisms abundant on these beds are *Ophiura texturata*, *Echinus acutus*, *Astropecten irregularis* and, at lesser extent, *Cidaris cidaris.*

Zones of high concentrations of adult specimens are identified both in the western and especially in north-eastern coasts of Sardinia (GSA11_S2) mainly at depth greater than 300 m (Fig. 2.2.5.11.4). These bottoms appear mainly characterized by the presence of bathyal muddy with a remarkable presence of *Funiculina quadrangularis.*

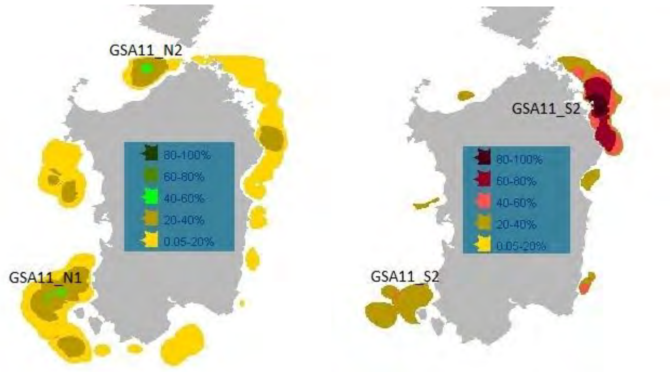


Fig. 2.2.5.11.4. Position of persistent nursery (left) and spawning areas of horned octopus (right) in GSA11

GSA 17

Two areas of persistency were identified for the recruits of horned octopus in GSA 17. R1 is the largest one, laying between 60-160 m, along the western side between Conero promontory and Tremiti islands (Fig. 2.2.5.11.5). The area is characterized by the presence of sand-muddy biocenosis (e.g. *Liocarcinus depurator and Turritella commun*is). R2 is located westwards the Croatian islands of Vis e Brac at a depth or 120-150 m.

Two areas of persistency were identified also for the spawners of horned octopus in GSA 17 (Fig. 2.2.5.11.5). S1 is located in the central portion of the basin comprising the Pomo/Jabuka Pit area at depths ranging from 100 m to 300 m. S2 is located in the southern portion of the GSA 17 in connection with the GSA 18 (eastern side) at depths ranging from 150 m to 300 m. These areas are characterized by the presence of sand-muddy biocenosis of the Pomo/Jabuka Pit area (look hake or Norway lobster).

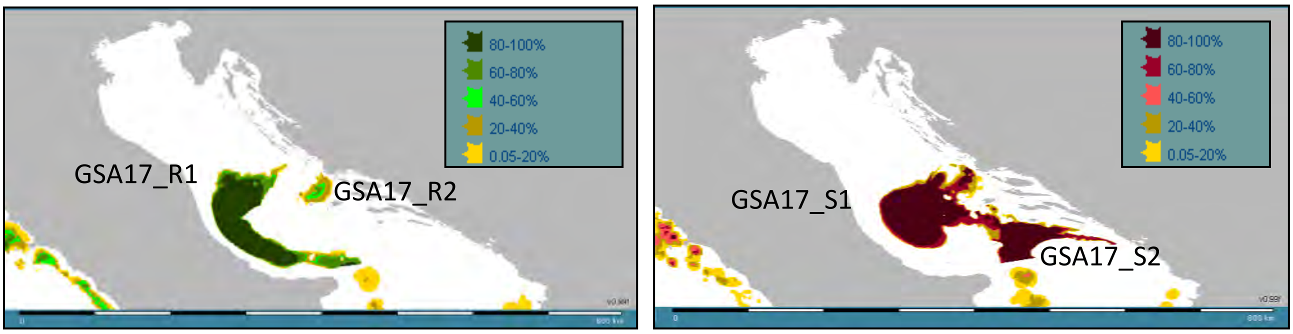


Fig. 2.2.5.11.5. Position of persistent nursery (left) and spawning areas of horned octopus (right) in GSA17

GSA 18

In the GSA18 nursery and adult aggregations are mainly localized along the western side of the GSA, where the more persistent nursery (GSA18_N1; probability 40-60%) is in overlap with one of the main aggregation of adult females (GSA18_S2, Fig. 2.2.5.11.6). Nursery areas and adult aggregations are mainly characterised by muddy bottoms and by the detritic bottom biocenosis (DL) with hidroids facies.

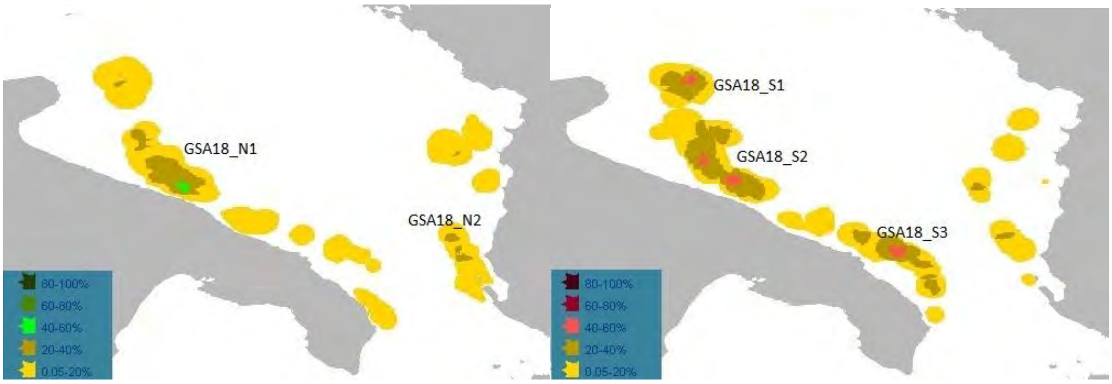


Fig. 2.2.5.11.6. Position of persistent nursery (left) and spawning areas of horned octopus (right) in GSA 18

GSA 19

In the GSA19 the main nursery and adult aggregations of the horned octopus were overlapped and distributed on the shelf and shelf break grounds around the Amendolara Bank in the Gulf of Corigliano (GSA19_N1 and GSA19_S1). Other small areas where high aggregation of spawners of *E. cirrhosa* occurred with persistency were observed south-eastern Otranto as well as offshore Catanzaro and Catania on the shelf break grounds.

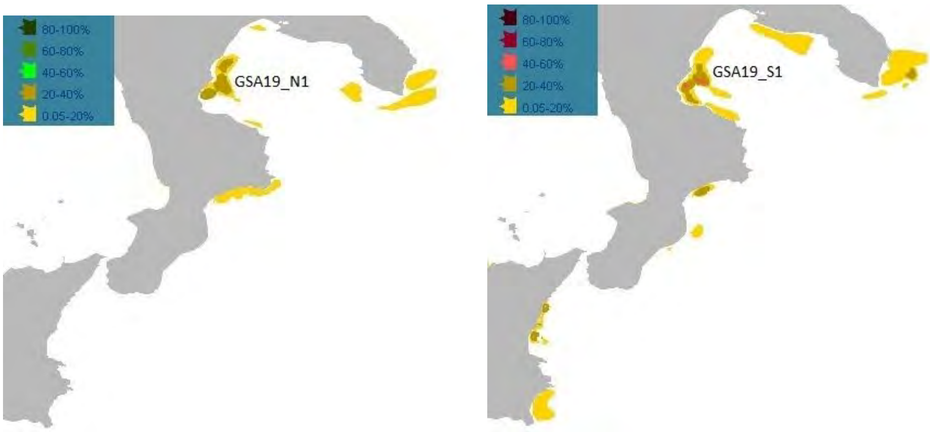


Fig. 2.2.5.11.7. Position of persistent nursery (left) and spawning areas of horned octopus (right) in GSA 19

GSAs 20, 22-23

The depth distribution of horned octopus extends from 35 to 525m in the Aegean Sea according to MEDITS catches. However, the higher abundances of the spawners of the species were found in the 0-250m depth zone, whereas recruits were located somewhat shallower (0-200m). Horned octopus (spawners and recruits) was also captured in the Ionian Sea, however the local distribution of the captures combined with the low numbers did not allow any modeling. Hence the only available distribution maps for the Ionian Sea are annual bubble plot maps.

The density maps of spawners revealed a distribution mainly located in the Saronikos gulf (Fig. 2.2.5.11.8). The density maps of recruits did not show any persistent hotspots with very high probability (>0.8) but were mainly found at the northwestern part of the Aegean Sea (mainly on the extended continental shelf of the Thermaikos gulf, Fig. 2.2.5.11.8).

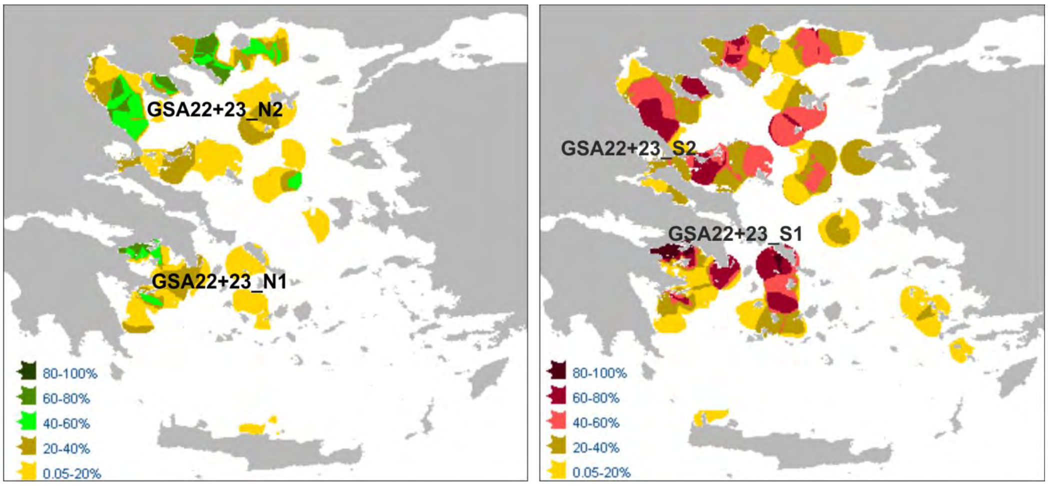


Fig 2.2.5.11.8. Position of persistent nursery (left) and spawning areas (right)of horned octopus in GSA 22-23.

Table 2.2.5.11.5. Main environmental features of the most persistent areas identified for horned octopus in European GSAs

GSA	Type of area	Code	Depth range (m)	Description
7	Adult females aggregation	GSA7_N1	90-100	Shelf, muddy bottoms
9	nursery	GSA9_N1	50-120	Deep shelf between Livorno and La Spezia
9	nursery	GSA9_N2	140-180	Outer shelf-upper slope East of Capraia Island (South Ligurian Sea). Detritics and muddy bottoms
9	nursery	GSA9_N3	140-250	Outer shelf-upper slope of North Tyrrhenian. Occurrence of detritic bottoms with crinoid beds.
9	nursery	GSA9_N4	95-130	Outer shelf between Montalto di Castro and Monte Argentario
9	nursery	GSA9_N5	60-140	Outer shelf of the central-south Latium
9	nursery	GSA9_N6	110-160	Shelf break between Capo Circeo and Gaeta

GSA	Type of area	Code	Depth range (m)	Description
9	Adult females aggregation	GSA9_S1	100-120	Outer shelf North Tyrrhenian Sea
9	Adult females aggregation	GSA9_S2	250-400	Upper slope North Tyrrhenian Sea
10	nursery	GSA10_N1	24-123	The northern seabeds of the Ischia Island are characterized by a wide continental shelf. The sandy-muddy bottoms are colonized by coastal terrigenous muds (VTC) biocenosis inhabited from typical species as *Alcyonium palmatum*, *Astropecten spp*, *Sternaspsis scutata*, *Bolinus spp* etc. The mainstream current direction is from south to north.
10	nursery	GSA10_N2	130-170	The large continental shelf of the Gulf of Naples is characterized by mud bottom and coastal terrigenous muds biocenosis (VTC). The characteristic species are *Alcyonium palmatum*, *Astropecten spp*, *Sternaspsis scutata*. The superficial currents are circular during the sampling period (spring).
10	nursery	GSA10_N3	64-182	The muddy bottoms inside the Gulf of Salerno are characterized by coastal terrigenous muds (VTC) with the characteristic species as *Alcyonium palmatum*, *Trachythyone tergestina*, *Astropecten spp*, *Pennatula rubra* etc. The superficial currents are circular during the sampling period (spring).
10	nursery	GSA10_N4	114-345	The bottom is muddy characterized by coastal terrigenous muds (VTC) biocenosis with an asteroids facies (*Astropecten irregularis*, *Astropecten bispinosus*, *Tethyaster subinermis* associated with species as *Alcyonium palmatum*, *Suberites dumuncula*, *Stichopus regalis* etc. The mainstream current direction is from west to east.
10	Adult females aggregation	GSA10_S1	65-413	The northern seabeds of the Ischia Island are characterized by a wide continental shelf. The sandy-muddy bottoms are colonized by coastal terrigenous muds (VTC) biocenosis inhabited from typical species as *Alcyonium palmatum*, *Astropecten spp*, *Sternaspsis scutata*, *Bolinus spp* etc. The mainstream current direction is from south to north.
10	Adult females aggregation	GSA10_S2	142-170	The large continental shelf of the Gulf of Naples is characterized by mud bottom and coastal terrigenous muds biocenosis (VTC). The characteristic species are *Alcyonium palmatum*, *Astropecten spp*, *Sternaspsis scutata* etc. The superficial currents are circular during the sampling period (spring).
10	Adult females aggregation	GSA10_S3	64-411	The muddy bottoms inside the Gulf of Salerno are characterized by coastal terrigenous muds (VTC) biocenosis and detritic bottom (DL) biocoenosis with facies of *Leptometra phalangium*. To this facies are associated species as *Astropecten spp*, *Latreillia elegans*, *Cidaris Cidaris* etc. The mainstream current direction is from south to north
10	Adult females aggregation	GSA10_S4	61-124	The infralittoral of Castellammare Gulf is characterized by the coastal detritic biocenosis (DC) on the tanatocenosis of *Neopycnodonte cochlear* with characteristic species as *Alcyonium palmatum*, *Pennatula phoshorea*, *Stichopus regalis*, *Peltaster placenta*. The superficial current during the sampling period is circular inside the gulf.
11	nursery	GSA11_N1	100-200	The bottoms are prevalently characterized by a biocenosis of detrictic, (facies at *Leptometra phalangium*)
11	nursery	GSA11_N2	100-200	The bottoms are prevalently characterized by a biocenosis of detrictic, (facies at *Leptometra phalangium*)

GSA	Type of area	Code	Depth range (m)	Description
11	Adult females aggregation	GSA11_S1	>300	Bathyal muddy with a remarkable presence of *Funiculina quadrangularis*
11	Adult females aggregation	GSA11_S2	>300	Bathyal muddy with a remarkable presence of *Funiculina quadrangularis*
17	nursery	GSA17_R1	60-160	- muddy-sediments - scavengers communities
17	nursery	GSA17_R2	120-150	- westwards the Croatian islands of Vis e Brac
17	Adult females aggregation	GSA17_S1	100-300	- muddy sediments - Pomo/Jabuka Pit area
17	Adult females aggregation	GSA17_S2	150-300	- muddy sediments - Connection with GSA18
18	nursery	GSA18_N1	109-118	The bottom is muddy and characterized by the detritic bottom biocenosis (DL) with hidroids facies (*Nemertesia antennina*, *Lytocarpia myriophyllum*) on tanatocenosis of *Neopycnodonte cochlear*. To this facies are associated species as *Alcyonium palmatum*, *Astropecten spp*, *Galeodea spp*, *Suberites dumuncula* etc. The mainstream current direction is from north to south.
18	nursery	GSA18_N2	155-177	The muddy bottoms are characterized by coastal terrigenous muds (VTC) biocenosis (*Alcyonium palmatum*, *Astropecten spp, Stichopus regalis Pennatula phosphorea* etc.) and the detritic bottom biocenosis (DL) inhabited by typical species as *Nemertesia antennina, Cidaris cidaris, Tetyiaster subinermis*. The mainstream current direction is from north to south.
18	Adult females aggregation	GSA18_S1	169-231	The bottom is muddy characterized by the detritic bottom biocenosis (DL) with hidroids facies (*Nemertesia antennina*, *Lytocarpia myriophyllum*). To this facies are associated species as *Alcyonium palmatum*, *Astropecten spp*, *Spatangus purpureus*, *Suberites dumuncula Thenea muricata*, *Desmacella annexa*, *Doris sticta* etc. The mainstream current direction is from north to south.
18	Adult females aggregation	GSA18_S2	117-137	The bottom is muddy and characterized by the detritic bottom biocenosis (DL) with hidroids facies (*Nemertesia antennina*, *Lytocarpia myriophyllum*) on tanatocenosis of *Neopycnodonte cochlear*. To this facies are associated species as *Alcyonium palmatum*, *Astropecten spp*, *Galeodea spp*, *Suberites dumuncula* etc. The mainstream current direction is from north to south.
18	Adult females aggregation	GSA10_S3	117-125	The bottom is muddy and characterized by coastal terrigenous muds biocenosis (VTC) with facies of *A. palmatum* on the soft bottom with associated species as *Pteria hirundo*, *Stichopus regalis*, *Pseudocnus syracusanus* etc. Moreover the detritic bottom biocenosis (DL) is present in the area with hidroids facies (*Lytocarpia myriophyllum Nemertesia antennina*) on tanatocenosis of *Neopycnodonte cochlear* with associated species as *Ascidia mentula*, *Homola barbata*, *Glossus humanus*, *Macropipus tuberculatus* etc. The mainstream current direction is from north to south.
19	nursery	GSA19_N1	26-152	The shelf in the Gulf of Corigliano is characterized by the Amendolara Bank (rising from 200 up to about 20 m below the surface). In particular, this area is characterized by the coarse sand and coastal detritic biocenosis.

GSA	Type of area	Code	Depth range (m)	Description
19	Adult females aggregation	GSA19_S1	26-152	The shelf in the Gulf of Corigliano is characterized by the Amendolara Bank (rising from 200 up to about 20 m below the surface). In particular, this area is characterized by the coarse sand and coastal detritic biocenosis.
22_23	nursery	GSA22-23_S1	50-200	Inner-most part of Saronikos gulf. Relatively deep area with mud as the main sediment types. Enclosed area with relatively stable oceanographic conditions.
22_23	nursery	GSA22-23_S1	50-200	Scattered persistent areas in the north, north-western Aegean Sea (mainly the off-shore part of Thermaikos gulf and the North Sporades Island complex). Oceanographic circulation is important in these areas with gyres and eddies affecting the distribution pattern of the meroplanktonic larval stages of the species and subsequently the location of their settlement.
22_23	Adult females aggregation	GSA 22-23_S1	50-200	Inner-most part of Saronikos gulf and northern part of Cyclades Island complex. Areas with mud as the main sediment type. In Saronikos gulf the area is enclosed with relatively stable oceanographic conditions, whereas in Cyclades exposure to strong winds is common. No additional environmental information is available.
22_23	Adult females aggregation	GSA 22-23_S1	50-200	Scattered persistent areas in the north, north-western Aegean Sea (mainly the off-shore part of Thermaikos gulf and the North Sporades Island complex). Main sediment type is mud. River outflows exist in some of the areas but their influence cannot be quantified.

2.2.5.11.4. Gaps in knowledge and future actions

Identification of nurseries in Western Mediterranean using survey data would require sampling also in autumn-winter. In Greek GSAs information on the species life-cycle is mainly derived from data collected in the North Aegean Sea; thus may be not representative for all the surveyed area. However, it seems that spawning does not overlap with the MEDITS survey and recruitment varies greatly even between neighboring areas. For this reason, the current findings should be faced with caution as may not be fully representative of the real situation.

2.2.5.12 Illex coindetii

2.2.5.12.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. Below the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

The size frequency distributions are polymodal in GSA 7, 8, 9, making often difficult to separate recruits.

The broadtail shortfin squid produces at least two alternating generations in the Strait of Sicily (GSA 15-16) each year, which are adapted to live in different seasonal environmental conditions. Because of the long reproductive period, immature and small-sized individuals are caught in all seasons (Soro and Paolini, 1994).

Recruits of *Illex coindetii* in the GSAs 10 and 18 are occurring both in spring and autumn. In GSA11 *I. coindetii* can be found in a wide depth range, from the surface up to more than 700 m, but is more common between 100 and 300 m.
In the North-Western Ionian Sea (GSA19) the broadtail shortfin squid was collected at depths ranging from 14 to 767 m. The minimum and maximum sizes were 22 and 291 mm DML. Up to date, no juvenile aggregations or nursery areas were detected for the broadtail shortfin squid in the GSA19.

Recruits are present in the populations of this species all year round in GSAs 20 and 22_23 due to the virtually continuous spawning season. However *Illex coindetii* recruitment can be affected by peculiar oceanographic features, like frontal zones shifting and upwellings, which allow an optimal embryonic development and peaks in recruitment.

Spawning

Reproduction and spawning extend throughout the year, with peaks in different seasons/months, depending on geographic location. In the Northern Balearic basin the peak occurs in autumn (Sánchez *et al*., 1998). Mature squids are distributed over the whole depth range and adults undergo vertical migrations, living close to the bottom during the day, ascending towards the surface at night (Jereb and Roper, 2010). Seasonal migrations have been described in the Northern Balearic basin, moving from shallower (up to 150 m) to deeper waters (up to 575 m) from spring to autumn-winter (Sánchez *et al*., 1998). The length at first maturity was estimated at 150 mm ML for females.

Mature specimens of *Illex coindetii* are found in GSA9 in a wide size range; males reach maturity at smaller sized than females. Length at first maturity in the Northern Tyrrhenian Sea is 120 mm ML for males and 150 mm ML for females. Spawning occurs in GSA9 all year long, with seasonal peaks according to the area. *I. coindetii* is considered an intermittent spawner; females spawn several times during the spawning period.

In GSA10, the broadtail shortfin squid reproductive cycle is extended from spring to summer when also recruits are occurring. A proxy of size at first maturity for females was estimated in the SAMED project that indicates an average length of about 13.3 cm. According to the data obtained from DCF in 2009, the proportion of mature females by length class gave an estimate of maturity ogive which indicates a $L_{50\%}$ of about 13.5cm (±0.18 cm; MR=2 ±0.24) a value slightly lower than in DCF 2010 ($L_{50\%}$= 14.5 ±0.32; MR= 2.2 ±0.35) when the estimate was obtained using a GLM.

In GSA11, mature individuals of *I. coindetii* are found in a wide range of sizes. Males reach maturity at smaller sizes than females. The size at first maturity is about 120 mm ML for males and 150 mm ML for females. Individuals at all stages of maturation are present at all depths, prevalently 100-450 m, throughout the year.

In GSA18, mature individuals are occurring mainly in spring-summer season. According to the data obtained from DCF in 2009, the proportion of mature females gave an estimate of maturity ogive which indicates an $L_{m50\%}$ of 13.3cm (±0.05 cm; MR=2.2±0.07), a value similar to DCF 2010 ($L_{50\%}$= 12.9 ±0.06; MR= 2.5 ±0.07) when the estimate was obtained using a GLM.

In the GSA19 the reproductive period of the broadtail shortfin squid extended from early spring to summer. The smallest mature female and male were 85 and 65 mm DML, respectively. Up to date, no spawning areas were clearly detected for *I. coindetii* in the GSA19.

Mature females are found in the Strait of Sicily throughout the year, suggesting year-round spawning, but peaks in spawning occur in the spring/summer. Sexual dimorphism in sizes is evident in maturing and mature adults, with females being larger than males. Estimate of L50% is 150 mm ML for females and 100-120 mm ML for males.

In GSA 17 spawning occurs all year long, with a seasonal peak in spring/summer. Size at first sexual maturity is 162 mm of mantle length for females and 126 mm for males (Soro and Paolini, 1994).

In GSAs 20 and 22_23 spawners of the species are found all year round, with the peak of the reproductive season varying between years and areas, due most probably to respective variability in environmental conditions that may affect recruits' survival, growth and maturation process.

2.2.5.12.2 Modeling approach

Identification of recruits and spawners

Tables 2.2.5.12.1 and 2.2.5.12.2 list the frequency of positive hauls and the number of *I. coindetii* specimens caught during MEDITS in each GSA. Recruitment and maturity sizes are indicated in Table 2.2.5.12.3.

GSAs 1-6, 5

The proportion of positive hauls is highly variable from year to year, varying from 0.32 to 0.90 in the GSA 05 and from 0.11 to 0.67 in the GSA 01 and 06. The number of specimens is highly variable ranging from 38 to 1260 in the GSA05 and from 13 to 3006 in the GSA 01 and 06.

Following the protocol developed in the R_RSI_MEDISEH script, we applied the Bhattacharya's method to extract the first modal component of the length-frequency distribution of *I. coindetti*, on a yearly basis for the GSAs 01 and 06. The mean length of the first modal component plus the standard deviation was applied as a threshold value of total length. This threshold and the swept area of each haul were used to calculate the standardized abundance index of recruits (n/km^2). Differences in the length frequencies between GSAs were observed, thus Bhattacharya's method was applied separately in each GSA. In the case of GSA 05, the low amount of individuals made it impossible to apply Bhattacharya's method and the minimum observed in the other Spanish GSAs (01 and 06) was applied.

In order to extract the spawners' fraction, females with maturity stage III (mature) were considered for modeling due to the lack of any other biological information or literature concerning this issue.

GSA 7, 8, 9

In GSA7 the frequency of occurrence of *Illex coindetii* was not constant during the years, it ranged from 0.09 in 2006 to 0.60 in 2000; the same was observed in GSA8, with frequency of positive hauls comprised between 0.13 to 0.68. On the contrary, in GSA9 the occurrence of the broadtail shortfin squid was rather constant throughout the years (from 35 to 57%).

Only the GSA9 showed abundant catches of *I. coindetii*: the specimens caught in the different years ranged from 253 in 1994 to 4087 in 2009. In GSA7 the catches varied from 9 to 168 specimens, while in GSA8 the catches ranged from 5 to 65 individuals.

GSA 10, 11, 18, 19

The frequency of positive hauls for *I. coindetii* in GSA10 ranges between 0.31 (MEDITS 1994, 1999, 2006 and 2010) and 0.

2007) and 0.77 (MEDITS 2010), with an overall catch fluctuating from a minimum of 250 (MEDITS 49 (MEDITS 2007), with an overall catch fluctuating from a minimum of 45 (MEDITS 2010) and a maximum of 2514 (MEDITS 2008) sampled specimens.

The frequency of positive hauls for *I. coindetii* in GSA18 ranges between 0.21 (MEDITS 1994) and 0.80 (MEDITS 2007), with an overall catch fluctuating from a minimum of 40 (MEDITS 1994) and a maximum of 6579 (MEDITS 2007) sampled specimens. The frequency of positive hauls for *I. coindetii* in GSA11 ranges between 0.32 (MEDITS 1994) and a maximum of 1341 (MEDITS 2005) sampled specimens.

The frequency of hauls positive to the catch of the broadtail shortfin squid in GSA19 oscillated between 0.14 and 0.80. A minimum of 47 and a maximum of 2174 specimens of *I. coindetii* were sampled in GSA19 during MEDITS 1994 and MEDITS 2008, respectively.

In the GSAs 10 and 18, the recruits have been identified annually according to ability of the survey to intercept the phenomenon. The threshold to separate the recruits has been generally estimated as the mean length of the first modal component + 2* sd using the Bhattacharya's method and the R_RSI_MEDISEH routine, specifically developed for the MEDISEH project. In the case of GSAs 11 and 19 an empirical value was adopted as threshold size as derived from other research studies carried out in the area.

To identify the adults or potential spawners, an average of the parameters of the maturity ogive among the years from the MEDITS survey and/or from biological samplings of DCR and DCF has been used in GSAs 10 and 18, selecting those better fitting to the model. For *I. coindetii* the empirical threshold value was 113 mm DML was adopted in GSA19, while a fixed threshold length from literature was used in the GSA11.

GSAs 15- 16

In spite of a wide depth distribution, catches of *Illex coindetii* in the Strait of Sicily occur mainly on the shelf and are not very high. The number of positive hauls is comprised between 32% and 54% whilst the total number of specimens caught is highly variable from year-to-year, ranging between 475 and 4218.

Since the identification of the first modal component in LFDs was not reliable, recruits of I. coindetii were identified using the mean length of individuals showing maturity stage "1" (90 mm ML), combining all the years. The Lm50% (130 mm ML for females) of maturity ogive obtained from biological sampling of commercial catches (DCF) was used to identify potential spawners.

GSA 17

GSA 17 MEDITS data are available for the period 2002-2010. The period 1994-2001 has been excluded from the analyses because data of the eastern side of the basin were not available.

In GSA 17 broadtail shortfin squid was quite abundant during MEDITS with more than 60% of positive hauls and an average of more than 3,500 specimens collected each year. The threshold sizes to detect recruits (mantle length ≤ 6 cm) and spawners (mantle length ≥ 16 cm) has been derived respectively from Piccinetti et al. (2012) and Soro and Piccinetti Manfrin (1994).

GSAs, 20, 22-23

The available data for broadtail shortfin squid that were suitable for analysis extended from 1996-2008 and from 1998-2008 for GSAs 22_23 and GSA 20, respectively. In GSA20 and in GSAs 22_23 the proportion of positive hauls for broadtail shortfin squid ranged from 53-84% and from 62-88%, respectively (Table 2.5.5.1). Data from the MEDITS surveys carried out before 1996 were not used due to the fact that the sampling scheme in the earlier years was not consistent with that from 1996 onwards. The approach followed in GSAs 20, 22_23 for the identification of recruits and spawners involved the estimation of threshold values, based on Bhattacharya plots in the case of recruits, and the size (L50) at which 50% of the female individuals were found to have gonads that were in a macroscopically mature stage. In a few cases, where data did not allow defining estimates based on the aforementioned approaches, threshold values were established based on literature information and expert knowledge.

GSA 25

In GSA 25 broadtail shortfin squid is quite scarce with usually less than 30% of positive hauls and an average of around 60 specimens collected each year. Given their low abundance, recruits and spawners threshold sizes have been derived from the data of GSAs 22-23.

Table 2.2.5.12.1. Frequency of positive MEDITS hauls (n of positive hauls/total number of hauls) for broadtail shortfin squid by GSA and year

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		0.10	0.33	0.35	0.31	0.44		0.21	0.14			0.11		
1995		0.15	0.32	0.51	0.34	0.55		0.44	0.31			0.34		
1996				0.42	0.36	0.35		0.45	0.38			0.46		0.62
1997		0.49	0.15	0.41	0.32	0.43		0.48	0.30			0.42		0.7
1998		0.38	0.43	0.44	0.42	0.56		0.49	0.45	0.59		0.39		0.83
1999		0.48	0.48	0.41	0.31	0.60		0.58	0.50	0.69		0.59		0.85
2000		0.60	0.41	0.53	0.34	0.53		0.60	0.36	0.66		0.60		0.84
2001		0.27	0.68	0.33	0.42	0.58		0.62	0.32	0.56		0.37		0.79
2002		0.52		0.45	0.33	0.33	0.76	0.52	0.44			0.51		
2003		0.16	0.35	0.36	0.41	0.65	0.54	0.58	0.26	0.81		0.67	0.52	0.88
2004		0.35	0.32	0.34	0.41	0.47	0.63	0.70	0.30	0.75		0.48	0.43	0.8
2005		0.40	0.48	0.44	0.41	0.71	0.65	0.73	0.47	0.78	0.20	0.50	0.32	0.87
2006		0.09	0.13	0.35	0.31	0.57	0.56	0.53	0.41	0.53	0.28	0.26	0.42	0.87
2007	0.32	0.19	0.40	0.57	0.49	0.32	0.82	0.80	0.53		0.28	0.23	0.54	
2008	0.32	0.45	0.28	0.44	0.39	0.43	0.80	0.67	0.80	0.84	0.33	0.49	0.48	0.87
2009	0.70	0.34	0.14	0.35	0.44	0.58	0.75	0.72	0.50		0.26	0.64	0.52	
2010	0.90	0.40	0.36	0.43	0.31	0.77	0.80	0.78	0.50		0.22	0.62	0.42	

Table 2.2.5.12.2. Number of specimens of broadtail shortfin squid caught during MEDITS by GSA and year.

	GSA													
YEAR	**5**	**7**	**8**	**9**	**10**	**11**	**17**	**18**	**19**	**20**	**25**	**1_6**	**15_16**	**22_23**
1994		21	30	253	138	250		40	47			13		
1995		16	27	823	187	317		108	160			93		
1996		0		673	546	198		234	152	147		609		1733
1997		154	14	1135	467	451		208	132	270		229		2058
1998		95	59	878	624	837		357	292	196		475		4626
1999		133	46	302	172	564		1828	568	319		410		5346
2000		168	52	1566	263	703		594	220			3006		19334
2001		22	65	310	233	705		3496	298	739		272		5295
2002		93		4087	281	164	9578	751	292	664		415		
2003		22	36	459	1619	844	1435	536	156	1953		843	4218	8878
2004		35	30	181	231	606	6897	3085	250	116		449	1341	9306
2005		59	26	1780	363	1341	1709	4847	733		11	520	475	7603
2006		9	5	3088	99	259	943	397	400	887	23	77	706	4815
2007	38	20	34	2217	1494	329	4156	6579	2047	147	44	54	2851	
2008	38	147	19	310	2514	549	3099	1692	2174	270	53	2019	1041	7457
2009	656	42	14	603	1303	353	2280	1820	949		55	1057	1285	
2010	1260	116	19	209	45	1150	2722	1733	539		63	609	532	

Table 2.2.5.12.3. Recruitment and spawning size identification for modeling purposes.

		Recruits			Spawners		
GSA	**Sampling years**	**Data source**	**Method used**	**Mean threshold length (ML mm)**	**Data source**	**Method used**	**Mean maturity length (cm) /Maturity stage**
05	-	MEDITS	Fixed threshold length	62	MEDITS	Maturity stage	III
01	1994-2010	MEDITS	Bhattacharya	72	MEDITS	Maturity stage	III
06	1994-2010	MEDITS	Bhattacharya	69	MEDITS	Maturity stage	III
7	1994-2010	DCF/MEDITS			DCF/MEDITS		
8	1994-2010	DCF/MEDITS			DCF/MEDITS		
9	1994-2010	DCF/MEDITS	Bhattacharya	60	DCF/MEDITS	Fixed threshold length (L50)	150
10	1994-2010	MEDITS	Bhattacharya	90	Biological sampling	Maturity ogive	140
11	1994-2010	MEDITS	Fixed threshold length	115	Jereb and Ragonese, 1995	Fixed threshold length (L50)	150
18	1994-2010	MEDITS	Bhattacharya	95	Biological sampling	Maturity ogive	131
19	1994-2010	MEDITS	fixed	90	MEDITS	Fixed threshold length (L50)	132
15+16	2003-2010	MEDITS	Fixed threshold	90	DCF	Fixed threshold length (L50)	130
17	2002-2010	Piccinetti et al., 2012	Fixed threshold length	60	Soro and Piccinetti Manfrin, 1994	Fixed threshold length (L50)	160
20	1998-2008	MEDITS	Bhattacharya	100	MEDITS	Fixed threshold length (L50)	160
22_23	1996-2008	MEDITS	Bhattacharya	100	MEDITS	Fixed threshold length (L50)	160
25	2005-2010	GSAs 22-23	Fixed threshold length	100	GSAs 22-23	Maturity ogive	160

Mapping of density and identification of hot spot areas

A summary of the spatial models implemented for mapping recruits and adults/spawners of broadtail shortfin squid is provided in Table 2.2.5.12.4.

GSAs 1-6

The spawners and recruits were modeled using GAM. Two models were developed independently, one for presence/absence data, and another for standardized abundances restricted to presence data only. The final presence/absence model for recruits included depth, interaction between longitude and latitude and year, whereas the final abundance restricted to presence samples model included year and the interaction between longitude and latitude as significant factors, these models explaining 27 and 24% of the total variance, respectively. Model for spawners included depth and the interaction between longitude and latitude, whereas the final abundance restricted to presence samples model included year and depth as significant factors, these models explaining 16 and 26% of the total variance, respectively.

GSA 5

The spawners were modeled using GAM. Two models were conducted independently, one for presence/absence data, and another for standardized abundances restricted to presence data only. The final presence/absence model included depth, interaction between longitude and latitude and year, whereas the final abundance restricted to presence samples model included year and depth as significant factors, these models explaining 63 and 29% of the total variance, respectively (Table 2.5.13.4).

GSA 7, 8, 9

Modeling was possible only in GSA 9 where both areas of concentration of adults and nurseries have been identified. Both recruits and spawners were modelled using a GAM with spatial component for the years 1994-2010. Model for recruit include a smooth function on the distance from the slope covariate, a fixed intercept, and a year effect. The covariance function was exponential in the year 2007 and spherical in the others. GAM model for spawners used a temporal effect on the distance form the coast and a smooth function on the bottom steepness covariate. The covariance functions are either exponential or spherical depending on the year.

GSAs 10, 11, 18, 19

In GSA10-11-18-19 annual abundance values were predicted by mean a ZIGAM model (Gaussian + Binomial GAM) with depth as covariate and ordinary kriging on regression residuals. In years in which ZIGAM did not succeeded, ordinary kriging was applied on real abundance values.

GSA 17

Modeling approaches employed to identify spawning and nursery grounds of broadtail shortfin squid in GSA 17 were respectively the zero-Inflated Generalized Additive Model (Liu and Chan, 2010) and Ordinary Kriging. COZIGAM-ZIGAM approach did not find any suitable model to describe the spatial distribution of recruits and, hence, Ordinary Kriging was chosen because it produces a spatial distribution simply basing on the location of sampled stations.

In both cases local G statistic (Getis and Ord, 1992) was employed to identify the hot spots, considered as the place where high values of densities cluster together. The covariates employed to identify the spatial pattern of spawners of shortfin squid were year (as factor), latitude, longitude and depth. The diagnostics of the ZIGAM model employed for spawners of broadtail shortfin squid in GSA 17 (table 2.5.1.4) show an acceptable fitting.

GSAs 15-16

Both recruits and spawners distribution of *I.coindetii* were modeled in GSA 15+16 using a GAM with spatial component and a smooth term on a combination of the coordinates (covariates longitude and latitude). Both the intercept and the spatial component were allowed to change in an annual basis. The models goodness-of fit was measured by the cross-validation index (CV) and the correlation index (R^2) between the observed values and the values predicted by cross-validation. The density hot spots were found using the local G statistic with a level of confidence of the 95% and a circle neighbourhood of 2 km. The persistence was obtained as the rate of years in which a point was a hot spot.

GSAs 20, 22-23

Generalized Additive Models were employed to model the distribution of broadtail shortfin squid in each Greek GSA (GSA 20 and GSA 22_23). The covariates used were “Longitude”, “Latitude” and “Depth”. The model was run (a) separately for each year and (b) with pooled data from all years. Mapping was made through the use of the Weighted Inverse Distance (IDW) Algorithm, followed by the tangent method for the identification of hotspots.

The period analysed was from 1996-2008 and from 1998-2008 for GSA 20 and GSAs 22_23, respectively. The depth distribution of broadtail shortfin squid spawners was found to range between 60 - 575 m and 25 - 735 m in GSA20 and GSAs 22_23, respectively, whereas recruits in GSA 20 were distributed in depths between 35 and 380m. No modeling was applied for recruits in GSA 22_23 due to the low number and the local distribution of specimens caught.

Table 2.2.5.12.4. Spatial models implemented for mapping recruits and adults/spawners of broadtail shortfin squid in European GSAs. CV=ss Validation Index

<table>
<tr><th>Life stage</th><th>GSA</th><th>Depth range (m)</th><th>Period</th><th>Model type</th><th>Covariates</th><th colspan="2">% dev. expl.</th><th colspan="2">Goodness of fit (R^2)</th></tr>
<tr><td rowspan="2">Recruits</td><td rowspan="2">01, 06</td><td rowspan="2">40-290</td><td rowspan="2">1995-1997, 1999-2006, 2008-2010</td><td>Pres./Abs.</td><td>Year, (Lon, Lat), depth</td><td colspan="2">26.8</td><td colspan="2" rowspan="2">0.31</td></tr>
<tr><td>Abundance</td><td>Year, (Lon, Lat)</td><td colspan="2">24.5</td></tr>
<tr><td rowspan="2">Spawner females</td><td rowspan="2">05</td><td rowspan="2">50-755</td><td rowspan="2">2007-2010</td><td>Pres./Abs.</td><td>Year, (Lon, Lat), depth</td><td colspan="2">62.5</td><td colspan="2" rowspan="2">0.69</td></tr>
<tr><td>Abundance</td><td>Year, depth</td><td colspan="2">29.1</td></tr>
<tr><td rowspan="2">Spawner females</td><td rowspan="2">01, 06</td><td rowspan="2">25-820</td><td rowspan="2">1995-2010</td><td>Pres./Abs.</td><td>(Lon, Lat), depth</td><td colspan="2">15.6</td><td colspan="2" rowspan="2">0.31</td></tr>
<tr><td>Abundance</td><td>Year, depth</td><td colspan="2">24.1</td></tr>
<tr><td>Recruits</td><td>9</td><td>100-150</td><td>1994-2010</td><td>GAM with spatial component</td><td>Distance from the shore</td><td colspan="2"></td><td colspan="2">CV=1.01
0.39</td></tr>
<tr><td>Spawners</td><td>9</td><td>80-160</td><td>1994-2010</td><td>GAM with spatial component</td><td>Distance from the shore, slope</td><td colspan="2"></td><td colspan="2">CV=1.08
0.42</td></tr>
<tr><td>Recruits</td><td>15+16</td><td>18-450</td><td>2003-2010</td><td>GAM with spatial component</td><td>Year, Longitude, Latitude</td><td colspan="2"></td><td colspan="2">CV=0.96
0.465</td></tr>
<tr><td>Spawners</td><td>15+16</td><td>18-600</td><td>2003-2010</td><td>GLM with spatial component</td><td>Year, Longitude, Latitude</td><td colspan="2"></td><td colspan="2">CV=1.006
0.248</td></tr>
<tr><td rowspan="2">Spawners</td><td rowspan="2">17</td><td rowspan="2">5-600</td><td rowspan="2">2002-10</td><td rowspan="2">ZIGAM</td><td rowspan="2">Year, Lon, Lat, depth</td><td>LR</td><td>GAM</td><td>LR</td><td>GAM</td></tr>
<tr><td>30.6</td><td>28.7</td><td>0.35</td><td>0.25</td></tr>
<tr><td rowspan="2">Recruits</td><td rowspan="2">17</td><td rowspan="2">5-600</td><td rowspan="2">2002-10</td><td rowspan="2">Kriging</td><td rowspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

Life stage	**GSA**	**Depth range (m)**	**Period**	**Model type**	**Covariates**	**% dev. expl.**	**Goodness of fit (R^2)**
Recruits	20	35-380	1998-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	52.3	0.45
Spawners females	20	60-575	1998-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	47.6	0.37
Spawners females	22_23	25-735	1996-2008	GAM(delta - lognormal)	Year, (Lon, Lat), depth	34.1	0.31
recruits	10	10-500	1994:2010	Gaussian GAM	Depth	23.55	0.18
				Binomial GAM	Depth	31.73	0.33
				Ordinary Kriging			
recruits	11	10-800	1994:2010	Gaussian GAM	Depth	20.67	0.17
				Binomial GAM	Depth	30.72	0.3
				Ordinary Kriging			
recruits	18	10-800	1996:2010	Gaussian GAM	Depth	17.07	0.14
				Binomial GAM	Depth	28.12	0.33
				Ordinary Kriging			
recruits	19	10-800	1994:2010	Gaussian GAM	Depth	20.9	0.2
				Binomial GAM	Depth	33.0	0.3
				Ordinary Kriging			
spawners	10	10-800	1994	Gaussian GAM	Depth	3.68	0.03
				Binomial GAM	Depth	30.03	0.29
				Ordinary Kriging			
spawners	11	10-800	2007:2010	Gaussian GAM	Depth	11.8	0.08
				Binomial GAM	Depth	13.12	0.12
				Ordinary Kriging			
spawners	18	10-800	1996:2010	Gaussian GAM	Depth	4.45	0.04
				Binomial GAM	Depth	16.45	0.17
				Ordinary Kriging (*)			

Life stage	GSA	Depth range (m)	Period	Model type	Covariates	% dev. expl.	Goodness of fit (R^2)
spawners	19	10-800	1994:2002 2004:2010	Gaussian GAM	Depth	31.2	0.3
				Binomial GAM	Depth	20.0	0.2
				IDW (*)			

**cross validation index*

2.2.5.12.3 Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

Table 2.2.5.12.5 summarizes the main environmental features of the most persistent areas identified for broadtail shortfin squid in European GSAs. For details see at http://mareaproject.net/mediseh/viewer/med.html.

GSAs 1-6, 5

Maps of temporal persistence of nurseries and spawning areas are showed in Fig. 2.2.5.12.1. Mature specimens are predicted over the entire surveyed area of GSA 5, with the highest abundance between 200 and 400 m depth. Similarly to GSAs 01 and 06, clear inter-annual differences in the abundance can be observed, with the highest values in 2009 and 2010. Two persistent density hot-spots areas for spawners were detected northern Mallorca-Menorca and southern Mallorca.

In the GSA 01 and 06, three persistent density hot-spots areas of mature specimens were detected, two in the GSA 06, northern and southern Ebro River delta shelf, and one in the GSA 01, around Cape Gata Other persistent areas with a narrower extent are found in the Catalan coast in the GSA 06 and in the Western Northern Alboran Sea in the GSA 01.

The predictions for recruits showed that they are located mainly in the GSA 06, from Cape Salou to Cape Palos, with the highest abundance observed between 100 and 200 m depth. High inter-annual differences in the abundance of the recruits of this species can be observed, with years where they are almost absent (e.g. 1998, 2007) and others with high abundance (e.g. 2000, 2008). However, these fluctuations do not seem to be related with the oscillations observed in the abundance of mature specimens of this species.

Mature specimens are predicted to be located in the entire surveyed area, with the highest abundance between 50 and 200 m depth and in the northern and southern part of the Ebro River delta shelf, the gulf of Alicante and around the cape of Gata. During the years with high abundance (e.g. 1996, 1997, 2000, 2003 and 2008-10), this area seems to be enlarged, covering almost the whole prospected area in both GSAs. Although there is not biological knowledge about this species in our study area, the environmental influence could be on the basis of the fluctuations in its abundance and distribution, similarly to the observed for other cephalopods in the western Mediterranean (e.g. Lloret et al., 2001; Vargas-Yáñez et al., 2009; Quetglas et al., 2011). The highest abundance along the depth range surveyed has been found at around 200 m in the presence/absence model and between 100 and 200 m depth in the abundance restricted to presence samples mode.

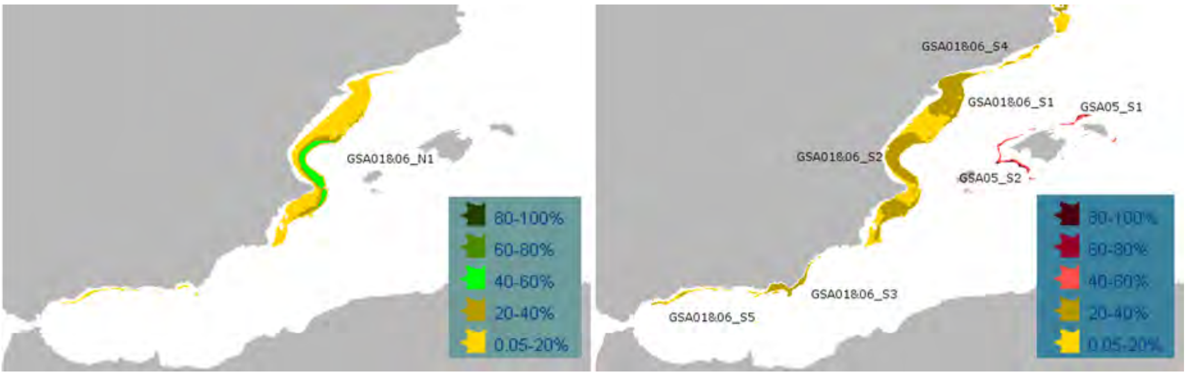


Fig. 2.2.5.12.1. Position of persistent nursery (left) and spawning areas (right) of broadtail shortfin squid in GSA 05, 01 and 06.

GSA 9

Two main spawning areas, with high persistency and density values were selected: both off the coasts of Tuscany, one at the north and another at south of Elba Island. Both are located from 50 to 120 m depth. Recruits show a more patchy distribution than spawners with few persistent density hot spots along the North Tyrrhenian shelf break (Fig. 2.2.5.12.2). Nurseries and spawning areas present a high degree of overlapping.

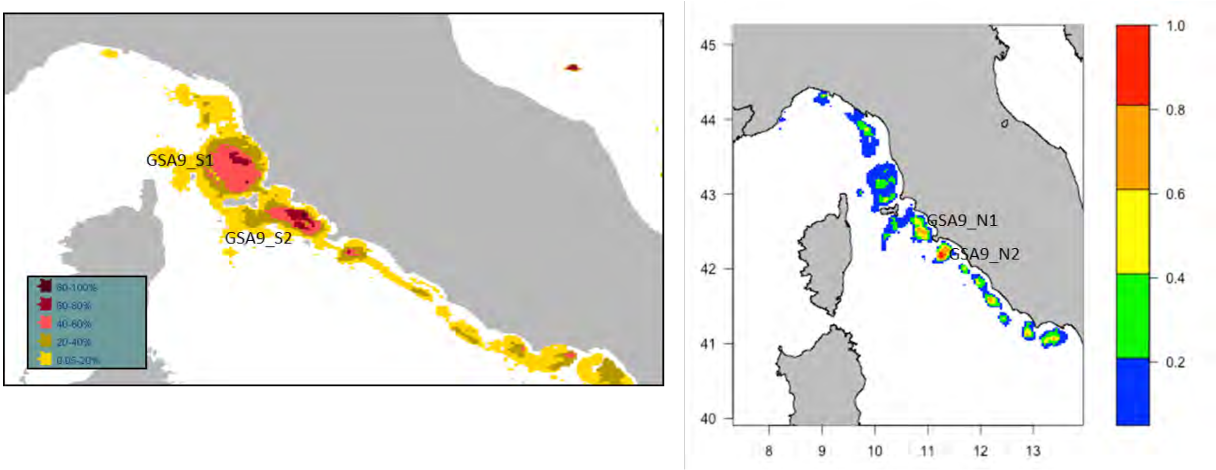


Fig. 2.2.5.12.2. Position of persistent spawning areas (left) and nursery (right) of broadtail shortfin squid in GSA 9

GSA 10

The most persistent nursery areas (probability 40-60%) were localized in the Gaeta Gulf (GSA10_N1) and off Capo Bonifati (GSA10_N2) mainly between 70 and 150 m depth (Fig. 2.2.5.12.3). These two areas partially overlap with the spawning aggregations GSA10_S1 and GSA10_S4. Several nuclei of recruits and spawners aggregation were found along the shelf of the GSA. The spawning aggregation with the higher level of persistence was localized in the Napoli Gulf (40-60%; GSA10_S2, Fig. 2.2.5.12.3). Details on the environmental characteristics of nursery areas and aggregations of adult females are reported in table 2.2.5.12.5.

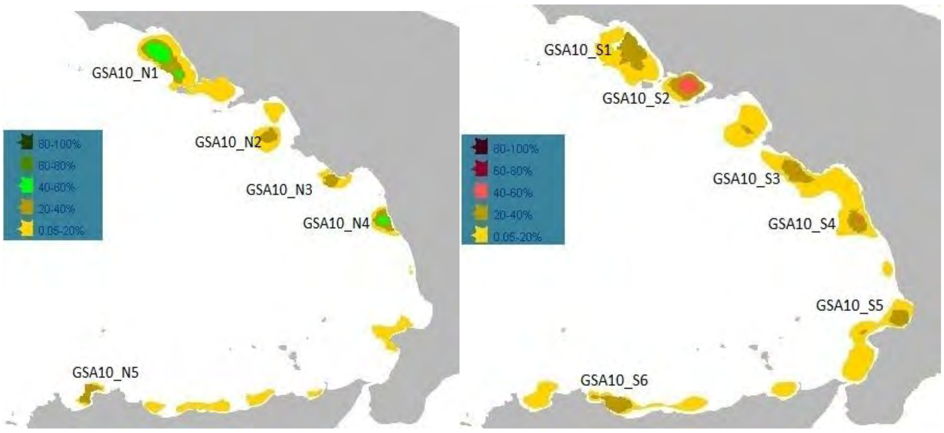


Fig. 2.2.5.12.3. Position of persistent spawning areas (left) and nursery (right) of broadtail shortfin squid in GSA 10

GSA 11

Nursery areas with a high level of persistence (40-60 %) are mainly identified in the central and southern coasts of Sardinia at depths comprised between 100- 300 m, preferentially at 100-200 m (Fig. 2.2.5.12.4). At these depths, the bottoms are characterized by the presence of the biocenosis of the Detritic bottom with a high presence of the crinoid *Leptometra phalangium*. Adult aggregations are mainly present in the western and northern coasts of Sardinia at depths between 100-450 m (Fig. 2.2.5.12.4).

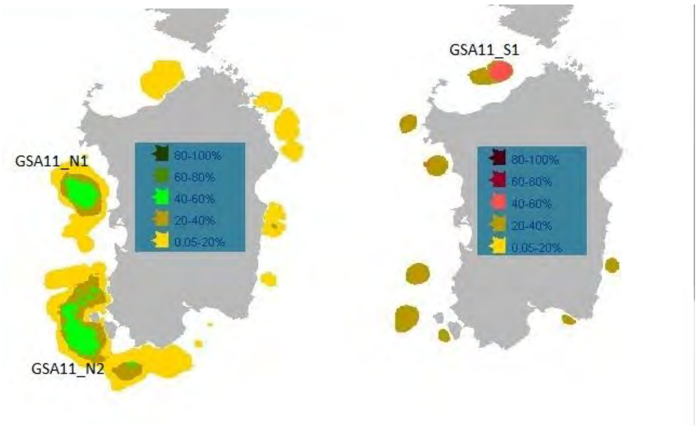


Fig. 2.2.5.12.4. Position of persistent spawning areas (left) and nursery (right) of broadtail shortfin squid in GSA 11

GSAs 15-16

Maps of temporal persistence of nurseries and spawning areas are showed in Fig. 2.2.5.12.5.

Ontogenetic difference in the habitat utilization between juvenile and mature specimens is observed for the short-finned squid over the Adventure Bank. The nursery (GSA15+16_N1) is located offshore along the southeast edge of the Bank, whereas the spawning areas (GSA15+16_S1 and GSA15+16_S2) are more coastal albeit deeper.

The nursery GSA15+16_N1 (over the Adventure Bank), is associated with the location of upwelling events linked to the westward flow of the Levantine Intermediate Water, bringing deep water onto the shelf. The nursery GSA15+16_N2 (along the south central coast of Sicily) is located in an area characterized by permanent upwelling and by the presence of a 'stagnant point' (still water), where the Atlantic Ionian Stream impinges the shore on the eastern side of the Adventure Bank. The nursery GSA15+16_N3 (along the eastern edge of the Malta Bank), is located in an area characterized by permanent upwelling and by the presence of the Ionian Slope Front (ISF). On the whole, the observed spatial pattern suggests that enrichment and retention mechanisms are key environmental factors for recruitment of short-finned squid.

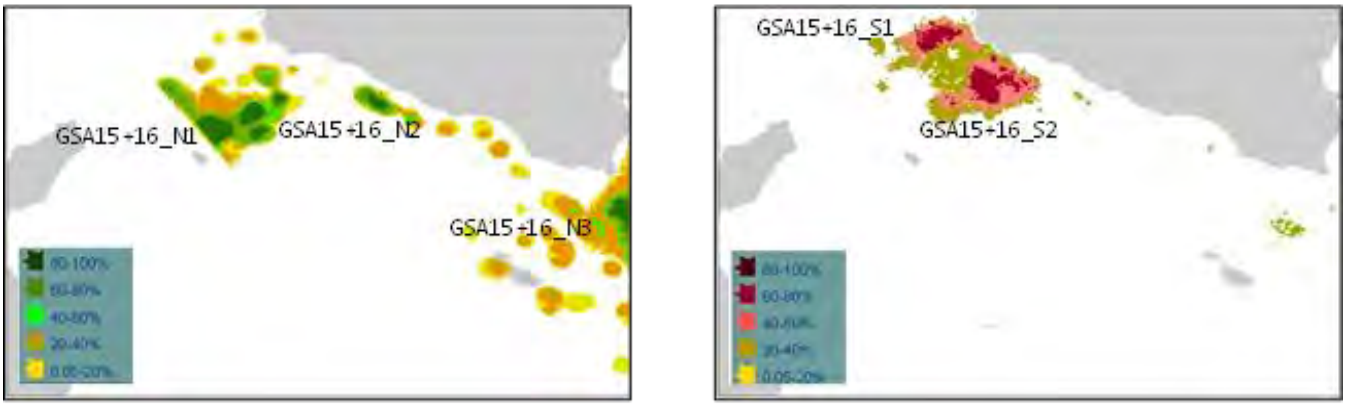


Fig. 2.2.5.12.5. Position of persistent nursery (left) and spawning areas (right) of broadtail shortfin squid in GSA 15+16

GSA 17

Maps of temporal persistence of nurseries and spawning areas are showed in Fig. 2.2.5.12.6.

The area of persistency identified for the recruits of broadtail shortfin squid in GSA 17 is wide, extending between 50 and 300 m of depth. Two main persistency areas can be identified. R1 extends from the Italian waters to the middle line and R2 from the middle line to the Croatian waters. The area of persistency identified for the spawners of broadtail shortfin squid in GSA 17 (S1) is located between 100 and 200 m, southwards 43.66° of latitude in the central portion of the basin with the exclusion of the Pomo/Jabuka Pit area.

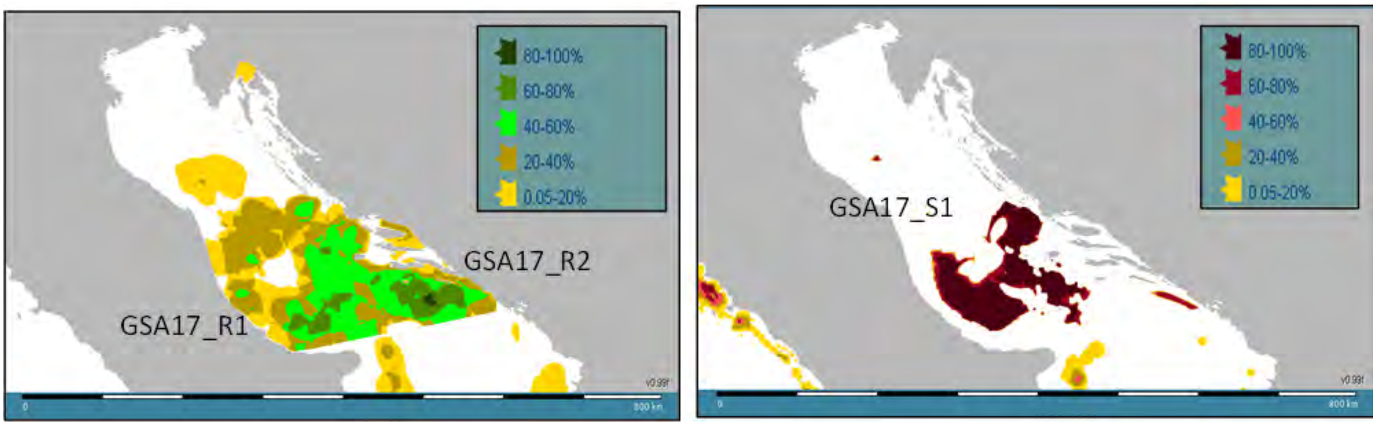


Fig. 2.2.5.12.6. Position of persistent nursery (left) and spawning areas (right) of broadtail shortfin squid in GSA 17

GSA 18

Nursery areas and aggregations of *I. coindetii* adult females mainly occur along the western side of the GSA 18, between 100 and 150 m depth. The more persistent nursery area (GSA18_N1) is very wide and partially overlaps with the more persistent spawning aggregations (GSA18_S3 and GSA18_S4, Fig. 2.2.5.12.7). Details on the environmental characteristics of nursery areas and aggregations of adult females are reported in table 2.2.5.12.5.

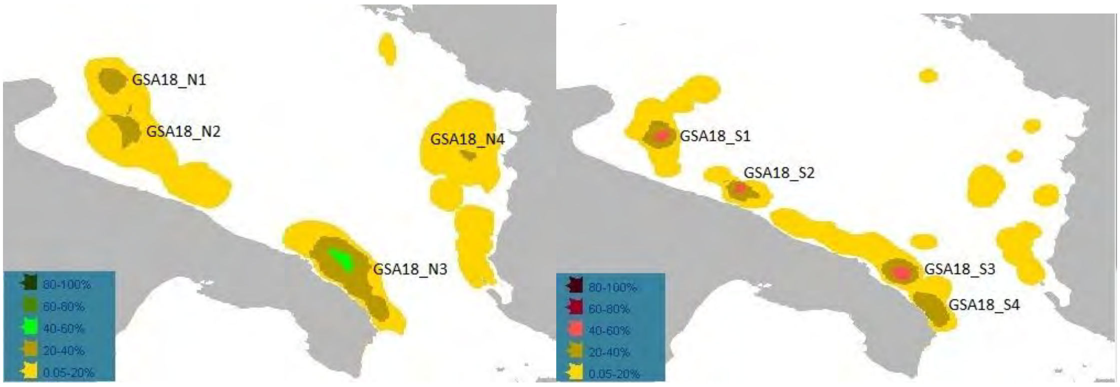


Fig. 2.2.5.12.7. Position of persistent spawning areas (left) and nursery (right) of broadtail shortfin squid in GSA 18

GSA 19

The main nursery area of the broadtail shortfin squid in the North-Western Ionian Sea showing the highest persistency levels was observed on the shelf grounds north-eastern Santa Maria di Leuca. Partial overlapping between nursery and adult aggregations is observed in the area eastern Santa Maria di Leuca. In addition, small but persistent areas of adult aggregation, were also detected on the shelf around the Amendolara Bank and offshore Punta Stilo (GSA19_S1) (Fig. 2.2.5.12.8).

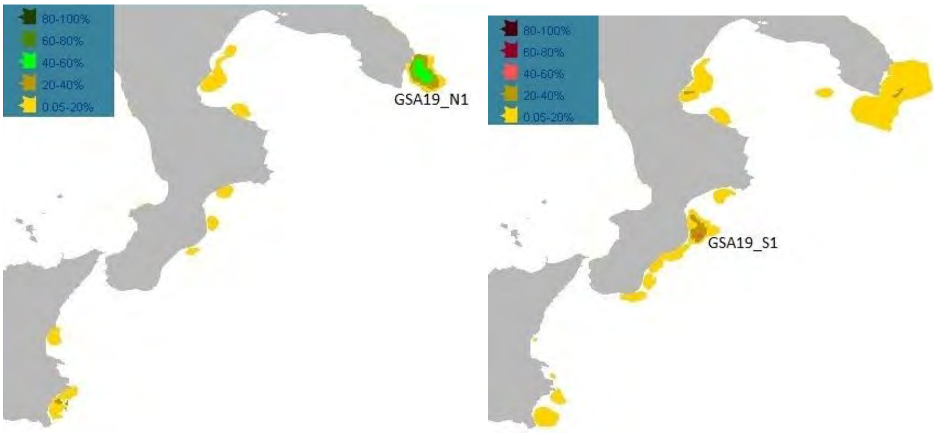
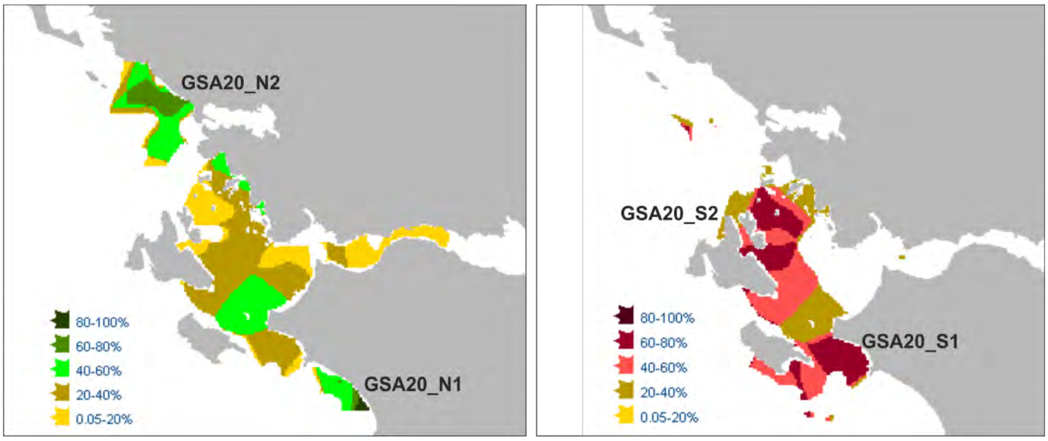


Fig. 2.2.5.12.8. Position of persistent spawning areas (left) and nursery (right) of broadtail shortfin squid in GSA 9

GSA 20, 22-23

Maps of temporal persistence of nurseries and spawning areas are showed in Figs. 2.2.5.12.9 (GSA 22-23) and 2.2.5.12.10 (GSA 20). The depth distribution of broadtail shortfin squid extends from 35 to 575m in the Ionian Sea and 25-735 in the Aegean Sea, according to MEDITS catches. Recruits in the Ionian were distributed in shallower depths (35-380m) than spawners, whereas in the Aegean recruits' catches were very low to allow for modeling. Our analysis demonstrated that the higher abundances of the recruits of the species were found in the 0-250m depth zone, whereas spawners were mostly located up to deeper waters (400m) in both the Aegean and Ionian Seas.

The density maps of recruits revealed a wide distribution in the Ionian Sea with the most persistent area of high abundance in the southernmost part of the MEDITS-covered area in GSA 20. On the contrary the spawners of the species in the Ionian Sea did not exhibit a very wide distribution (mainly found in the area between the Ionian islands and continental Greece). In the Aegean, however, spawners of the species were mainly distributed along the western part of the Aegean Sea, with the most persistent areas being outside Thermaikos gulf in the northwestern Aegean and outside Argolikos gulf in the west-central Aegean.



Fig, 2.2.5.12.9. Position of persistent nursery (left) and spawning areas (right) of broadtail shortfin squid in GSA 20.

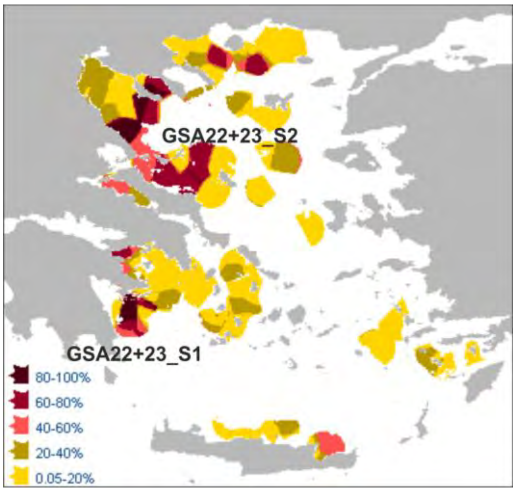


Fig. 2.2.5.12.10. Position of persistent spawning areas in GSA 22_23.

Table 2.2.5.12.5. Main environmental features of the most persistent areas identified for broadtail shortfin squid in European GSAs.

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
01 and 06	nursery	GSA01 and 066_N1	> 800	Large persistent area South of the GSA06 Deep shelf
05	spawning	GSA05_S1	250-500	Northern Mallorca-Menorca Shelf-break to upper slope
05	spawning	GSA05_S2	250-500	Southern Mallorca Shelf-break to upper slope
01 and 06	spawning	GSA01 and 06_S1	around 250 m	Northern Ebro Delta river shelf Shelf-break
01 and 06	spawning	GSA01 and 06_S2	around 250 m	Southern Ebro Delta river, off-shore Castellón port Shelf-break

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
01 and 06	spawning	GSA01 and 06_S3	around 250 m	Around Cape of Gata Shelf-break
01 and 06	spawning	GSA01 and 06_S4	around 250 m	Catalan coast Shelf-break
01 and 06	spawning	GSA01 and 06_S5	around 250 m	Western Northern Alboran Sea Shelf-break
9	nursery	GSA9_N1	100-140	Muddy bottoms (VTC) of the outer shelf and detritic sediments of the South Tuscany shelf break with crinoids beds (*Leptometra phalangium*). The northern part of the Tyrrhenian basin exerts a crucial role in the general water mass budget on the Tyrrhenian Sea. A principal effect is that the associated upwelling provides a mixing of the MAW (Modified Atlantic Water) and the LIW (Levantine Intermediate Water) below, with a corresponding modification of the water properties.
9	nursery	GSA9_N2	100-150	Muddy bottoms (VTC) of the outer shelf and detritic sediments with crinoids beds (*Leptometra phalangium*).
9	Adults aggregation	GSA9_S1	80-140	Detritic bottoms of the deep shelf of the South Ligurian Sea.
9	Adults aggregation	GSA9_S2	90-160	Muddy bottoms (VTC) of the outer shelf and detritic sediments of the South Tuscany shelf break with crinoids beds (*Leptometra phalangium*). The northern part of the Tyrrhenian basin exerts a crucial role in the general water mass budget on the Tyrrhenian Sea. A principal effect is that the associated upwelling provides a mixing of the MAW (Modified Atlantic Water) and the LIW (Levantine Intermediate Water) below, with a corresponding modification of the water properties.
10	nursery	GSA10_N1	65-122	The northern seabeds of the Ischia Island are characterized by a wide continental shelf. The sandy-muddy bottoms are colonized by coastal terrigenous muds (VTC) biocenosis inhabited from typical species as *Alcyonium palmatum*, *Astropecten spp, Sternaspsis scutata, Bolinus spp* etc. The mainstream current direction is from south to north.
10	nursery	GSA10_N2	158-172	This area in the Gulf of Salerno is characterized by detritic bottom (DL) biocoenosis with facies of *Leptometra phalangium*. To this facies are associated species as *Astropecten spp*, *Latreillia elegans*, *Cidaris Cidaris* etc. The mainstream current direction is from south to north.
10	nursery	GSA10_N3	115-287	The bottom is muddy with detritic bottom (DL) biocoenosis with facies of crinoides *Leptometra phalangium* and associated species as *Cidaris cidaris*, *Stichopus regalis*, *Tethyaster subinermis* etc. The mainstream current direction is from south to north.
10	nursery	GSA10_N4	78-180	The bottom is muddy with detritic bottom (DL) biocoenosis with facies of crinoides *Leptometra phalangium* and associated species as *Cidaris*

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
				cidaris, *Stichopus regalis*, *Tethyaster subinermis*, *Natica millepunctata* etc. The mainstream current direction is from south to north.
10	nursery	GSA10_N5	108-124	The bottom is muddy with coastal terrigenous muds (VTC) biocenosis inhabited from typical species as *Alcyonium palmatum*, *Astropecten spp, Suberites dumuncula Pteroides spinosum*, *Stichopus regalis*, *Galeodea echinophora* etc. The mainstream current direction is from east to west.
10	Adults aggregation	GSA10_S1	60-122	The northern seabeds of the Ischia Island are characterized by a wide continental shelf. The sandy-muddy bottoms are colonized by coastal terrigenous muds (VTC) biocenosis inhabited from typical species as *Alcyonium palmatum*, *Astropecten spp, Sternaspsis scutata, Bolinus spp* etc. The mainstream current direction is from south to north.
10	Adults aggregation	GSA10_S2	142-170	The large continental shelf of the Gulf of Naples is characterized by coastal terrigenous muds biocenosis (VTC). The characteristic species are *Alcyonium palmatum*, *Astropecten spp*, *Sternaspsis scutata*. The superficial currents are circular during the sampling period (spring).
10	Adults aggregation	GSA10_S3	84-356	The bottom is muddy with detritic bottom (DL) biocoenosis with facies of crinoides *Leptometra phalangium* and associated species as *Cidaris cidaris*, *Stichopus regalis*, *Tethyaster subinermis* etc. The direction of the superficial current in the sampling period (spring) is parallel to the coast from southern to northern.
10	Adults aggregation	GSA10_S4	123-396	The bottom is muddy with detritic bottom (DL) biocoenosis with facies of crinoides *Leptometra phalangium* and associated species as *Cidaris cidaris*, *Stichopus regalis*, *Tethyaster subinermis*, *Natica millepunctata* etc. The mainstream current direction is from south to north.
10	Adults aggregation	GSA10_S5	76-360	The bottom is muddy with the coastal detritic biocenosis (DC) species as *Alcyonium palmatum*, *Pennatula phoshorea*, *Stichopus regalis*. Moreover in the area the deep muddy biocenosis (VP) with facies of *Funiculina quadrangularis* is present along the slope. The associated species are *Echinus spp*, *Actinauge richardi*, *Macropipus tuberculatus* etc. The mainstream current direction is from south to north.
10	Adults aggregation	GSA10_S6	115-356	The bottom is muddy characterized by coastal detritic biocenosis (DC) with an asteroids facies (*Astropecten irregularis*, *Astropecten bispinosus*, *Tethyaster subinermis)* associated with species as *Alcyonium palmatum*, *Suberites dumuncula*, *Stichopus regalis*, *Ophiura ophiura* etc. Moreover in the area it is possible to recognize the presence of detritic bottom (DL) biocoenosis with species as *Echinus melo*, *Macropipus tuberculatus*, *Aporrhais pespelecani* etc The mainstream current direction

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
				is from east to west.
11	nursery	GSA11_N1	100-300 m preferentially at 100-200 m	Bottoms are characterized by the presence of the biocenosis of the Detritic (DL) with an high presence of the crinoid *Leptometra phalangium)*
11	nursery	GSA11_N2	100-300 m preferentially at 100-200 m	Bottoms are characterized by the presence of the biocenosis of the Detritic (DL) with an high presence of the crinoid *Leptometra phalangium)*
11	Adults aggregation	GSA11_S1	100- 450 m	Bathyal muddy
15+16	nursery	GSA15+16_N1	120-165	Bathyal muds, facies with *Funiculina quadrangularis* The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the extension of upwelling over the shelf and the temperature regime of surface waters. Moreover, upwelling events may occur, linked to the westward flow of the Levantine Intermediate Water, bringing deep water onto the shelf. The mean value of SST observed in late spring-early summer changes from 21.5 to 22 °C when going offshore
15+16	nursery	GSA15+16_N2	125-140	Bathyal muds. The area is characterized by permanent upwelling and by the presence of a 'stagnant point' (still water), where the AIS impinges the shore on the eastern side of the Adventure Bank. The mean value of SST observed in late spring-early summer changes from 21.4 to 21.7 °C when moving eastward
15+16	nursery	GSA15+16_N3	90-150	Bathyal muds, facies with Funiculina quadrangularis. Persistent mesoscale structures in the area are the cyclonic Ionian Shelf Break Vortex (IBV) and the temperature and salinity fronts over the Ionian slope (Ionian Slope Front, ISF) located at the eastern boundary of IBV. The mean value of SST observed in late spring-early summer changes from 22.8 °C to 23 °C when moving southward.
15+16	Adults aggregation	GSA15+16_S1	134-234	Bathyal muds. The general circulation in the area is characterized by the Atlantic Ionian Stream, flowing eastward near the surface (above 200 m depth), whose path and year-to-year variability determines the extension of upwelling over the shelf and the temperature regime of surface waters. The mean value of SST observed in late spring-early summer is 22.2 °C.
15+16	Adults aggregation	GSA15+16_S2	130-165	Bathyal muds. The area is characterized by permanent upwelling and by the presence of a large cyclonic vortex, called Adventure Bank Vortex (ABV), a dominant feature linked to the meanders of Atlantic Ionian Stream (AIS) (flowing eastward up to 100 m depth). The mean value of SST observed in late spring-early summer is 21.2 °C.

GSA	Type of area	Code	Depth range (m)	Description (few lines of text)
17	nursery	GSA17_R1	50-300	- mud and sand- sediments
17	nursery	GSA17_R2	50-300	- mud and sand- sediments
17	Adults aggregation	GSA17_S1	100-200	- mud and sand- sediments
18	nursery	GSA18_N1	102-137	The bottom is muddy and characterized by the detritic bottom biocenosis (DL) with hidroids facies (*Nemertesia antennina*, *Lytocarpia myriophyllum*). To this facies are associated species as *Alcyonium palmatum*, *Astropecten spp*, *Spatangus purpureus*, *Suberites dumuncula*, *Thenea muricata*, *Desmacella annexa*, *Doris sticta* etc. The mainstream current direction if from north to south.
18	nursery	GSA18_N2	106-115	The bottom is muddy and characterized by coastal terrigenous muds biocenosis (VTC) with hidroids facies (*Nemertesia antennina*, *Lytocarpia myriophyllum*) on tanatocenosis of *Neopycnodonte cochlear*. To this facies are associated species as *Alcyonium palmatum*, *Astropecten spp*, *Galeodea spp*, *Suberites dumuncula*, *Munida intermedia Macropodia longirostris* etc. The mainstream current direction if from north to south.
18	nursery	GSA18_N3	40-150	The bottom is muddy and characterized by coastal terrigenous muds biocenosis (VTC) with facies of *A. palmatum* on the soft bottom with associated species as *Pteria hirundo*, *Stichopus regalis*, *Pseudocnus syracusanus* etc. Moreover in the area the detritic bottom biocenosis (DL) is present with hidroids facies (*Lytocarpia myriophyllum Nemertesia antennina*) on tanatocenosis of *Neopycnodonte cochlear* with associated species as *Ascidia mentula*, *Homola barbata*, *Glossus humanus*, *Macropipus tuberculatus* etc. The mainstream current direction if from north to south.
18	nursery	GSA18_N4	115-116	The bottom is muddy characterized by coastal terrigenous muds biocenosis (VTC) with hidroids facies (*Lytocarpia myriophyllum Nemertesia antennina*) on tanatocenosis of *Neopycnodonte cochlear* with associated species as *Ascidia mentula*, *Pteria hirundo*, *Ascidia mentula*, *Macropipus tuberculatus*, *Glossus humanus* etc. The mainstream current direction if from north to south.
18	Adults aggregation	GSA18_S1	52-83	The bottom is muddy characterized by the coastal terrigenous muds biocenosis (VTC) with hidroids facies (*Nemertesia antennina*, *Lytocarpia myriophyllum*) on tanatocenosis of *Neopycnodonte cochlear*. To this facies are associated species as *Alcyonium palmatum*, *Astropecten spp*, *Galeodea spp*, *Suberites* dumuncula etc. The mainstream current direction if from north to south.

GSA	**Type of area**	**Code**	**Depth range (m)**	**Description (few lines of text)**
18	Adults aggregation	GSA18_S2	83-131	The bottom is muddy characterized by the detritic bottom biocenosis (DL) with hidroids facies (*Nemertesia antennina*, *Lytocarpia myriophyllum*) on tanatocenosis of *Neopycnodonte cochlear*. To this facies are associated species as *Alcyonium palmatum*, *Astropecten spp*, *Galeodea spp*, *Suberites dumuncula*, *Munida intermedia Macropodia longirostris* etc. The mainstream current direction if from north to south.
18	Adults aggregation	GSA18_S3	86-125	The bottom is muddy and characterized by coastal terrigenous muds biocenosis (VTC) with facies of *A. palmatum* on the soft bottom and associated species as *Pteria hirundo*, *Stichopus regalis*, *Pseudocnus syracusanus* etc. Moreover in the area hidroids facies (*Lytocarpia myriophyllum Nemertesia antennina*) is present on tanatocenosis of *Neopycnodonte cochlear* with associated species as *Ascidia mentula*, *Homola barbata*, *Glossus humanus*, *Macropipus tuberculatus* etc. The mainstream current direction if from north to south.
18	Adults aggregation	GSA18_S4	39-93	The bottom is muddy and characterized by coastal terrigenous muds biocenosis (VTC) with hidroids facies (*Funiculina quadrangularis*, *Lytocarpia myriophyllum Nemertesia antennina*) on tanatocenosis of *Neopycnodonte cochlear* with associated species as *Ascidia mentula*, *Pteria hirundo*, *Ascidia mentula*, *Macropipus tuberculatus*, *Glossus humanus* etc. The mainstream current direction if from north to south.
19	nursery	GSA19_N1	40-125	The shelf north-eastern Santa Maria di Leuca is characterized by the biocenosis of the terrigenous mud and shelf-edge detritic.
19	Adults aggregation	GSA19_S1	82-171	The shelf north-eastern Punta Stilo is characterized by the biocenosis of the terrigenous mud.
20	nursery	GSA20_N1	50-250	Southmost part of the survey area (central-west Peloponesse).Main sediment type is mud
20	nursery	GSA20_N2	50-300	Western Greece (coasts of Epirus). Main sediment typeis mud
20	Adults aggregation	GSA20_S1	100-400	West part of Peloponissos. Main sediment type is mud
20	Adults aggregation	GSA20_S2	100-400	Relatively shallow area in the part between continental Greece and the Ionian islands. Substrate is mud.
22_23	Adults aggregation	GSA22_23_S1	50-350	Scattered areas in the North Aegean. (outer part of Thermaikos, North Sporades Island complex and south part of the Thracian Sea). Presence of semi-permanent oceanographic features (frontal zones). Main sediment typeis mud

2.2.5.12.4 Gaps in knowledge and future actions

The lyfe cycle of the species, including spawning and recruitment periods is still not very well understood in the central Mediterranean. Recruits present aggregation over small areas thus requiring a sampling design with an adequate number of stations to identify these areas. The large fluctuations in the number of individuals caught from year to year, i.e. two orders of magnitude in the Spanish GSAs, raises the question of whether a significant proportion of the population of *I. coindetti* is not accessible for demersal trawls. In this sense, hydroacoustic surveys have been proposed to try to estimate squid stocks (Starr and Thorne, 1998). In Greek GSAs, given the extended spawning period of the species and the presence of recruits all year around it is unknown how representative of the real situation is the habitat mapping that resulted from an annual survey, such as MEDITS. The lack of fine resolution of oceanographic data does not allow identifying the environmental features that favor the presence of hot spot areas. No biological information available for GSA 25.

2.2.5.13 Solea solea

2.2.5.13.1 Biological features

A detailed description of knowledge related to recruitment and spawning processes of target species is provided in Suppl 2.2.1. In this chapter the main biological knowledge (i.e. recruitment/spawning periods and sizes) are summarized.

Recruitment

The recruitment of *S. solea* occurs in fall. As suggested by Froglia (1993), the young soles leave the lagoons of the northern Adriatic Sea in late summer and migrate southwards along the western Adriatic coast following the main current (Russo and Artegiani, 1996) and concentrating in a well-defined recruitment area located around the Po River mouth, and characterized by shallow water and high nutrient concentration (Piccinetti and Giovanardi; 1984, Campanelli et al., 2011).

Spawning

Adults aggregated in a wider and different area in respect to recruits. The extension of the spawning ground represented from 31% (2010) to 56% (2009) of the GSA17. Size at first sexual maturity for females estimated from the Solemon project was 25.82 cm TL. This length was calculated on the basis of the relative frequency of mature females (stage 4 and 5 of the Holden and Raitt, 1974, classification).

2.2.5.13.2 Modeling approach

Identification of recruits and spawners

GSA 17 SoleMon data are available for the period 2005-2010. In GSA 17 SoleMon data common sole is quite abundant with more than 85% of positive hauls and an average of more than 1,400 specimens collected each year (Table 2.2.5.13.1). The approach employed to detect the recruits was the Bhattacharya, which identified threshold sizes comprised between 17.7-20.4 cm of total length. The threshold length (L_{50} = 25.8 cm) to detect the spawners has been derived from Fabi et al., 2009 (Table 2.2.5.13.2).

Table 2.2.5.13.1. Frequency of positive hauls and number of specimens of common sole caught in GSA 17 during the SoleMon survey

GSA 17		
YEAR	Positive hauls	N. of specimens caught
2005	0.88	1756
2006	0.90	1716
2007	0.93	2103
2008	0.85	792
2009	0.90	952
2010	0.92	1083

Table 2.2.5.13.2. Recruitment and spawning size identification for modeling purposes.

		Recruits				Spawners			
GSA	Sampling years	Data source	Method used	Mean threshold length (TL cm)	Length range (TL cm, min-max)	Data source	Method used	Mean maturity length (TL cm) /Maturity stage	Length range (TL cm, min-max)
17	2005-2010	SoleMon survey	Bhattacharya	19.1	17.7-20.4	Fabi et al., 2009	Fixed threshold length (L_{50})	25.8	25.8

Mapping of density and identification of hot spot areas

Modeling approaches employed to identify spawning and nursery grounds of common sole in GSA 17 were respectively the zero-Inflated Generalized Additive Model (Liu and Chan, 2010) and Ordinary Kriging. COZIGAM-ZIGAM approach did not find any suitable model to describe the spatial distribution of recruits and, hence, Ordinary Kriging was chosen because it produces a spatial distribution simply basing on the location of sampled stations (Table 2.2.5.13.3).

In both cases local G statistic (Getis and Ord, 1992) was employed to identify the hot spots, considered as the place where high values of densities cluster together. The covariates employed to identify the spatial patterns of spawners of sole were year (as factor), latitude, longitude and depth.

The diagnostics of the ZIGAM model employed for spawners of sole in GSA 17 show an acceptable fitting.

Table 2.2.5.13.3. Modeling applied in GSA 17 for mapping common sole.

Life stage	GSA	Depth range (m)	Period	Model type	Covariates	% dev. expl.		Goodness of fit (R^2)	
Spawners	17	5-100	2005-2010	ZIGAM	Year, Lon, Lat, depth	LR	GAM	LR	GAM
						32.6	28.5	0.32	0.21
Recruits	17	5-100	2005-2010	Kriging					

2.2.5.13.3. Description of the spatial distribution and the associated environmental characteristics of nurseries and spawning grounds (Deliverables 2.2 and 2.3)

GSA 17

The areas of persistency identified for the recruits of common sole are mostly concentrated in the north-western Adriatic Sea along the Italian coast up to 20 m depth. The core of the recruits distribution is located around the mouth of the Po River (R1), and the extension of that area southwards varied among years (R2). These areas are characterized by high fresh water inflow, especially by the Po River, determining eutrophication state from nutrient discharge. The sea bottom of coastal areas consists mostly of mud and sand-detritic sediments. The biocenosis of the area is numerically dominated by Polychaetes and other filter-feeding bivalves (mainly *Corbula gibba*), followed by small crustaceans (mostly amphipodes and decapods as *Liocarcinus* spp.) and burrowing Ophiuroids.

The areas of persistency identified for the spawners of common sole are essentially three. S1 is located from Trieste to the Po River mouth at depths ranging from 10 m to 30 m. S2 extends from Ravenna to San Benedetto del Tronto and depth ranges from 10 m to 30 m. The main adults' aggregation ground (S3) included the central portion of the surveyed area from the inshore waters at North to the deeper waters at South just in front of Istria peninsula. This area is characterized by upwelling events, associated to the prevailing NW winds, frequent along the Croatian coast during summer months (Cushman-Roisin et al., 2001). The area is characterized by relict sand (from times when the water level was lower and the area was a sandy beach), with high densities of holothurian (e.g. *Holoturia forskali*) and bivalves (e.g. *Atrina pectinata*) (Fig. 2.2.5.13.1 and Table 2.2.5.13.4).

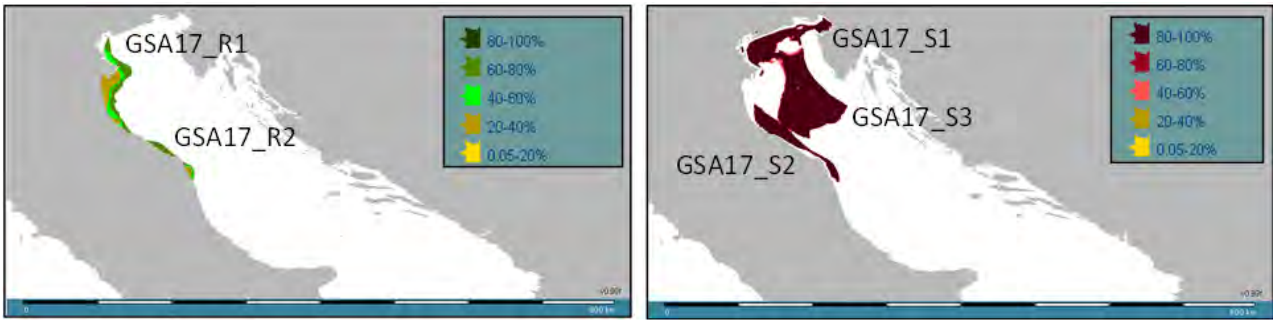


Fig 2.2.5.13.1. Position of persistent nursery (left) and spawning areas (right)of common sole in GSA 17

Table 2.2.5.13.4. Environmental characteristics on nurseries and spawning grounds.

GSA	Type of area	Code	Depth range	Description (few lines of text)
17	nursery	GSA17_R1	5-20	- mud and sand-detritic sediments - high fresh water inflow and eutrophication - biocenosis dominated by Polychaetes
17	nursery	GSA17_R2	5-20	- mud and sand-detritic sediments - biocenosis dominated by Polychaetes
17	spawning	GSA17_S1	10-30	- mud and sand-detritic sediments
17	spawning	GSA17_S2	10-30	- mud and sand-detritic sediments - fresh water inflow and eutrophication
17	spawning	GSA17_S3	30-70	- upwelling events - relict sand - holothurians community

2.2.5.13.4 Gaps in knowledge and future actions

No major gaps in the data of GSA 17 were identified.

2.2.6 General conclusions

GSA 1, 5 and 6

The studied areas (Iberian Peninsula and Balearic Islands) present clear differences in the potential environmental (e.g. hydrodynamics, geomorphology and sediments of the bottom) and anthropogenic (e.g. fishing effort) drivers of the demersal resources and ecosystems. The main results are consistent with previous scientific knowledge. The largest density hot-spots of recruits and spawners for *M. merluccius* and *M. barbatus*, respectively have been identified in GSA 06, between the Ebro River delta and Cape Nao, with a wide continental shelf, frequent upwellings and an important land runoff, which temporary discharges due to storms may produce intense local enrichment. In fact, this is one of the areas with higher productivity within the general oligotrophy of the Mediterranean. A second important area in the GSA 6 is located in the northernmost part, between Cape Creus and Cape Bagur, also influenced by upwellings and land runoff from the Gulf of Lions. In this area, high density of *M. merluccius* recruits and spawners of *M. surmuletus* and *E. cirrhosa* have been identified and modeled.

Adults of the decapod crustaceans *A. antennatus* and *N. norvegicus* showed a wider geographic distribution, which seems to be related to a specific bathymetric range (500-800 m and 300-500 m, respectively). However, these species could also be related to topographic features, such as the submarine canyons in the case of *A. antennatus* (Gulf of Vera and Almería in GSA 1 and from Barcelona to Cape Creus in GSA 6) and sediment characteristics of the bottom in the case of *N. norvegicus*. By contrast, the third decapod crustacean analyzed, *P. longirostris*, is mainly restricted to the Alboran Sea (GSA 1) and the southernmost part of the GSA 6, where persistent density hot-spots have been identified for both recruits and spawners. This species has also shown large fluctuations in its abundance along the time series analyzed, which in other areas of the Mediterranean has been explained as climate-related changes in recruitment success of this short life span and fast growing shrimp.

Spawners of *M. merluccius*, *M. barbatus*, *M. surmuletus* and *I. coindetii* showed the highest persistent density hot-spots off Balearic Islands (GSA 5), where persistent density hot-spots of *M. merluccius* recruits in the north-eastern and southern Mallorca have been detected. In the case of *Mullus* species, these hot-spots areas correspond to a part of the continental shelf where the activity of the bottom trawl fishery is lower, so besides environmental drivers (e.g. hydrograghy, bottom type), factors like the fishing impact, could also affect *Mullus* distribution. A similar hypothesis could be raised for the elasmobranch *G. melastomus*, a vulnerable species which shows the greatest densities of recruits and adults over the slope of Alboran Sea and off Ebro River delta shelf, where the deep water trawl fishery targeting the red shimp is not well developed. This potential driver, the fishing impact, was not taken into account when it comes to spatial modeling.

Last but not least, it must be pointed up that, according to the scientific knowledge, MEDITS data used in the present project cannot be useful for the modeling of some fractions of the populations of the targeted species. This is the case of recruitment fraction for *A. antennatus* and *Mullus* spp., which has been located during autumn-winter and autumn, respectively. It must be also considered that although this fishery-independent information provides high quality and useful data, the results for those species like *A. antennatus*, with seasonal and small-scale temporal variability in the population dynamics and catchability, must be considered with cautious. Similar comments should be made for adults of *M. merluccius*, due to the low number of big specimens captured (or sampled) with bottom trawl, because they are mostly distributed in bottoms not accessible to this fishing gear, and for the spawners of *G melastomus*, a species distributed between 100 and 1800 m depth, with its main fraction of the adult population found below 800 m depth.

GSA8

MEDITS data on distribution of demersal species Corsica (GSA8) area available for the eastern sector, the only characterized by the predominance of soft bottoms. The low density of samples obtained in very scattered trawl stations, often associated to the low catches of most of the species investigated, did not allow to successfully develop spatial models for recruits and spawners /adults. Therefore, the distribution of these life stages have been shown only by means of bubble plot maps of observed density values.

The scarce density of most of the species selected in this study in GSA8 is consistent with previous information. A more appropriate sampling design should be necessary to gather the required spatio-temporal data on abundance of recruits and spawners in order to study their spatial distribution in Corsican waters. MEDITS data however showed that the catches of species like *M. merluccius, N. norvegicus* and *P. erythrinus*, are characterized by an important proportion of specimens of big size, attesting that Corsica is subjected by a generally low fishing pressure and can be considered as a refugium area for overexploited species.

GSA 9

The overview of recruit and spawner hot spot areas GSA9 (Ligurian Sea and central-northern Tyrrhenian Sea) revealed the presence of several stable areas with co-ocurrence of species/life stages.

Undoubtedly, the most important areas are those where recruits of important commercial species, such as European hake and deep water pink shrimp are present in high densities; this is particularly evident for the European hake recruits, which display huge concentration of specimens, reaching values among the highest for the whole Mediterranean area.

These areas are distributed along the coast of Tuscany and Latium on detritic bottoms, from the continental shelf (from 100-129 m depth) to the beginning of the continental slope (shelf break, to 200-220 m depth). The areas with highest presence of recruits of the two species are covered by a *facies o*f the crinoid *Leptometra phalangium.* At lest three areas with these characteristics are present: one from Capraia to Elba Island, another located north-west to Giglio Island and another in the southern part of Latium, in from of Gaeta.

L. phalangium offers an important substratum for settlement of juveniles of many demersal species; several studies have demonstrated that the crinoids beds are an hot spot of biodiversity and are also characterized by important values of secondary production. Study on the trophic ecology revealed the massive presence in these areas of the Mysid *Lophogaster typicus*, which is the primary food for the juveniles of European hake and other demersal species (as the poor cod) not included in this study.

These characteristics qualify the above mentioned areas as Essential Fish Habitat for many species, with high ecological relevance and, consequently, with appropriate characteristics from the management point of view. As a matter of fact, inside these important nursery areas two No Take Zones (NTZ) (one to the west of Giglio Island, in Tuscany, the other off Gaeta, in Latium) have been enforced since 1995; in addition, other two areas (one to the south of Capraia Island, the other between Elba and Pianos isles, both in Tuscany) have been selected as NTZ for the future, which management efficacy to be monitored under specific management plans.

As concerns the deep water pink shrimp, the highest concentration of recruits of this species is located south of Elba Island. These areas are also characterized by the aggregation of spawners of some species, as the red mullet (in particular north to the Elba island) and the squid *Illex coindetii*.

On deeper bottoms, an area comprised from the southern coast of Liguria and the northern coast of Tuscany, between 400 to 500 m is characterized by persistent presence of spawners of Norway lobster and recruits of the blackmouth catshark, *Galeus melastomus*; this areas present patches of the white coral *Lophelia pertusa*.

An area with hot spots of spawners of *P. longirostris* and *Galeus melastomus* was identified off the northern coast of Latium region (between Citivavecchia to Fiumicino), on muddy bottoms from 250 to 350 m depth.

GSAs 10-11-18-19

A remarkable result of the project has been that spatial modeling of nurseries and spawning grounds was successful for almost all the species of the four analyzed GSAs. Often historical observations were confirmed even applying different methods of spatial analysis compared to the past. In many cases the level of persistence was remarkable, considering that the phenomenon was modeled on the length of the whole time series (15-17 years, depending on the GSA).

This is for example the case of the localization of nursery areas of European hake in the northernmost part of the GSA10 (Gulf of Gaeta), in the south-western side of GSA11 (offshore Capo Pecora), in the northern west side of the GSA18 (offshore Gargano Promontory) and southward the eastern Sicily coast in the GSA19 (between Capo Passero and Siracusa). The nurseries of European hake were in partial overlapping with those of the deep water rose shrimp, both sharing the same bathymetric preferences. This overlapping was observed for the GSA10, in the Gulf of Salerno and offshore of the Gulf of Castellammare (north Sicily), for the GSA11 offshore Capo Pecora, and for the GSA19 in the shelf break-upper slope between Siracusa and Capo Passero. The adult aggregations of *P. longirostris* were often co-occurring in the vicinity of nursery aggregations, but at deeper waters (in general down 200 m depth). The northernmost localized nursery of the broadtail short squid in the GSA10 was in partial overlapping with that of hake in the Gulf of Gaeta, where one of the more persistent nurseries of horned octopus was also localized. Thus in this area recruits of several species as European hake, broadtail short squid and horned octopus are concentrated, which qualifies this part of the GSA as a retention area for these species.

Similarly was also for the juvenile aggregations of the broadtail short squid in the GSA11 that were localized offshore Capo Pecora, in partial overlapping with those of deep water pink shrimp and European hake, sharing similar depth preferences (between 100- 200 m).

In the GSA18 both nurseries and adult aggregations of the two cephalopods were occurring along the coasts of the western side, while aggregations of these species were less persistent on the east side, which was instead richer of the deep water rose shrimp hot spots. This more abundant and persistent presence is consistent with the water mass flow of warmer and saltier waters along the east side, which is one of the components of deep water rose shrimp habitat.

As regards bathyal species, nursery and spawning grounds of the giant red shrimp were partially overlapping each other in the GSA10, in particular offshore Capo Bonifati. This localization was also one of the more persistent hot spot for both nursery and spawning grounds of blackmouth catshark. The spawning areas of *A. foliacea* and *A. antennatus* were overlapping offshore Punta Licosa, in the central part of the GSA, sharing the same depth range.

A partial overlapping of the spawning grounds of the two red shrimps was also observed in the GSA11 southeast of Sant'Antioco.

Also in the GSA18 the spawning grounds of these two species were partially overlapping in an almost unique south Adriatic hot spot, placed on the borders of the Bari pit, in the Otranto Channel. This aggregation was also partially shared with the spawning ground of *Galeus melastomus*. This area is characterized by a complex topography and upwelling that takes place in the south Adriatic pit.

In the GSA19, instead, the hot spots of *A. antennatus* were more persistent than those of *A. foliacea*, and indeed the former species is a key species in this area. These main aggregations were localised offshore Capo Rizzuto and Punta Stilo and were partially in overlap with the spawning grounds of *Galeus melastomus*.

Norway lobster nursery and adult hot spots were not found in overlap with those of other species. More persistent adult hot spots were found in the northernmost part of the GSA10 (Gulf of Gaeta). In the GSA11 more persistent nursery and adult patches were not overlapping, as well as in the GSA19.

As regards the coastal species like red mullet and common pandora, more persistent spawning hot spots of both species in the GSA10 were spatially in overlap in the Gulf of Castellammare and the in the Gulf of Patti (north Sicily) as well as along the neritic zones of Amantea and Capo Suvero in the mainland. It is worth mentioning that in the two gulfs of north Sicily trawler fishery is restricted within 200 m depth.

In the GSA 10, the most important nursery of common pandora was localised in the northernmost area (Gulf of Gaeta). In the GSA18 spawning hot spots of red mullet and common pandora were mainly localized on the eastearn side of the GGSA, where nursery and spawning grounds of common pandora were to some extent overlapping. The nurseries of red mullet were instead localized also in the northern part of the west side. In the GSA11 the spawning areas of common pandora were diffuse along the central and north part of the west side of the island, while a persistent nursery patch was localized southward Bosa Marina. In the GSA19 a persistent nursery of red mullet was localized in the neritic zone along Punta Stilo.

Worth mentioning is that nurseries and spawning grounds of *Raja clavata* occurred only in Sardinia waters (GSA11) with an overlap in the north-eastern side. Probably in the Sardinia seas habitat characteristics and a lesser fishing pressure play more in favor of thornback ray population. The species is instead absent in the GSA19.

In the GSA10, 11, 18 and 19 the identification of nursery areas had been carried out in a research project funded by Italian Ministry of Agriculture (Lembo G. (coord.). 2010) for the following target species: *Eledone cirrhosa*, *Merluccius merluccius*, *Mullus barbatus*, *Nephrops norvegicus*, *Parapenaeus longirostris*, *Phycis blennoides*, in all GSAa, *Aristaeomorpha foliacea*, *Illex coindetii*, *Loligo vulgaris*, *Pagellus erythrinus*, as locally important in some GSAs. The years from 1994 to 2005 were considered in the analysis, using MEDITS and GRUND surveys. In the GSAs 11, 19 and 10 spawning areas of red shrimps were also studied by the REDs project (AA.VV., 2008) using the time series 1994-2004 of MEDITS and GRUND surveys and applying a simplified approach.

The MEDISEH project allowed to expand the analysis in different directions: increasing the number of species with *I.coindetii, R.clavata, G.melastomus, P.erythrinus, M. surmuletus* and *A. antennatus,* updating the time series to 2010, testing a new methodological approach which combined different methods, including GAM and geostatistics, succeeding in modeling the spatial occupation of species that could not be modeled in the past projects. Environmental characterization of nursery and spawning areas was addionally considered in MEDISEH.

In the GSA10, some cases occurred in which the lack of suitable data for some species/life stage has prevented the possibility to model their spatial distribution. The list of the species/life stage for which gaps in knowledge remain, includes: 1) spawners of *M.merluccius*, because the abundance indices were rather low, distributed over a wide bathymetric range, and didn't show a clear spatial structure; spawners of *M. surmuletus*, *R. clavata* and *Solea vulgaris*, species rather scant in the area 2) recruits of *M. barbatus*, because the survey sampling period was inappropriate to intercept the species recruitment, *A. antennatus*, because recruits are not accessible to the gear, given that distribution is likely down 800 m depth, *N. norvegicus*, because the modeling gave poor results and finally *M.surmuletus, R. clavata*, and *Solea vulgaris* because these species are very scant in the area. For the same reasons, the same species were not modeled also in the GSA18, where in some years the later survey period and/or the anticipated recruitment event indeed allowed the interception of *M. barbatus* recruits. In the GSA19 gaps were similar to GSA10 and, in addition, also modeling of nurseries and spawning hot spots of *P. erythinus* gave poor results, while *Raja clavata* has not been ever caught in this area. In GSA11, by contrast, nurseries and spawning grounds of *Raja clavata* and *M. surmuletus* could be modeled, as well as the spawning hot spots of *M. merluccius*. A second survey in the year might contribute to overcome some the lack of knowledge, besides a fully use of DCF fishery-dependent data to elucidate some life-history traits.

GSAs 15-16

A valuable result emerges from the synoptic view of the nurseries and spawning grounds identified in the Strait of Sicily (GSA15+16), revealing different areas of overlap for species/life stages with the same bathymetric preferences. Overall, results indicate that the spatial distribution patterns of the recruits and/or spawners of most species are well defined and very stable in the long term. Spawning areas of striped red mullet and common pandora partially overlap on offshore grounds (up to 80 m depth) of the Adventure Bank (GSA 16) and Malta Bank (to the east of Malta; GSA 15) respectively, whereas spawners of red mullet co-occur with spawners and juveniles of thornback ray in the southwest edge of the Adventure Bank. Several persistent patches of red mullet spawners occur as well, along the south Sicilian coast and over the Malta Bank to the east of Malta, straddling the border of the 25 nautical mile FMZ at a depth of around 100 m. The distribution of the persistent nurseries of European hake, deep-water pink shrimp and short-finned squid shows a similar pattern across the Strait of Sicily, with areas of co-occurrence located on the eastern outer shelf of the Adventure Bank and Malta Bank respectively, as well as along the south central coast of Sicily. The three above mentioned areas are also preferential grounds for the spawners of deep-water pink shrimp. Recruits of Norway lobster persistently occur northwest and east of the Adventure Bank at depth between 300 and 400 m.

As regard bathyal species, a large area of the meso-bathyal basin to the east of the Maltese Islands, provides spawning grounds for a number of species including giant red shrimp, blue and red shrimp and blackmouth catshark. It is located between two deep trenches (Malta Graben and Linosa Graben) at a depth between about 500 and 700 m where a nursery of giant red shrimp occurs as well. Finally, nurseries of blackmouth catshark and giant red shrimp, partially overlap to spawning grounds of Norway lobster south of Malta (close to the edge of GSA 15) and south east of Linosa Island (along the edge of GSA 16).

The finding of closed or overlapped sites which regularly host vulnerable life stages of different exploited species, to the east of the Adventure Bank and Malta Bank respectively, qualifies these two areas into areas of great ecological significance. Based on current knowledge, they are strongly related to the spatial pattern of major oceanographic processes. The circulation characterized by a two-way exchange flow (AIS and LIW) through the Strait of Sicily and its complex topography makes the Strait a high productivity and retention area. The high productivity is due to enrichment of the surface water through the coastal upwelling, with two long filaments of upwelled water persisting over Adventure Bank and the Maltese shelf, and the cyclonic vortices along the AIS current. In the case of the GSA 15, the enrichment factors are coupled with an important retention and concentration structure determined by the intermittent anti-cyclonic vortex in the Malta channel and the permanent front on the eastern edge of the Malta Bank. The co-occurrence of all these features favors spawning activity and success of recruitment processes, turning GSA 15+16 in a really important area of concentration of nursery and spawning grounds for species of high commercial relevance, as further confirmed by this study. It should also be noted that the presence of a number of persistent areas close to the east and southeast border of GSA 15, indicates that the vulnerable habitats of the demersal species studied, extend to adjacent GSAs.

GSA17

The results obtained in the present study support the hypothesis that the geomorphological and hydrological characteristics of the central and northern Adriatic Sea considerably influence the distribution pattern of demersal fish.

Recruits of common sole, red mullet and common pandora mostly concentrate along the coastal waters of Italian side of GSA17, which is a shallow water area characterized by a high concentration of nutrients (Campanelli et al., 2011) and the presence of muddy bottoms inhabited by a benthic community dominated by the bivalve *Anadara inaequivalvis* and the echinoderm *Astropecten irregularis* and Polychaetes. In contrast, spawners of these species were observed in more deep waters and spread to a wider area. The spatial distributions of spawners and of recruits reveal the changes in the species' habitat preferences during their life-cycles, with recruits concentrated along coasts and adults moving offshore. The spawning areas of these species were located from the central portion of the basin eastwards to the Croatian islands. The area is characterized by a great variety of environments ranging from the relict sands more offshore, inhabited by a very rich community dominated by the cnidarian *Alcyonium palmatum* and the echinoderm *Holothuria forskali*, to the more onshore detritic bottoms, characterized by the occurrence of gravel and debris from mollusc shells and branched bryozoans, and muddy seabed. The current might transport the pelagic eggs of these three species from the offshore spawning grounds to the nursery areas where the larvae settle down after metamorphosis. Afterwards, as they grow, they migrate towards deeper waters. High concentrations of recruits and spawners of these species persistently occupied these areas, representing stable nursery and spawning areas.

Recruits and spawners of hake showed a different distribution pattern, characterized by the presence of spawning areas along the eastern side of GSA17 (within the Croatian islands) and recruitment areas just southwards the Pomo/Jabuka Pit and near the southern limit of GSA17. On both areas, key life stages occur in a persistent distribution with a clear separation between recruitment and spawning areas. The role of the mesoscale oceanographic features in the area (upwelling, eddies, filaments and frontal systems) should be investigated further so as to understand how they influence and maintain the observed spatial structure.

The present study confirmed for the Norway lobster that the Pomo/Jabuka Pit represents a spawning ground. Although the area is characterized by the presence of small individuals it is not possible to consider it as a proper nursery ground because the smaller size of the specimen collected is due to slower growth rate related to environmental condition (Froglia and Gramitto, 1981). Other spawning grounds were found inside the Italian and Croatian national waters. Recruits and spawners of Norway lobster persistently occupied the same areas in GSA 17 across years. Anyway, because the range of this species in the Adriatic is a continuous one, particular Norway lobster settlements cannot be regarded as isolated (Karlovac, 1953). Nevertheless, some differences do exist, primarily in length frequencies among the settlements around Ancona and the Pomo/Jabuka Pit (Froglia and Gramitto, 1981, Froglia and Gramitto, 1988, IMBC et al., 1994), as well as among the settlements in the northern Adriatic channels and the Pomo/Jabuka Pit (Karlovac, 1953; Crnković, 1964, Crnković, 1965, Crnković, 1970; Jukić, 1974; Županović and Jardas, 1989). Froglia and Gramitto (1981) discussed these differences as the consequence of the difference in ecological factors that dramatically depress growth of *N. norvegicus* and other benthic decapods in the Pomo/Jabuka Pit. Similarly, Mantovani and Scali (1992), using genetic analysis, found that differences between Norway lobster off Ancona and the Pomo/Jabuka Pit did not surpass those at the population level. The differences were only a consequence of different environments.

The hornet octopus mainly concentrated in the southern portion of GSA 17 and it was more abundant over 75 m (Casali et al., 1998). It was mainly found in the stations surveyed in the Pomo/Jabuka Pit where it does not show any preference towards a particular depth or sediment type (Jukić, 1975; Županović and Jardas, 1989). Spawning and recruitment areas are close to each other and also partially overlay, the former is located more in the central portion of the southern portion of GSA 17 (120-300 m depth) while recruits concentrate mostly in the south-western area more shallow waters at depths ranging from 60 and 160 m.

The recruitment area of deep-water rose shrimp is wide and located just southwards the Pomo/Jabuka Pit area, while the spawning area is located in the south-eastern side of the GSA in front of Croatian waters. As already found by Fortibuoni et al. (2010) young-of-the-year concentrated on the outer shelf while mature females occurred mostly between the outer shelf and the upper slope. The reproductive behavior of this shrimp in relation to its bathymetric distribution shows a clear segregation of the different life stages. Females in advanced stages of maturity or imminently spawning are found at depths of 100-200 m. This behavior has been described for other areas. In the Tyrrhenian Sea, Mori et al. (1986) localized the reproductive zone in bottoms between 150 and 300 m, while in the Gulf of Guinea, it is at depths of more than 200 m (Sobrino and Fernández, 1991), and in the waters off Angola, they are concentrated between 100 and 400 m in depth (Sobrino and De Cárdenas, 1996).

The present results provide new and more updated results in comparison with the Project *Nursery* (Lembo, 2010), in particular for the first time spawning and nursery ground of common sole and broadtail squid are identified.

For some species was not possible to identify the sensitive habitats mainly because of their low occurrence.

GSAs 20, 22-23

Although the timing of the MEDITS survey did not allow the complete identification of spawning and nursery areas in the Aegean (GSAs 22+23) and eastern Ionian (GSA 20) seas, the available data provided, in several cases, clear evidence about areas with high occurrence of recruits and/or spawners of the studied species. Depending on the species and the life stage, various important areas were identified and only few areas, such as the Saronikos gulf, were found to serve as hot spots for several species.

Previous studies on the distribution pattern of demersal species in the aforementioned GSAs have been based on spatially and temporally limited data sets and were rarely focusing on specific life stages. The present work gave the opportunity to examine the distribution pattern of numerous species taking also into account the species life-cycle. The fact, however, that the MEDITS survey is performed once per year did not allow to obtain a full picture of the species habitat preferences in relation to their life stage, because the timing of the survey does not sufficiently overlap with the spawning/recruitment period of most species.

GSA 25

In GSA 25 the identification of nursery and spawning areas through modeling approaches was not possible due in general to the few positive hauls in each annual survey and their relatively high distance that did not allow implementing any reasonable model denying the estimate of spatial covariance. Anyway the analyses of MEDITS data of GSA 25 using standardized methodologies has been useful to detect possible sensitive ground for demersal species (e.g. *Mullus barbatus* and *Pagellus erythrinus*) and to identify gaps in the sampling design of the survey. From the analyses carried out seems that an increase in the sampling effort in terms of number of stations is needed in order to provide an improved coverage of the GSA.

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WP3. GIS rendering: GIS viewer and geo-reference database

WP3. GIS rendering: GIS viewer and geo-reference database

(Scientific Responsible: V. Valavanis (HCMR), Partners involved: HCMR, CNR-IAMC, CNR-ISMAR, IEO,CIBM)

Cited as: Valavanis V., C. Martin, S. Nikolopoulou, P. Tugores, G. Garofalo, A. De Felice, M. Gristina, A. Belluscio, L. Telesca, G. Fabi, F. Grati, S. Frascheti, F. Colloca, M. Giannoulaki, N. Papadopoulou, V. Markantonatou *2013* GIS rendering: GIS viewer and geo-reference database. *Mediterranean Sensitive Habitats (MEDISEH) Final Report, DG MARE Specific Contract SI2.600741, Heraklion (Greece).*

Background

Based on the following Terms of Reference of the content of the European Commission DG MARE request Ares (2011)665688:

"Compile information supporting the identification and location of nursery areas (juveniles in their first and, if appropriate, second year of life) and spawning aggregations. This information, which is to be collated and archived in formats adequate for GIS rendering, shall refer to all the demersal and small pelagic species in the Mediterranean included in Appendix VU of Council Regulation (EC) No 199/2008 as well as for the species subject to minimum size (Council Regulation (EC) No 1967/2006-Annex III). In addition, ecological characterisation of these areas, both in terms of biological community (assemblage) and habitats therein, must be provided."

The technical tender form of the Specific Contract 2 (MEDISEH) defined the following objective for WP3:

> Integrate and present the aforementioned information through a web-based GIS viewerwith an associated geo-referenced database that will operate as a consulting tool for spatial management and conservation planning.

In order to meet these objectives within the framework of MEDISEH an expert team was composed within the MAREA Consortium from fisheries biologists with GIS experts with long term expertise on GIS tools and databases, working at different areas in the Mediterranean basin (see Table 3.1, CV details available on the MAREA expert's web site).

Table 3.1. List of experts involved in WP3.

Participant	Affiliation
V. Valavanis	HCMR
C. Martin	HCMR/ Current affiliation: UNEP-WCMC (Cambridge, UK)
S. Nikolopoulou	HCMR
P. Tugores	IEO
G. Fabi	CNR-ISMAR
F. Grati	CNR-ISMAR
M. Gristina	CNR-IAMC
G. Garofalo	CNR-IAMC
A. De Felice	CNR-ISMAR

Participant	Affiliation
A. Belluscio	CIBM, input from Task 1.1
L. Telesco	CIBM, input from Task 1.1
S. Frascheti	CoNISMa input from Task 1.2
F. Colloca	CNR-IAMC input from Task 2.2
M.M. Pirounaki	HCMR input from Task 2.1
N. Papadopoulou	HCMR input from Task 1.4
E. Palikara	HCMR input from Task 1.4
V. Markantonatou	HCMR input from Task 1.4

This final report of MEDISEH-WP3 covers the whole duration of the project. The main task of WP3 was to homogenize the variety of data products produced by MEDISEH WP1 and WP2 under a common GIS environment and disseminate the GIS data products through the Internet. Thus, WP3 accumulates and mirrors the work developed and produced by the whole MEDISEH Consortium. HCMR coordinated WP3 and the involved personnel is listed in Table 3.1. The collaboration within the MEDISEH Consortium was excellent and this fact greatly contributed to the overall success of WP3 outputs. Specifically, an online viewer of GIS datasets, an online GIS database, and an online dissemination platform of the technical background were developed through MEDISEH-WP3 activities.

Objectives

The specific objectives of MEDISEH-WP3 were to:

- Organize all related datasets and output products in a GIS database under a common georeference system and common data format

- Develop an online GIS data viewer to serve data and project products over the Internet.

- Organise all WP3-related work in a web-based GIS seminar to further disseminate background technicalities of WP3

Deliverables and Milestones foreseen by the Project

Within the framework of WP3 and according to MEDISEH proposal four meetings were held within the framework of the project.

A kick-off meeting was held in Heraklion (Crete) on 10-13 October 2011, in order to standardise the work among the partners involved: timeframe for work and deliverables, the input data format, and GIS (Geographic Information Systems) requirements. In addition an introduction on the modeling techniques that could be applied was made. The work was held in parallel concerning the three work packages in order to save time and travelling cost. Several WP3 activities were agreed among the MEDISEH Consortium including the standardization of the involved data format and georeference system, the selected tools involved in the development of the GIS Viewer, and the various modeling techniques and required environmental data necessary for models development for WPs 1 and 2.

A second meeting was held by month 6 according to the proposal, in Palermo (Italy) on 6-8 February 2012. Brief presentations on the progress of work were made, emphasis was given on the difficulties and the problems encountered and extended presentations were made on the modeling techniques that could be applied depending on data nature and data availability. Concerning especially WP3, a presentation of the first version of the GIS Viewer was made and a dissemination of the environmental data to be used as model predictors was carried out.

A third meeting was held by month 12 according to the proposal, in Orto Botanico Rome (Italy) on 26-28 September 2012. During this third meeting, the second version of the GIS Viewer was presented and several improvements were discussed regarding the viewer's capabilities and the involved datasets. In addition, the finalization of the models predictors (environmental data) was carried out among the MEDISEH Consortium.

A fourth meeting was held by month 17 and took place in Astoria Capsis Hotel (Heraklion-Greece) 8-10 January 2013. During this fourth meeting, the close-to-final version of the GIS Viewer was presented, including deliverables already finalized by the time of the meeting. A thorough discussion was followed on the development of specific spatial queries among the assembled and modelled datasets.

Table 3.2. The state of art for the milestones and deliverables foreseen by the proposal

Deliverable	Description	% of foreseen results
M3.1.1	Development of common protocol for data standardization, classification, presentation and analysis addressing data of WP1 and WP2 (Month 2)	100%
M3.2.1	One online GIS seminar on data GIS transformation and GIS mapping tools (by month 6)	100%
M3.2.2	Export and standardization of satellite environmental data to be used for modeling mainly within Tasks 1.3 and 2.1 (Month 6)	100%
M3.3.1	A one day workshop to be organised in the framework of this WP order to standardize habitat modeling results for input into GIS systems (by month 12)	100%
M3.3.2	Development of GIS database to store the results of WP1 and WP2 (Month 12)	100%
M3.4.1	Development of an online GIS data viewer to facilitate the inspection of project results and provide an integrated picture of sensitive habitats related to fisheries within the Mediterranean basin (Month 16).	100%
D3.1.1	Framework for a common GIS database	100%
D3.1.2	Web-based GIS data Viewer and maps derived from WP1, WP2	100%
D3.1.3	Synthesis maps presenting the persistent spawning and nursery	100%

Deliverable	Description	% of foreseen results
	grounds of the target small pelagic and demersal species along with the locations of protected habitats	

Task 3.1. Standardization of data for GIS rendering. (D3.1.1, M3.1.1, M3.2.1)

Progress achieved

A common protocol on data standardization was decided during the kick-off meeting of the project. A GIS database was developed in order to store historical and current information on substrate habitats (including seagrass beds, coralligenous and mäerl formations) as well as historical information on fish nursery and spawning grounds in the Mediterranean. In addition, environmental satellite-derived data were incorporated in the GIS database as images as well as various other basemap datasets, which were either created from scratch or downloaded from online data archives.

The common data standardization protocol includes a common georeference of all datasets under the same geo-reference system (WGS84 in decimal degree units) (see Wikipedia reference). All datasets were re-projected under this reference system in the data format of shapefiles (i.e. a group of files with data attribute and data representation characteristics) for the vector datasets and in the format of image and grid data for the raster datasets. The software used for the processing of datasets was ESRI's ArcGIS (see ESRI reference) and specific data processing programming routines were developed for each dataset. In addition, data format conversions between raster and vector datasets were carried out, depending on specific needs for specific work tasks.

Metadata were created for each individual dataset based on the Infrastructure for Spatial Information in the European Community (INSPIRE) specifications (listed at http://inspire.jrc.ec.europa.eu/) and metadata were organised using Extensible Markup Language (XML). Metadata in XML format were created by the MEDISEH Consortium using the INSPIRE Metadata Editor (located at http://inspire-geoportal.ec.europa.eu/).

All latest versions of the standardized GIS datasets were organised in a GIS database (using a Geodatabase), which in turn, was loaded to a Geoserver (http://geoserver.org/) for online database dissemination. Two main web locations were developed, an 'official' one linked in the MAREA website (http://mareaproject.net/mediseh/viewer/med.html) as well as a 'back-up' one placed at HCMR premises (http://arch.her.hcmr.gr/mediseh/viewer/med.html).

Task 3.2. GIS derived information for modeling. GIS based mapping tools. (M3.2.2)

Progress achieved

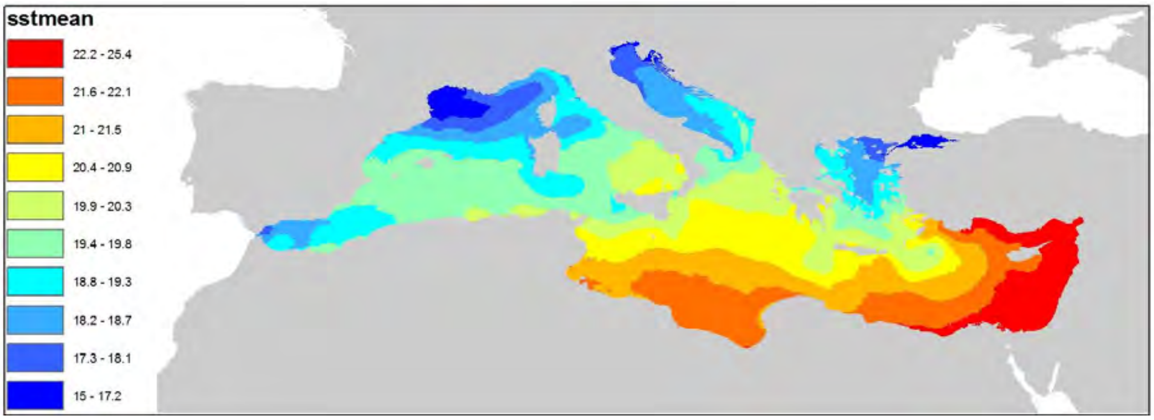
An extensive exploration and processing of environmental satellite archives was performed to facilitate the modeling requirements of the project. Derived satellite datasets were distributed to WP1 and WP2 for model testing and development of final data products. Archives and associated satellite datasets are listed in Tables 3.2 and 3.3. To describe the technical downloading and processing details of the environmental satellite datasets, a web-based workshop-seminar was developed and placed online as weblink through the GIS data viewer webpages (http://arch.her.hcmr.gr/mediseh/eowebsem/).

Specifically, satellite data were downloaded from the respective online satellite data archives in various distribution formats (including TIFF, HDF, NetCDF, etc) and all different distribution formats were processed under a common GIS grid format. For this purpose, specific GIS routines were developed for the processing and harmonization of the satellite datasets.

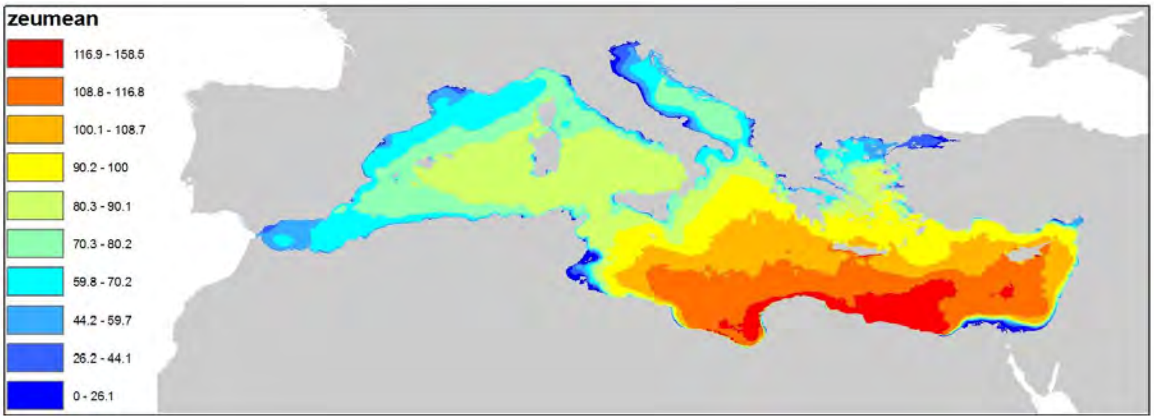
No specific difficulties were encoundered during the processing process of the satellite data. Examples of processed satellite datasets are presented in Fig. 3.1.

Table 3.2. Processed raster datasets through the MEDISEH Project for the modeling purpose of WP1 and WP2.

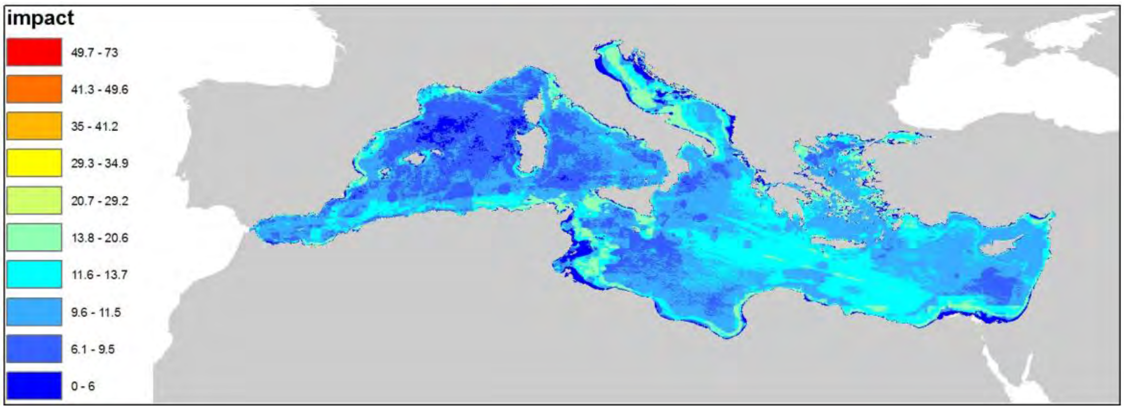
PARAMETER	SENSOR/MODEL	ARCHIVE SOURCE
Sea Surface Temperature	MODIS Aqua	oceandata.sci.gsfc.nasa.gov
Sea Surface Chlorophyll	MODIS Aqua	oceandata.sci.gsfc.nasa.gov
Photosynthetically Active Radiation	MODIS Aqua	oceandata.sci.gsfc.nasa.gov
Euphotic Depth	MODIS Aqua	oceandata.sci.gsfc.nasa.gov
Sea Surface Salinity	NOAA GODAS	iridl.ldeo.columbia.edu
Bathymetry	GEBCO08	www.gebco.net
Bathymetry	EMODNET	www.emodnet-hydrography.eu
Profile Temperature and Salinity	HRTSAWO	www.nodc.noaa.gov
Nitrate concentration	Bio-ORACLE	www.oracle.ugent.be
Nutrient input		
Ocean acidification		
Human impact		
pH		
Phosphate concentration		
Pollutants (inorganic)		
Pollutants (organic)		
Pollution (ocean-based)		
Population pressure		
Shipping (commercial activity)		
Silicate concentration		
Slope of the seafloor		
Artisanal fishing pressure	MARSPEC	www.marspec.org
Aspect of the seafloor		
Bottom salinity		
Bottom temperature		
Bottom type		
Calcite		
Climate change (SST)		
Climate change (UV)		
Diffuse attenuation coefficient		
Dissolved oxygen		
Distance to 200m isobath		
Distance to coast		
Distance to main ports		
Distance to major river mouths		



SST: Sea Surface Temperature (°C)



ZEU: Euphotic Depth (m)



HUMAN IMPACT (index)

Fig. 3.1 Examples of processed satellite datasets within the framework of MEDISEH (warmer colors show higher values).

Task 3.3. GIS database development (M3.3.1., M3.3.2)

Progress achieved

Database development was performed in a 2-step procedure. First, a Geodatabase was created using ArcGIS software. The typical procedure included the creation of a new empty geodatabase (GDB), the adding of all vector and raster datasets to the geodatabase, and the definition of their schema and properties. Secondly, the Geodatabase was transferred to a Geoserver for online use. The procedure included the creation of a datastore within Geoserver and the insertion of the Geodatabase to the datastore. The MEDISEH Geoserver delivers datasets through a Web Map Service (WMS) facilitating data interoperability through online tools. The main WMS service is accessible through http://server.orbisnetwork.net:8080/geoserver/wms?request=GetCapabilities&service=WMS&version=1.0.0 where users can link to view spatial data and attributes. The WMS service is accessible through widely-used online free tools such as Quantum GIS, Google Earth, ArcGIS Explorer, etc.

The above architecture provided the means to the GIS databasing of harmonised datasets and their access through online media and feature services.

Task 3.4. Online GIS data viewer development (M3.4.1, D3.1.2, D3.1.3)

Objectives

- Develop an online GIS data viewer to serve data and project products over the Internet.

- Organise all WP3-related work in a web-based GIS seminar to further disseminate background technicalities of WP3

Progress achieved

As mentioned, the 2 web locations of the web-based GIS MEDISEH data viewer and Geoserver database are accessed at:

http://mareaproject.net/mediseh/viewer/med.html (official version)

http://arch.her.hcmr.gr/mediseh/viewer/med.html (identical back-up version)

As agreed in the project's meetings, the web-compliant GIS data viewer was based on ALOV Map, a multi-platform, portable Java® application for publication of vector and raster datasets to the Internet and interactive viewing on last generation web browsers. The viewer was developed and highly cuctomized to the requirements of the project in a 'standalone' approach, where no dedicated server side is required to view shapefiles and georeferenced images of raster datasets (Fig. 3.2). Datasets are browsed and viewed in data compressed format to facilitate bandwidth issues. A basic operational manual of the viewer is developed in the form of online help. In addition, a complete organisation and development of a data downloading area was performed. Online help and print services were developed, as well.

The online GIS data viewer is based on a user-friendly interface for scalable selection and viewing of an extensive number of assembled and produced datasets. Datasets were organised in various data themes, namely:

- BaseMap Datasets (e.g. coastline, isobaths, management units, etc)
- Fish Historical Datasets (historical spawning and nursery grounds for the target fish species)
- Fish Habitat Models (modelled spawning and nursery grounds for the target fish species)
- Marine Habitats Models (model output for Posidonia, coralligenous and mäerl)
- Models Predictors (e.g. images of satellite and other environmental data used for modelling)
- Marine Protected Areas (e.g. MPAs, FRAs, SPAMIs, general fishing prohibitions etc)

- Specific Spatial Queries that involve the co-presentation or the synthesis of two or more datasets towards a spatial management perspective (e.g. overlapping of Posidonia and MPAS across the Mediterranean Sea)

Users are able to view all data themes through the online viewer while all datasets are interoperable through the interoperability services of the Geoserver database.

The online viewer has typical zoom utilities as well as 'HELP' and 'PRINT' capabilities. Downloading of data may be performed in 2 ways:

1. Directly through weblinks at the viewer's downloading area
2. Through the Geoserver database interoperability services

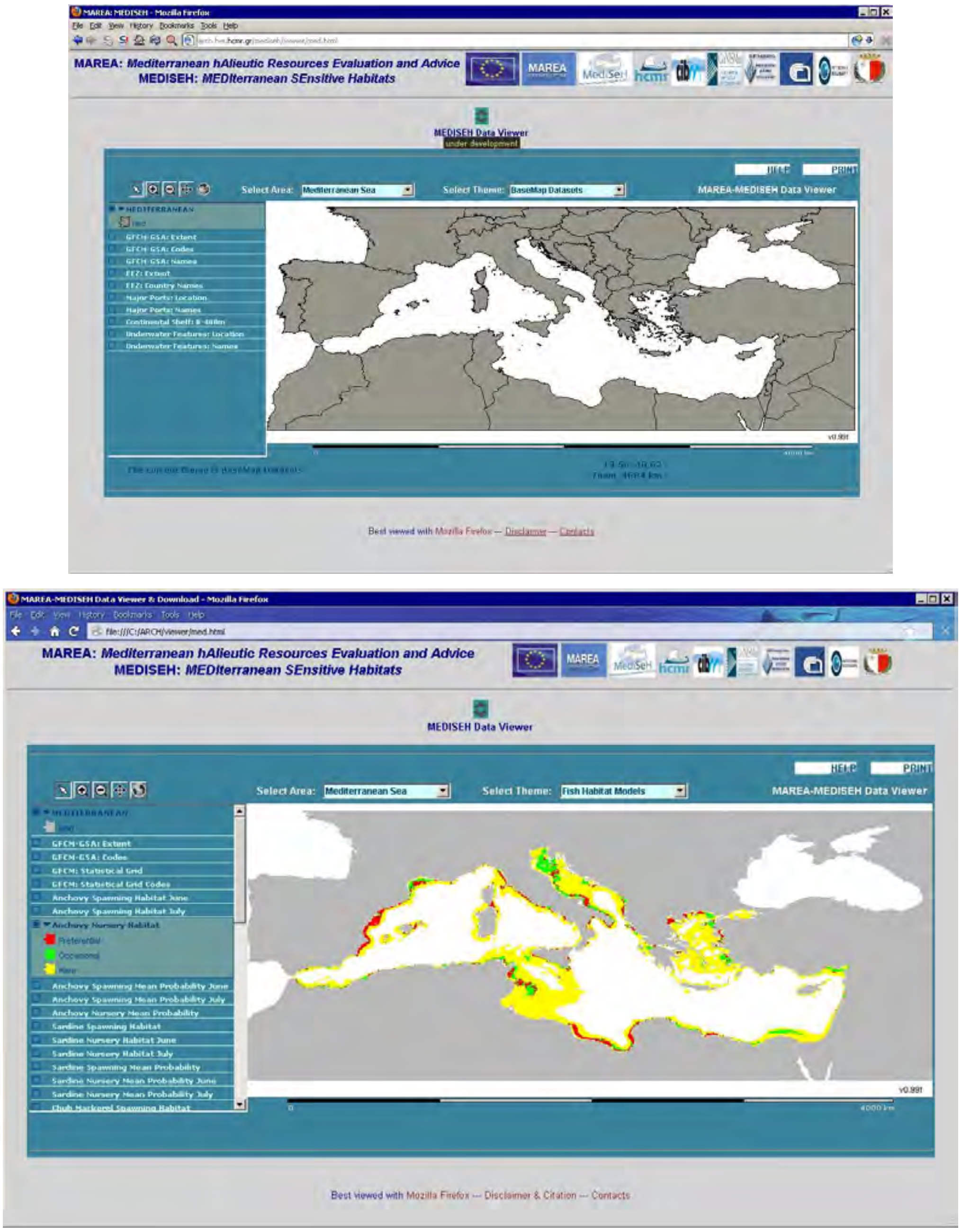
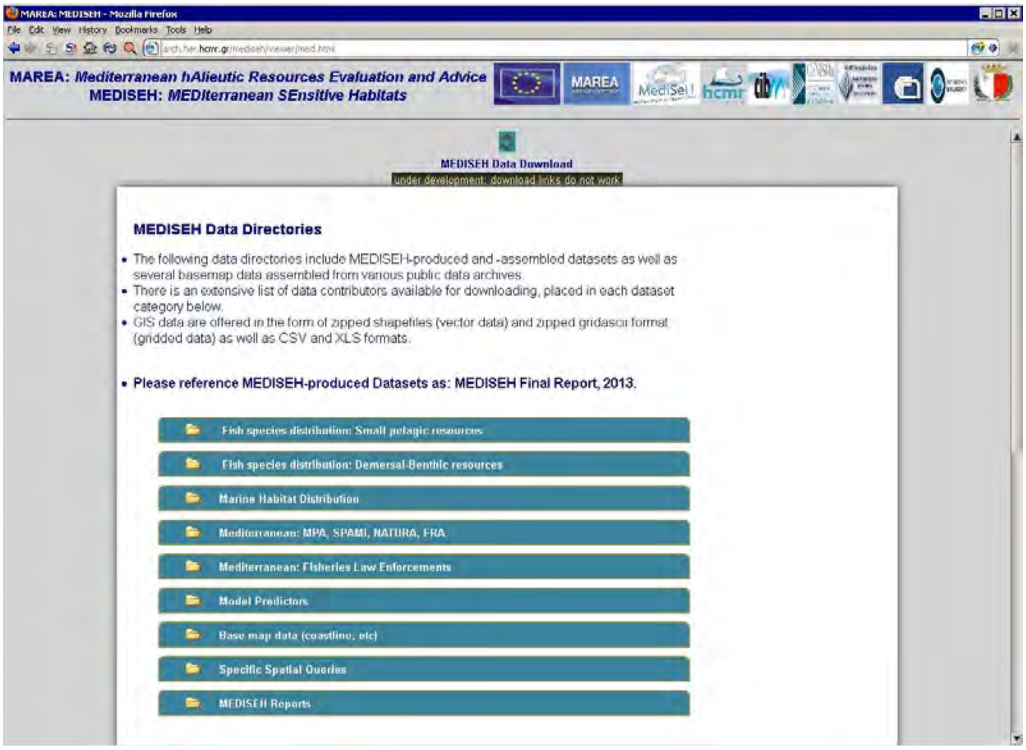


Fig. 3.2. Examples of the data maps incorporated in the MEDISEH online GIS Viewer. Details in http://mareaproject.net/mediseh/viewer/med.html



MAREA: *Mediterranean hAlieutic Resources Evaluation and Advice*
MEDISEH: *MEDIterranean SEnsitive Habitats*

MEDISEH Data Download

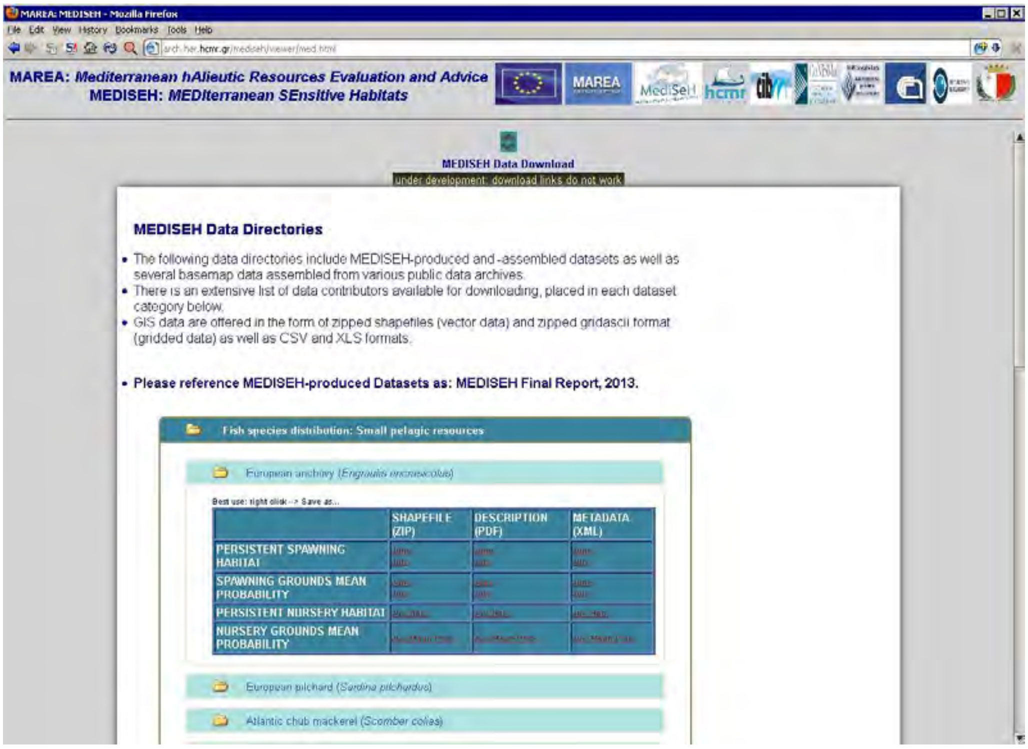
under development: download links do not work

MEDISEH Data Directories

- The following data directories include MEDISEH-produced and -assembled datasets as well as several basemap data assembled from various public data archives.
- There is an extensive list of data contributors available for downloading, placed in each dataset category below.
- GIS data are offered in the form of zipped shapefiles (vector data) and zipped gridascii format (gridded data) as well as CSV and XLS formats.

- **Please reference MEDISEH-produced Datasets as: MEDISEH Final Report, 2013.**

- Fish species distribution: Small pelagic resources
- Fish species distribution: Demersal-Benthic resources
- Marine Habitat Distribution
- Mediterranean: MPA, SPAMI, NATURA, FRA
- Mediterranean: Fisheries Law Enforcements
- Model Predictors
- Base map data (coastline, etc)
- Specific Spatial Queries
- MEDISEH Reports



MAREA: *Mediterranean hAlieutic Resources Evaluation and Advice*
MEDISEH: *MEDIterranean SEnsitive Habitats*

MEDISEH Data Download

under development: download links do not work

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- **Please reference MEDISEH-produced Datasets as: MEDISEH Final Report, 2013.**

- Fish species distribution: Small pelagic resources

  - European anchovy (*Engraulis encrasicolus*)

Best use: right click --> Save as...

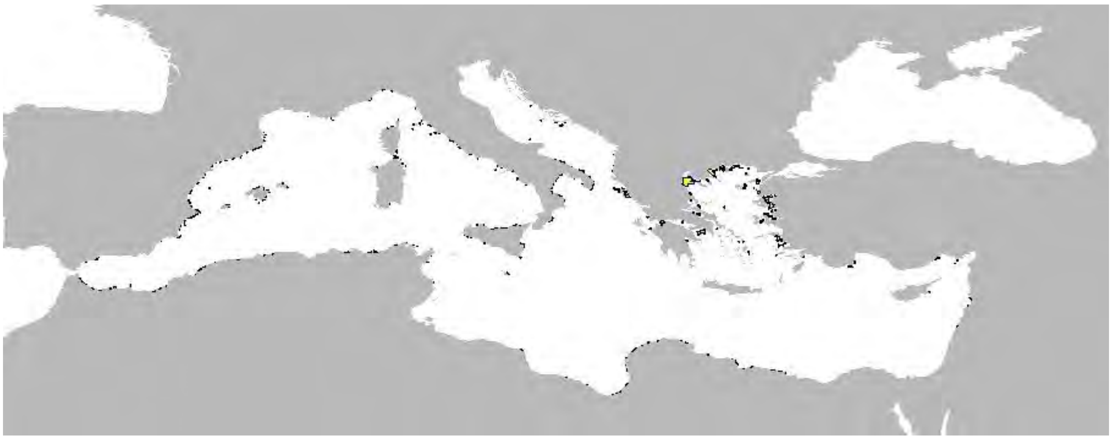
	SHAPEFILE (ZIP)	DESCRIPTION (PDF)	METADATA (XML)
PERSISTENT SPAWNING HABITAT	[illegible]	[illegible]	[illegible]
SPAWNING GROUNDS MEAN PROBABILITY	[illegible]	[illegible]	[illegible]
PERSISTENT NURSERY HABITAT	[illegible]	[illegible]	[illegible]
NURSERY GROUNDS MEAN PROBABILITY	[illegible]	[illegible]	[illegible]

  - European pilchard (*Sardina pilchardus*)
  - Atlantic chub mackerel (*Scomber colias*)

Fig. 3.3. Examples of the Data downloading pages in the MEDISEH online GIS Viewer.

D3.1.3 Synthesis maps presenting the persistent spawning and nursery grounds of the target small pelagic and demersal species along with the locations of protected habitats

An extensive synthesis of datasets on modelled habitats for small pelagic and demersal species was performed along with assembled fisheries restriction/protected areas. This task was carried out in order to map the protected habitat of the various species. These spatial queries are available as ready-to-use output through the viewer under the 'Specific queries' data theme and they present the common areas identified between species modelled habitat and marine protected areas/fisheries restricted areas. Examples of these spatial queries are shown in Fig. 3.4.



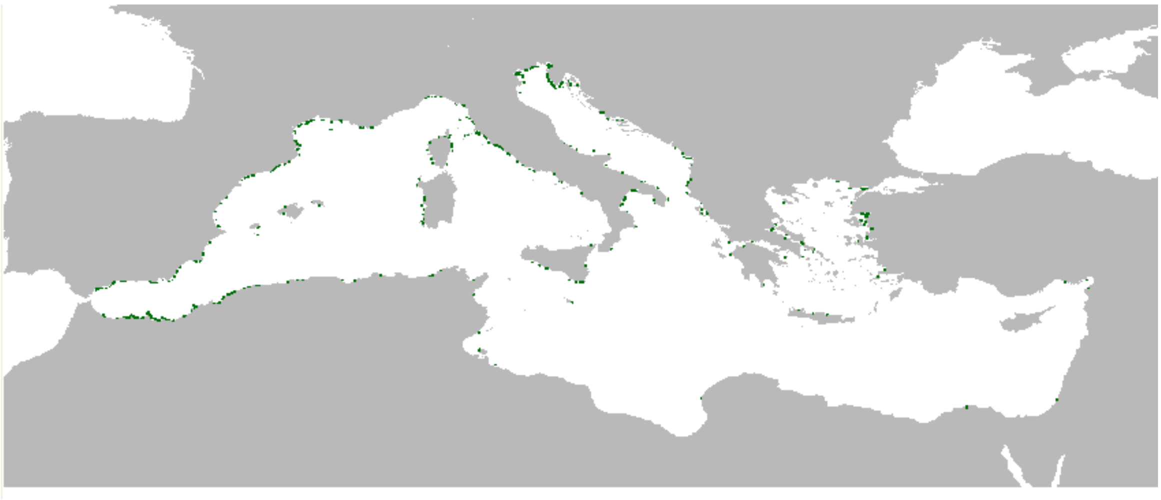
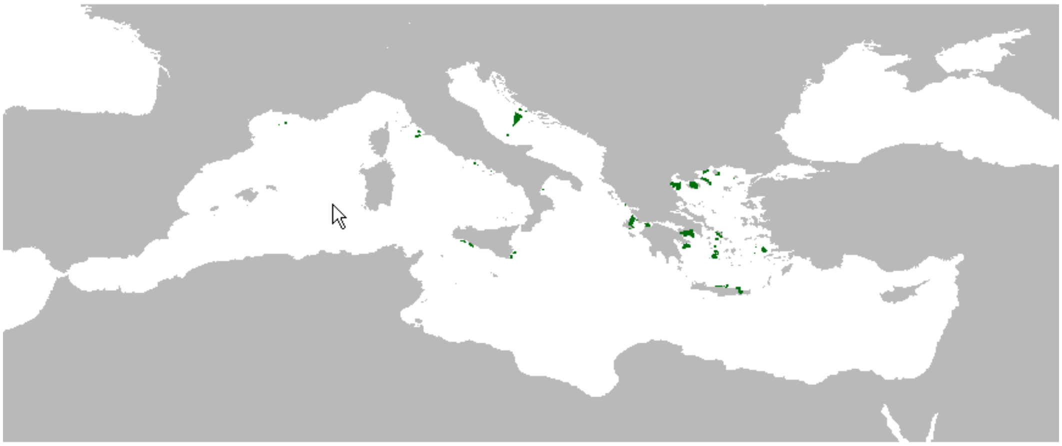


Fig. 3.4. Examples of spatial queries between small pelagic species habitats and fisheries restriction areas (protected habitat). Top: Anchovy preferential nursery habitat protected by fisheries restrictions for purse seiners. Bottom: Med horse mackerel preferential nursery habitat protected by fisheries restrictions for trawlers. Further details in Task 2.1 and at http://mareaproject.net/mediseh/viewer/med.html



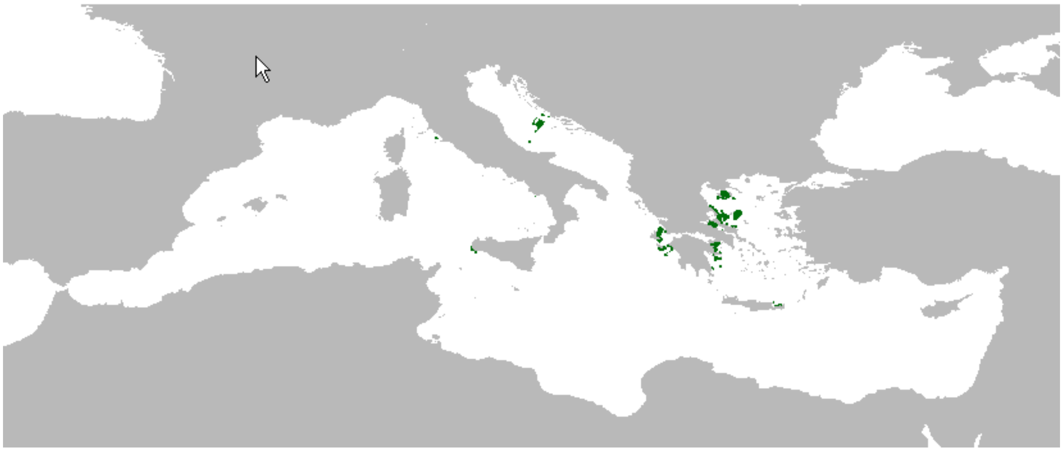


Fig. 3.5. Examples of spatial queries between demersal species habitats and fisheries restriction areas (protected habitat). Top: European hake persistent nursery habitat protected by fisheries restrictions for bottom trawl. Bottom: Broadtail shortfined squid persistent nursery habitat protected by fisheries restrictions for bottom trawl. Further details at http://mareaproject.net/mediseh/viewer/med.html

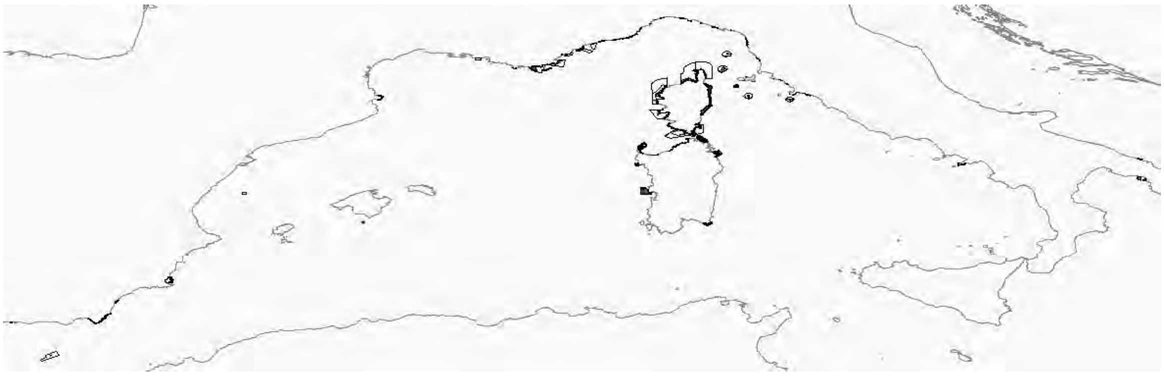


Fig. 3.6. Example of a spatial query output that shows the overlapping among areas characterized as MPAs, SPAMIs και NATURA in the western Mediterranean.

Based on a similar spatial query that it was developed in collaboration with Tasks 1.3 and 1.4 4 the spatial overlapping among areas characterized as MPAs, SPAMIs και NATURA (Fig. 3.6) was calculated resulting in a common area of 22562km^2. Within this common area it seems that we have 2938km^2 of *Posidonia* meadows if we consider >-0.28% probability as presence from model estimates. Similar queries are easy to develop within a future perspective.

Difficulties encountered and remedial actions

Some temporary difficulties were encountered during data re-projection at the beginning of the project. These difficulties were due to errors in initial data projections plus the error introduced by the re-projection. To overcome these data displacements and due to the fact that most data include coastal information, a detailed coastline was used for the whole Mediterranean to match the fine scale of the coastal datasets. The coastline used is the Global Self-consistent, Hierarchical, High-resolution Shoreline Database (GSHHS) downloaded from the NOAA Geosciences Lab (http://www.soest.hawaii.edu/wessel/gshhs/).

Overall comments

The online GIS data viewer is based on a user-friendly interface for scalable selection and viewing of an extensive number of assembled and produced datasets. Datasets were organised in various data themes, namely: BaseMap Datasets, Fish Historical Datasets, Fish Habitat Models, Marine Habitats Models, Models Predictors, Marine Protected Areas, and Specific Spatial Queries.

Users have access to all data themes through the online viewer while all datasets are interoperable through the interoperability services of the Geoserver database.

The 'Specific Queries' data theme includes the synthesis among many individual modelled and assembled datasets and provides scientifically analysed information for spatial management and conservation planning.

Finally, some deliverables were completed later than initially planned due to the amount of the assembled and modelled datasets, which reached their final version after continous enrichement and testing. However, these short delays resulted in more comprenhesive and integrated datasets, which improved the overall quality of the MEDISEH outputs and products.

The related to MEDISEH-WP3 web locations are listed in the following Table:

Table 3.3. List of web addresses related to MEDISEH-WP3.

WEB APPLICATIONS	URL (Uniform Resource Locator)
MEDISEH Data Viewer: (official version)	http://mareaproject.net/mediseh/viewer/med.html
MEDISEH Data Viewer: (backup version)	http://arch.her.hcmr.gr/mediseh/viewer/med.html
GeoDatabase and GeoServer	http://server.orbisnetwork.net:8080/geoserver/wms?request=GetCapabilities&service=WMS&version=1.0.0
Workshop-Seminar on Satellite Data	http://arch.her.hcmr.gr/mediseh/eowebsem/

References

ESRI- Environmental Systems Research Institute. http://www.esri.com/products. Accessed January 20, 2011.

WIKIPEDIA. http://en.wikipedia.org/wiki/Geographic_coordinate_system. Accessed January 20, 2011.

Marine Spatial Planning: Marxan application

4. The step forthworth: a preliminary analysis with the software Marxan

Participants (Prof S. Fraschetti (CoNISMa), Dr Paolo D’Ambrosio (MPA Porto Cesareo, Italy), Dr Francesco De Leo)

Cited as: S. Fraschetti, P. D’Ambrosio F. De Leo *The step forthworth: a preliminary analysis with the software Marxan. Mediterranean Sensitive Habitats (MEDISEH) Final Report, DG MARE Specific Contract SI2.600741, Heraklion (Greece).*

The MEDISEH project provided an unprecedented opportunity for filling an important gap of knowledge: providing a quantitative assessment of the distribution of vulnerable habitats such as *Posidonia* meadows, coralligenous and mäerl across the Mediterranean Sea. The project obtained relevant results especially if we consider the acquisition of information from traditionally data-poor areas. Our results represent an important basis for implementing strategies inspired to Marine Spatial Planning.

The obtained information is critical for spatial prioritization. In the Mediterranean Sea, multiple spatial conservation plans have been developed in recent years. However, despite the plethora of initiatives, major challenges still face Mediterranean biodiversity and conservation. These include the need for spatial prioritization within a comprehensive framework for regional conservation planning, the acquisition of further information from several areas of the basin, species or habitats, and addressing the challenges of establishing transboundary governance and collaboration in socially, culturally and politically complex conditions. Collective prioritised action, not new conservation plans, is needed for the north, western, and offshore waters of the Mediterranean. Developing initial information-based plans for the south and eastern Mediterranean is an urgent requirement for true regional conservation planning.

In this framework, spatial prioritization in conservation is required to invest limited resources where actions are most urgently needed and most likely to produce effective conservation outcomes. An important outcome of future projects will be to identify priority sites for conservation/management in the Mediterranean Sea through a systematic approach where quantitative data on the distribution of priority habitats, threats and already existing conservation initiatives will be merged and analysed by means of a software for spatial optimization, such as MARXAN.

We used MARXAN (Ball and Possingham, 2000; Possingham et al., 2000) which is a software with an algorithm that relies on static distributions of biodiversity features, like species, habitats and landscape types to identify, prioritise and select candidate sites for conservation/management. This software has the advantage of meeting the desired fixed targets for biodiversity conservation, while minimising as much as possible the area or the number of sites of the MPA. It can also be used either for terrestrial, marine or freshwater environments.

In general, to efficiently set conservation priorities, i.e. with the goal of minimising the economic losses while meeting the desired conservation targets, the best way to go is considering both ecological and pressure factors. The motivating idea is designing anMPA at the lowest cost, while meeting the conservation goals, so that suggested solutions to be easily accepted by the local communities adjusted to each study area. Since we used Marxan for the first time, here we present a solution where the only pressure included was the presence of harbours, irrespective of their size.

MARXAN was run with the adaptive annealing and interactive improvement algorithms and performed 100 repeat runs for each reserve design scenario. After each run, MARXAN generated a summary data that included the objective function score, together with the number of planning units and the boundary reserve length.

MARXAN details

The study area was divided into 2860 hexagonal planning units (PUs, side of the hexagon: of 20 km, total area 1039 km^2), using Repeating Shapes for ArcGIS, and their size was decided according to the size of the area under investigation (Fig. 4.1). Hexagonal planning units, instead of squares, produce more efficient and less fragmented scenarios. Also, using larger planning units produces portfolios that are less efficient but more likely to identify the same priority areas. The PUs included only one (coralligenous, *Posidonia* meadows, or a mosaic of both) or more habitat types in addition to the presence/absence of Marine Protected Areas (MPAs). This last layer was provided by the Database with GIS Information on already existing MPAs of this project (input from Task 1.4 and WP3). The extension of *Posidonia* has been estimated as a total of 10612,2335 km^2(i.e. estimated as input from Task 1.1 and Posidonia polygons without taking into account point data sources), the extension of bioconstructors is 676598.81 m^2, then the mosaic of the two covers 15234.73 m^2.

Our conservation values, in terms of habitats included in the analyses, were:

1- GIS data on coralligenous/mäerl formations. We used the model output of Task 1.3 (Fig.1.3.15a), predicting the occurrence probability for coralligenous formations (Fig. 1.2.20).
2- GIS data on *Posidonia*. Since the GIS layer of this habitat was considered quite exhaustive, real data were considered (see Fig. 1.1.4. on Task 1.1, Current distribution of *P. oceanica* across the Mediterranean Sea).

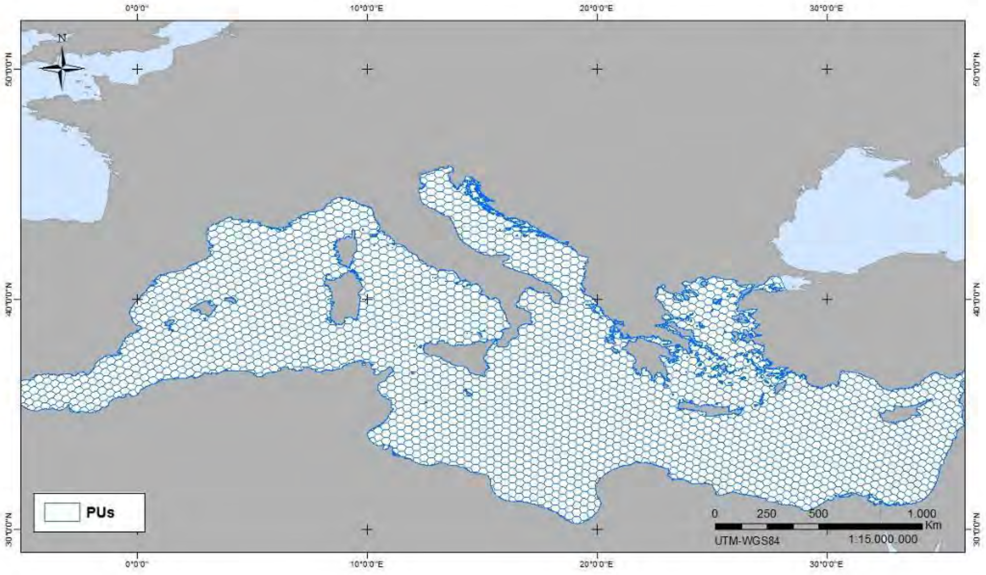


Fig. 4.1. The figure shows the distribution of the planning units (PU) across the Mediterranean Sea.

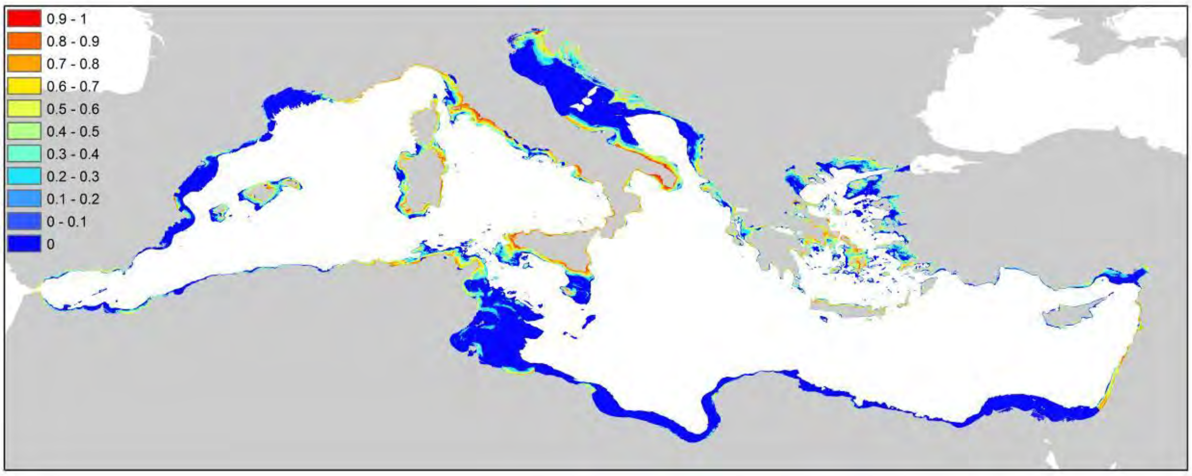


Fig. 4.2. Predicted occurrence probability for coralligenous formations (see Fig.1.3.15a of WP1 Task 1.3)

We set the conservation targets according to EU commitments and considering the ecological value of each habitat type. Even though we are aware that setting 60% can have relevant spatial consequences in terms of percentage of habitat included in the conservation scenarios, we decided to select this high target since aware of the underestimation of the extension of both habitats (especially coralligenous formations) across the basin.

The cost of each planning unit was set to 0, for simplicity. The algorithm type was the simulated annealing and interactive improvement; the number of simulations were 100 with 1000 000 interactions per simulation; the number of temperature decreases per simulation was 10000; and the choice of the initial temperature and cooling factor was set as adaptive.

Already existing Marine Protected Areas were also included in the analysis so that the new scenarios cannot disregard present conservation efforts. With the aim of assessing the effect of the presence of already implemented MPAs in new conservation scenarios, MARXAN analysis was carried twice: with and without the account of MPAs.

The Boundary Length Modifier calibration

The Boundary Length Modifier (BLM) is a variable that controls the length of the boundary of the reserve system. When we set the BLM at zero, or with a low value, the algorithm will drive the result in order to reduce the cost, in our case, the area. With higher values of BLM, the algorithm will be driven to minimize the boundary length and therefore forming a more clustered and compact reserve system (Ball and Possingham, 2000; Stewart and Possingham, 2005). We decided to set the BLM at zero, to maximize the distribution of areas to be included in conservation initiatives, reducing cost of this attempt.

Results and Comments

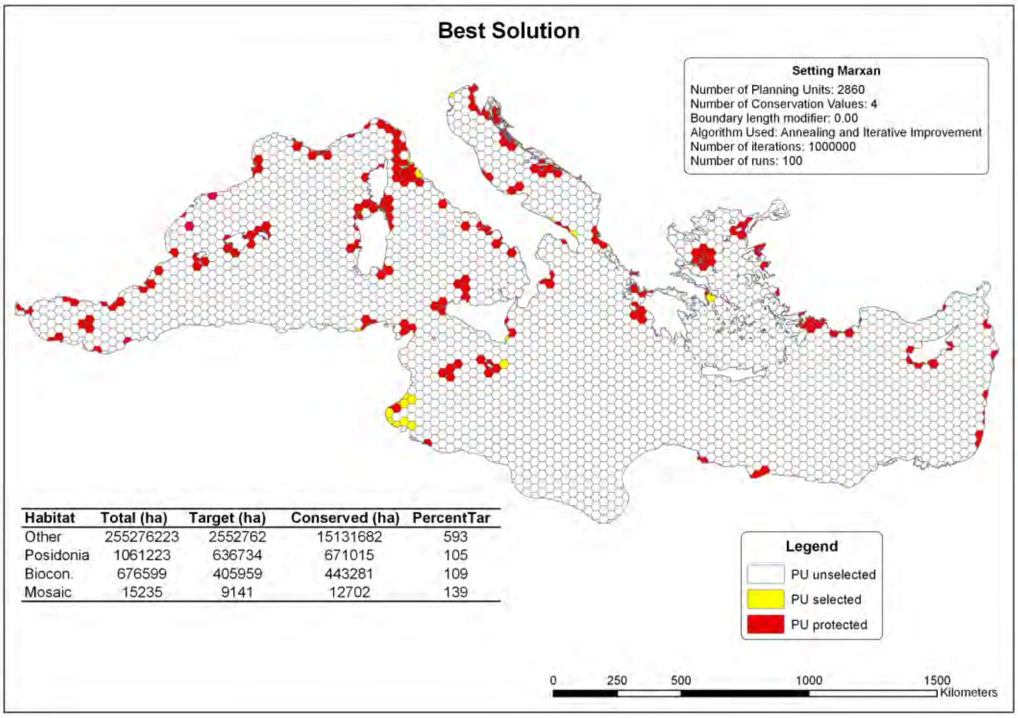
Here we comment the results from the two scenarios obtained, including or not including MPAs distribution. Results show that, at present, only the 4% of *Posidonia* and the 8% of coralligenous are presently protected within the already established MPA's. The best solution reported in Fig. 4.2, with the MPAs included, meets the set conservation targets and shows a scenarios protecting the 6,3% of the basin. Results from Marxan show that areas such as Tuscany, Apulia, portions of Tunisia and Greece are most frequently selected to reach conservation targets.

The best solution reported in Fig. 4.2 meets all conservation targets. However, the area under conservation/management regime is much smaller than the previous (1,7 % of the basin) (46093,9 Km^2 vs 162586,80 Km^2 of the previous analysis). Tuscany, Apulia, portions of Tunisia and Greece come out also from this second analysis.

These results are surely driven by data availability. In fact, these are the areas (with the exception of Tunisia) where most of the information on habitat distribution occurs. Marxan selects more PU in the western (indicating continuous distribution for both habitats) than in the eastern Mediterranean Sea, where information is still very scarce. In all cases, conservation targets were achieved by the analyses. This means that the 60% on the known distribution of the two habitats have been successfully included in the two scenarios. However, these analyses were run without considering human pressures. The inclusion of human pressures in the analyses might greatly change our results.

Certain issues rose from our analysis:

- at present available GIS information on the extent of protected sites (e.g. MPAs, Natura 2000 sites), although increasingly available at a better geospatial accuracy, is often inaccurate. In addition the designated and actual levels of realized protection measures vary significantly within protected areas which are likely to result into the overestimation of the present conservations initiatives at the basin scale.
- habitat distribution and extent, especially coralligenous formations, is severely underestimated limiting the potential of using spatial optimization tools. Even though it is preliminary, this analysis represents a first attempt to identify the challenges of using systematic approaches to conservation prioritization in the Mediterranean Sea, and clearly documents the present gaps of knowledge to be addressed for true regional conservation planning.

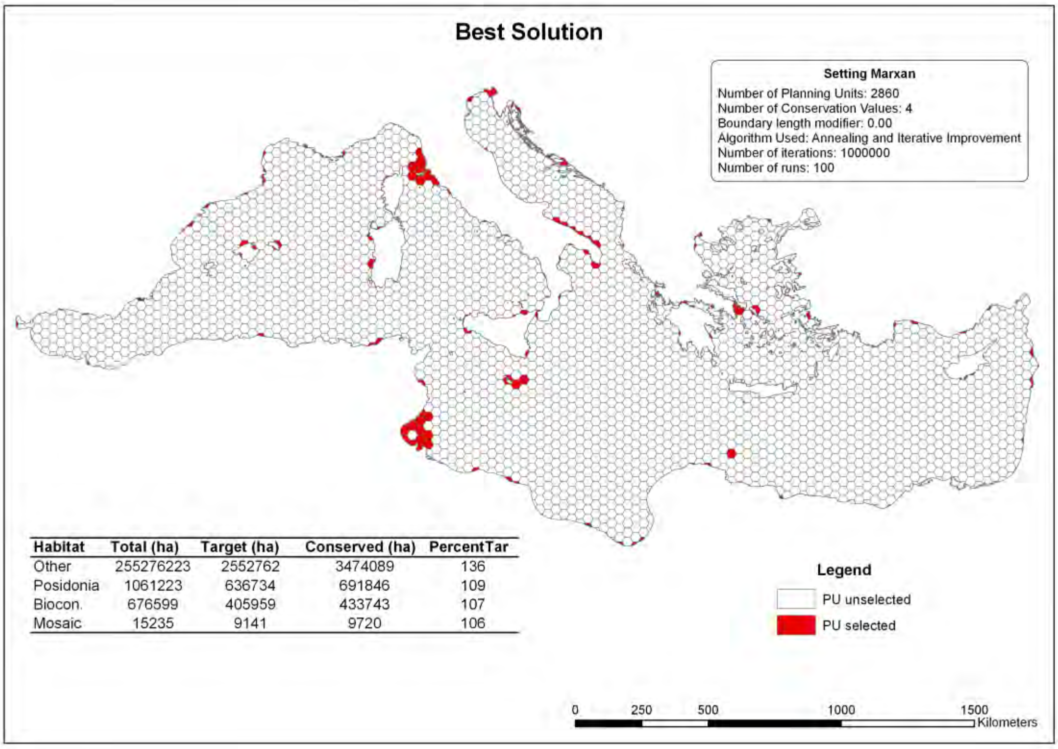


Setting Marxan

Number of Planning Units: 2860
Number of Conservation Values: 4
Boundary length modifier: 0.00
Algorithm Used: Annealing and Iterative Improvement
Number of iterations: 1000000
Number of runs: 100

Habitat	Total (ha)	Target (ha)	Conserved (ha)	PercentTar
Other	255276223	2552762	15131682	593
Posidonia	1061223	636734	671015	105
Biocon.	676599	405959	443281	109
Mosaic	15235	9141	12702	139

Fig. 4.3. MARXAN scenario output, considering existing MPAs.



Setting Marxan

Number of Planning Units: 2860
Number of Conservation Values: 4
Boundary length modifier: 0.00
Algorithm Used: Annealing and Iterative Improvement
Number of iterations: 1000000
Number of runs: 100

Habitat	Total (ha)	Target (ha)	Conserved (ha)	PercentTar
Other	255276223	2552762	3474089	136
Posidonia	1061223	636734	691846	109
Biocon.	676599	405959	433743	107
Mosaic	15235	9141	9720	106

Fig. 4.4. MARXAN scenario output, not considering existing MPAs.

References

Ball, I. and Possingham, H., 2000, MARXAN (v1.8.2): Marine Reserve Design using Spatially Explicit Annealing, 1.8.2, (Available at: http://www.uq.edu.au/marxan/

Possingham, H. P., I. R. Ball and S. Andelman 2000. Mathematical methods for identifying representative reserve networks. In: S. Ferson and M. Burgman (eds) Quantitative methods for conservation biology. Springer-Verlag, New York, pp. 291-305.

Overall Discussion, Conclusions, Recommendations

5. Overall Discussion, Conclusions, Recommendations

MEDISEH was an inter- and multidisciplinary project, covering the issue of sensitive marine habitat in the Mediterranean Sea from different perspectives: marine phanerogam beds and distribution, coralligenous and mäerl beds, nurseries and spawning grounds for the main commercial small pelagic and demersal species in the Mediterranean. Available information was revised across the Mediterranean and habitat modeling was applied integrating survey data and envitronmental data for Posidonia, coralligenous and mäerl as well as the nurseries and spawning grounds for small pelagic and demersal species across the Mediterranean, all these for the first time. In addition, up to date information was collected concerning marine protected areas under any kind of national and international legislation and the associated fishing restrictions applied. And all these datasets were combined into a GIS environment that serves both for storing and downloading the information as well as a tool to implement spatial overlapping. The work although it was part of a contract service with a very tight 19 months timeframe, provided the basis for ecosystem approach to fisheries management at a Mediterranean scale.

The project collected most of the available information on the different phanerogams, coralligenous and mäerl habitats across the Mediterranean Sea. The analyses of our results clearly show that the GIS information on Posidonia, coralligenous formations and mäerl has largely increased in the last ten years. Understanding how this information can be included into conservation planning is critical to reverse present trajectories of change and degradation. Despite this increased recognition, available information still largely refers to shallow waters from 20 to 30 meters depth. Data on deeper areas are still too scarce and this gap of information should be filled through systematic surveys.

The main problems we encountered were:

- the great amount of information, widely distributed in different forms (i.e. scientific papers, reports, grey literature, websites, etc.) and effort needed to collect it.
- the lack of electronic georeferenced files (shapefile format) in most countries
- the great heterogeneity of the restitution scale of maps (from 1:4.000 to 1:250.000) and the legends.
- different geographical projection and data in maps of different Country and Regions.

Habitat models for Posidonia, coralligenous and mäerl aimed at exploiting the existing information as effectively as possible, and therefore the modeling approach was adapted to the available data characteristics. We opted for Random Forests to model *P. oceanica* distribution because both presence and absence records were available over large regions. As for coralligenous and mäerl, presence records were less abundant than those for *P. oceanica* and the only viable option was to use maximum entropy models that allowed getting the very best results from the available data. Concerning Posidonia, the predictive variables that played the most relevant roles are nitrate and silicate concentrations, followed by the average depth, sea surface temperature and salinity. Among the 10 most relevant variables are also found distance from river mouths, phosphate concentration, pH, bottom salinity and Photosynthetic Active Radiation.

Concerning coralligenous nutrient input, bathymetry and slope of the seafloor were the three main contributors to the model (combined contribution of 64%), whilst the remaining six predictors had a combined contribution of 36%. The predictor variable with most information was bathymetry. Predicted occurrence for coralligenous formations was found to be consistent with the known distribution of this group of species across the Mediterranean Sea, especially in relatively well-sampled areas such as the Italian coastline. The model had the tendency to overpredict occurrence, though this could be corrected in places where information on absence was available (e.g. Nile delta, parts of the Libyan coast, part of the eastern Spanish coast, north-eastern coast of Italy). Except from the area surrounding the region between Algeria and Tunisia, which was the one best sampled of the North African coast, predicted occurrences for the rest of the North African coast were comparatively low, most probably due to too few occurrence points to train the model. For mäerl, phosphate concentration, distance to ports, bottom salinity and bathymetry were the four main contributors to the model (combined contribution of 61%) whilst the remaining five predictors had a combined contribution of 39%. Areas with known occurrences were relatively well predicted by the model. Again, the absence of occurrence record for the North African coast (excepted at two locations in Tunisian waters) meant that the model could not be trained efficiently in this area, and predicted occurrences remained very low as a result, two exceptions being on the Lybian (off Misrata) and Egyptian (West of Alexandria) coasts.

Habitat modeling techniques are very effective in filling the gaps in available data, but it cannot be taken for granted that their predictions are correct over huge unknown areas. The best way to improve habitat distribution models is to collect new data, both for validating existing models and for developing new ones. Although no model can fully overcome these problems, and that some uncertainty must be accepted, the models we developed are state-of-the-art and as accurate as possible. Despite its limitation, our modeling approach has shown great potential. Therefore, we are confident that their results will be useful to support environmental management policies at Mediterranean basin scale.

Concerning the existing Marine Protected Areas (MPAs), the Fishing Restricted Areas (FRAs) and the Proposed Marine Protected Areas the work done within the framework of MEDISEH revealed 146, 422 and 333 records respectively. Although this sort of information is often considered readily available in the web this is not the actual situation. In many cases accurate spatial information is missing, there is a large amount of conflicting information along with a large number of inconsistencies and variations in names whereas information on the applied fishing measures are generally lacking. Moreover, it should be noted that there are only a few EU/GFCM FRAs with an international recognition status. EU GFCM FRAs are well known and cover substantial areas. The work done within MEDISEH is the first attempt to record the nationally defined FRAs per general fishing gears categories, a task that presented a high degree of difficulty due to the lack of georeferenced shapefiles. Our work revealed that Greece has the highest number of FRAs (120 for bottom trawls/ 86 for purse seines and 47 for small scale gears) followed by Turkey (48 for bottom trawls/ 31 for purse seines and 2 for small scale gears). Nevertheless, the work done within MEDISEH goes beyond recording the extent and the distribution of existing and proposed protection measures. We developed a series of spatial queries that look into the spatial overlap of current and existing measures with key habitats and primarily with *Posidonia oceanica.* It seems that Posidonia meadows cover an area up to 53000 km^2 based on model results. The respective area covered by coralligenous formations was estimated up to 111409 km^2. Moreover, a significant part (>60%) of the Posidonia habitat seems to be covered by some form of fisheries restrictions (area or depth or distance from shore). Actual protection levels might be less however, as the term FRA applies to all gears operating over and on the habitat. The part of the habitat that corresponds to the 1.5 nm distance from shore trawling prohibition is around 60% and an even larger part of the habitat (around 85%) lays within the 50 m isobath, one of the most common depth restrictions. For coralligenous it seems that a percentage up to 14% and 8.3% occurs within existing MPAs and NATURA sites, respectively. The percentage that corresponds to existing FRAs seems to rise up to 82%. However, this percentage concerns all gears types not only those associated with the bottom.

A major part of the work done in MEDISEH involved the spatial analysis of survey data to determine the persistent nursery and spawning grounds of six small pelagic species (*Engraulis encrasicolus, Sardina pilchardus, Trachurus mediterraneus, Trachurus trachurus, Scomber colias,* *Scomber scombrus)* and 12 demersal species (i.e. *Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris, Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa).* Extensive revision was done concerning the available information of the spawning and nursery grounds of these species. For the small pelagic species acoustic survey data, ichthyoplankton data and MEDITS bottom trawl data were used depending on the species and data available. Habitat suitability modeling using survey data along with environmental satellite data was applied in order to identify suitable habitat areas throughout the Mediterranean basin. For certain species revised information showed almost complete lack of knowledge for both nurseries and spawning grounds e.g. *Trachurus spp., Scomber ssp*. This gap was largely covered by habitat modeling output providing preliminary habitat information across the Mediterranean Sea. For example, Atlantic horse mackerel (*Trachurus trachurus*) presents wide persistent juvenile grounds covering most of the middle Adriatic Sea, the Thracian Sea (northern Aegean Sea), the outer part of the shelf in Catalan Sea and the Gulf of Lions, the coastal waters of the Tyrrhenian Sea. On the other hand, Mediterranean horse mackerel (*Trachurus mediterraneus*) persistent juvenile grounds are limited to the inner part of the Gulf of Lions and the Catalan Sea, the northeast part of the Adriatic Sea and the east part of Thracian Sea (northern Aegean Sea). Habitat modeling techniques based on environmental data are very effective in filling the gaps in available data, but it cannot be taken for granted, considering that predictions are correct over huge unknown areas. The best way to improve habitat distribution models is to include information from additional areas, especially from the North African countries and Turkey both for validating existing models as well as for improving them.

In the case of the demersal fish species, the MEDITS bottom trawl survey data /species/ life stage were used to identify length at first maturity and obtain No/km^2 per recruits/spawners (depending on the species spawning period). Spatial analysis techniques were applied per species/GSA/life stage and different modeling approaches were applied per GSA depending on data peculiarities in order to identify persistent spawning and nursery grounds of the target species in the areas covered by the survey within the European part of the Mediterranean. Thus for hake persistent nursery grounds were showed off Baleares at the north-eastern and southern Mallorca, east of Corsica, along the coast of Tuscany and Latium on detritic bottoms, at the Gulf of Gaeta), offshore Capo Pecora and at the northern west side of the GSA18 offshore Gargano Promontory and southward the eastern Sicily coast between Capo Passero and Siracusa, along the eastern side of GSA17 within the Croatian islands. Moreover, for species like *Aristaeomorpha foliacea, Aristeus antennatus, Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa* the contribution of the project was highly significant, since available information on their spawning and nursery grounds was generally lacking. Difficulties encountered involved mainly the problem that MEDITS bottom trawl survey is not designed to cover the distribution of all target species: especially the coastal ones. In addition, the MEDITS takes place during the summer period only, which generates an issue of matching between spawning season and survey period and the lack of adequate or consistent data for spatial analysis. Moreover, bottom type, a variable strongly related to the distribution of demersal fish, is available at a very coarse spatial resolution for the whole Mediterranean.

Finally, within a preliminary approach, we considered important to identify priority sites for conservation/management in the Mediterranean Sea through a systematic approach where quantitative data on the distribution of priority habitats, threats and already existing conservation initiatives were merged and analyzed. For this purpose additionally to project's deliverables we applied MARXAN which is a software designed for spatial optimization. It uses an algorithm that relies on the static distribution of biodiversity features, like species, habitats and landscape types to identify, prioritize and select candidate sites for conservation/management. We set the conservation targets according to EU commitments and considering the ecological value of each habitat type, so we decided to use 60% conservation of coralligenous and

Posidonia formations across the basin. The best solution suggested by the software, taking into account the current MPAs in order to meet the conservation targets, involves a scenario that protects the 6,3% of the basin. Analytical results of Marxan show that areas such as Tuscany, Apulia, portions of Tunisia and Greece are most frequently selected to reach conservation targets.

Annex I

WP2 Joined Session report of Second Meeting

Identification of common approaches for the spatial analysis of data

During the kick-off project meeting held at Heraklion in October 2011, the subtask participants agreed on the necessity to discuss and identify common methodological approaches for the analyses of survey indices aimed at the identification of nurseries and spawning aggregation, as foreseen by Milestone 2.2.3.

Thus, a special session focusing on these objectives was held in the second meeting. Different R-packages, scripts and case studies were presented during both the afternoon session of the second day and the morning session of the third day of the Palermo meeting. The main aim of these meeting sessions was to introduce participants in the use of some potential useful methodological approaches and at the same time evaluate and discuss their pros and cons.

The following approaches have been tested for case study areas and presented during the meeting:

- Delta approach and zero inflated models for hake in Greek waters (G. Tserpes, HCMR)
- Mix Gams for hake recruits in the GSA 9 (G. Mastrantonio, CIBM)
- Spatial indicators, poor data situation (I. di Bitetto, M.T. Spedicato, COISPA)
- Presence/absence GAMS (M. Giannoulaki, HCMR)
- Hot spot identification and persistence analysis (G. Mastrantonio, F. Colloca, CIBM)

All the R-scripts developed have been uploaded into the ftp server of the Marea project web site.

After a discussion the participants agreed on the following recommendations for the development of spatial analyses according to the quality of the data available for each species and area.

Good data situations (e.g. sufficient numbers of positive hauls, adequate number of years, good area coverage, etc.)

Use statistical models (GAMs) or geostatistical methods and adjust them depending on data peculiarities.

Recommendations: take into account spatial autocorrelation, zero inflated distribution, possible correlations with environmental variables.

Data poor situations

When the number of positive hauls are not adequate to support the above mentioned spatial modeling then machine learning approaches (e.g. Maxent), or spatial indicators will be applied. In case that area characteristics and data availability do not allow the application of these approaches then bubble plots of the observed density indices will be used.

Method to identify hot spots areas

Estimation of Cumulative Aggregation Curves of predicted values and 45° tangent estimate is suggested as method to identify density hot spots. If information on stock boundaries is not available then analysis will be applied at the GSA level.

Modeling based on environmental variables

The participants agreed on the use of a common grid for environmental covariates and survey data in order to standardise the maps produced by the different participants at the Mediterranean scale. The resolution of the common grid would largely depend on the spatial resolution of environmental covariates. The SST data (surface water temperature) and Chl have a 1.6 km and 4 km resolution (cell size of the estimation grid) respectively, whereas the topographic data, which are considered by participants absolutely relevant to increase the resolution of the analyses, are available at a resolution of 1 km. These data (MARSPEC dataset) are not yet available for MEDISEH participants and should be urgently required by the MEDISEH coordinator to the authors of the dataset.

Considering the differences in resolution, an estimation grid with cell of 1 km side can be therefore adopted as a common grid by all participants.

Different approaches can be used to align all available covariates to the same grid, from simple spatial samples techniques available in GIS tools to kriging or inverse distance interpolation.

Mapping

The format of spatial maps of density distribution will be decided after the production of the initial results.

Analysis of persistent nursery and spawning areas is also suggested. Persistent values will be classified based on 4 different classes (0-0.25, 0.25-0.5, 0.5-0.75, 0.75-1).

Annex II

Scripts for data analysis and habitat modeling

(available at http://mareaproject.net/FTPMareaProject/#2)

RoME (version 1.1):

R code to perform multiple checks on MEDITS Survey data (TA, TB and TC files)

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Objectives

In order to unify the checks that are made independently over the MEDITS data by the 18 GSAs (Geographical Sub-Area) participating to MEDITS Survey, an R code performing all the main checks on TA, TB and TC files was developed.
The R code is structured in on 3 different scripts: functions.r, main.r and RoME.r.
The code does not correct the data, but it detects the errors warning the user that there is the possibility of one or more errors occurred, specifying the type of the error and easing the data correction. The user can decide to check files in .xls or .csv format (separator “;”). The check is performed simultaneously on the TA, TB and TC of one year at a time. For this reason the three files should be stored together in the same folder.

Script functions.r

In this script there are 37 functions (+ 7 “facility functions”) associated with a specific check in TA, TB and TC. All the checks have been designed according to INSTRUCTION MANUAL VERSION 5 MEDITS 2007 specifications.

The script is available for downloading at http://mareaproject.net/FTPMareaProject/#2

MEDISEH (MEDIterranean SEnsitive Habitats) – R routine for the estimation of mean length of Recruits and Spawners and for the calculation of Indices from scientific survey data

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R-RSI which is an R routine for the estimation of mean length of Recruits and Spawners and for the calculation of Indices from scientific survey data

The R_RSI MEDISEH-ver1.0 routine is written in R language and developed with R 2.12.2.
The software is composed by the following four main modules:
1. Data transformation from SGMED database to MEDISEH meta-database;
2. Threshold computation sub-divided into LFD standardization and threshold computation;
3. Selection of recruits and/or spawners from MEDISEH meta-database;
4. Abundance indices computation by haul. The routine refers to the Bhattacharya's method for separation of modal components (Bhattacharya, 1967; Sparre e Venema, 1998) and to the estimation of maturity ogive using Generalized Linear Models (Report ICES Workshop on Maturity Ogive Estimation for Stock Assessment (WKMOG)); moreover, the calculation of standardised length-frequency distribution (SLFD) is performed using stratified mean standardization formulas

After the selection of the GSA and the species to be investigated, the routine works for all the years in sequence, according to the instructions given by the user.

The script is available for downloading at http://mareaproject.net/FTPMareaProject/#2

COZIGAM

Made and presented by G. Tserpes (HCMR) based on Liu and Chan 2011 and Liu and Chan 2010

Zero-inflation problem is very common in ecological studies as well as other areas. Zero-inflated data abound in ecological studies as well as in other scientific and quantitative fields, where the data contain an excess of zero responses. The problem is known as zeroinflation. Zero-inflated data are often analysed via a mixture model specifying that the response variable comes from a probabilistic mixture of zero and a regular component whose distribution (referred to as the regular distribution below) belongs to the 1-parameter exponential family distribution. Nonparametric regression with zero-inflated data may be studied via the zero-inflated generalized additive model (ZIGAM).

Based on this approach an R script called COZIGAM was written to apply constrained and unconstrained Zero-Inflated Generalized Additive Models (COZIGAM) with Model Selection Criterion for analyzing zero-inflated data (Liu and Chan 2010; 2011).

The script is adapted to analyze hake juveniles' abundance as an example. Algorithms on exploratory analysis, modeling spatial residuals with ZIGAM and mapping are included.

The script is available for downloading at http://mareaproject.net/FTPMareaProject/#2 along with the related published papers.

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Presence/Absence GAMs based on environmental data

Made and presented by M. Giannoulaki (HCMR)

Generalized Additive Models (GAMs) are a flexible and automated approach to identifying and describing non linear relationships between predictors and response. The main advantage of GAMs over traditional regression methods is their capability to model non-linearities using non-parametric smoothers (Hastie and Tibshirani, 1990; Wood, 2006). In this case GAMs were applied in a presence/absence approach to relate fish spatial distribution with environmental data in order to define the set of the environmental factors that describe fish habitat A script was written and presented for this purpose. The script was adapted to analyze sardine adults echo abundance as an example.

Moreover, algorithms to evaluate model results using the Area Under Curve (AUC) criterion and Receiver Operating Curves (ROC plots) are included. The Receiver Operating Characteristic curve (ROC) (Hanley and McNeil, 1982; Guisan and Zimmerman, 2000) and the AUC metric, the area under the ROC. AUC is a threshold-independent metric, widely used in the species' distribution modeling literature (Franklin, 2009; Weber and McClatchie, 2010) of evaluating the performance of presence/absence models.

Algorithms on exploratory analysis, GAM model selection using the MGCV R library, mapping, model validation using AUC and ROC plots based on the presence/absence R library are included.

The script is available for downloading at http://mareaproject.net/FTPMareaProject/#2 along with the related published papers.

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MixGAM

Made and presented by F. Colloca (CIBM) and Gianluca Mastrantonio (CIBM)

Generalized additive mixed models (GAMMs) are proposed for overdispersed and correlated data, which arise frequently in studies involving clustered, hierarchical and spatial designs. This class of models allows flexible functional dependence of an outcome variable on covariates by using additive nonparametric functions to model effects to the additive predictor (Lin and Zhang 1999). GAMMs are more complicated than GAMs, although they provide specialized approaches to deal with modeling limitations. These tools offer accurate species distribution maps based on sampling areas, as well as predictions of species distribution in wider areas than the sampling, or in a different temporal extend. Generalized Additive Mixed Models are used complementary to GAMs, in order to deal with spatial autocorrelation that could lead to biased models and predictions. (Wood 2006; Zuur et al., 2009).

Within the framework of MEDISEH an R script was written (MixGAM) to apply spatial analysis using the Mixed GAMs approach. It uses hake recruits in the GSA 9 as a practical example. It includes algorithms to apply GAMMs and predict in a specific grid.

The script along with a tutorial in pdf is available for downloading at http://mareaproject.net/FTPMareaProject/#2.

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Spatial indicators approach

Presented by Maria Teresa Facchini, Isabella Bitetto, Maria Teresa Spedicato and Giuseppe Lembo COISPA Tecnologia and Ricerca, Bari (Italy)

Spatial Indicators are a set of descriptors of the population or population fractions (stages) distribution developed by Woillez *et al*. (2007) and applied within the framework of the European project FISBOAT (Fisheries Independent Survey Based Operational Assessment Tools) to capture the spatial pattern of different stocks (Spedicato *et al*. 2007; Woillez *et al*. 2009). These indicators are calculated using geo-referred data and allow to evaluate the distribution pattern of a species from different points of view (dispersion around the mean location, positive area, etc…), allowing to detect change in the spatial distribution across space and time and derive relationships between abundance and the characteristics of the spatial distribution, represented by the indicators. Moreover, they can be useful to investigate the spatial distribution of a species also in data poor situation. Below a summary for each indicator is also reported.

Center of Gravity : This indicator represents the mean location of the population; different centres of gravity for stages of study population have to be interpreted as a signal that on average they reside in different locations. By definition, the CG reduces the effects of the variations in the sampling design along the time series and tends to be closer to locations presenting major abundance.

Inertia : Inertia represents the mean square distance between an individual fish and the CG. A low value of inertia corresponds to quite aggregated and fairly distributed populations. Different values of inertia for each stage of a given population (e.g. juveniles and adults) should be interpreted as different type of dispersion for each age group around the same centre of gravity.

Isotropy and Anisotropy : Anisotropy gives information about the distribution of the population along 2 orthogonal directions. A value of Anisotropy quite close to 1 indicates a population distributed without any preferred direction. Large deviations from the value of 1 indicate the existence of pronounced anisotropy.

Global Index of Collocation (GIC) : This indicator provides information about the degree of mixing two populations or life stages of the same population. This indicator varies from 0 (populations totally distinct and concentrated) to 1 (centre of gravity coincident).

Number of Patches: The Number of Spatial Patches with abundance >10% (or more) gives an information about the number of significant distinct aggregations in the area. The mapping of spatial patches allows to obtain an immediate information about the position of the spatial patches in the area.

Positive Area, Spreading Area and Equivalent Area: Positive Area gives information about the area occupied by the stock apart from density value in the particular locations. The Spreading Area reveals how population abundance is split into low and high density values in time. It is related to the Gini index, but it does not take into account the contribution of zero values. Similar values of Spreading Area and Positive Area indicates that the population is evenly spread with a quite constant density.

Equivalent Area represents the area that would be covered by the population if every individual had the same density (exactly equal to the mean density per individual). The method is based on the representation of the spatial structure by a transitive covariogram. This indicator varies between 0 and the Positive Area; it would be exactly equal to it, if all the strictly positive density values were the same.

Microstructure Index : Microstructure Index measures how irregular is the surface of density of a given population at a fine scale; values close to 0 correspond to very regular, well-structured density surface, and values close to 1 correspond to a highly irregular, poorly structured, density surface.

RSI_MEDISEH routine allows to obtain the abundance indices of spawners and recruits in the format suitable to run Spatial Indicators routine.

The script is available for downloading at http://mareaproject.net/FTPMareaProject/#2.

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Hot spot identification and persistence analysis

Presented by G. Mastrantonio, F. Colloca, (*Dipartimento di Biologia Ambientale, University of Rome La Sapienza)*

To identify areas that host high annual densities of fish juveniles (i.e. annual nursery areas), a geostatistical aggregation curve can be built for the estimated spatial distribution of each early summer and autumn. Geostatistical aggregation curves were originally defined by Matheron (1981), and subsequently elaborated by Petitgas (1998), to describe spatial distribution changes as a function of variations in population abundance. They can however also used to identify density hot spot interpreted as nursery areas (Colloca et al., 2009, Bartolino et al., 2010).

A geostatistical aggregation curve relates the relative abundance of individuals P(y) to the area T(y) occupied by those individuals for densities greater than y. For calculation of the aggregation curve, all cells are ranked according to their density from maximum to minimum. Along this gradient, it is possible to calculate for each cell the cumulative abundance as a proportion of the total abundance, P(y), and the proportion of the total area, T(y). Both P(y) and T(y) range from 0 to 1, and the resulting curve describes the cumulative abundance with increasing area. P(y) and T(y) can be formalised mathematically as:

$$P(y) = \sum_{i=1}^{k} \frac{n_i}{N} \qquad (3)$$

$$T(y) = \sum_{i=1}^{k} \frac{a_i}{A} \qquad (4)$$

where n_i is the number of fish in the density class i, a_i is the area occupied by those fish for each class i and N is the total number of fish in the total area A. A relative geostatistical aggregation curve P(T) for each annual estimated spatial distribution can be calculated combining Eqs. (3) and (4). For each geostatistical aggregation curve, the location where the tangent line to the curve had a 45° slope can be identified. The tangent point can be adopted as a threshold for the identification of nurseries over each annual estimated surface.

Each curve up to the 45° tangent point includes a specific percentage of cells. This percentage was used to find the corresponding percentile of the estimated fish density distribution and thus the nursery density threshold.

The geometrical properties of the 45° tangent to the relative aggregation curve correspond to a change in the spatial distribution of fish from a dispersed distribution pattern to an aggregated pattern. For fish densities lower than the above identified threshold, a relative increase in the area is followed by a proportionally lower increase in the number of fish included. Conversely, above the threshold the relative increase is higher in the number of fish than in the area.

Persistence Index

The approach suggested for identification of nursery and spawning aggregation requires the use of temporal series of maps of density or biomass hot-spot that can be obtained with different geostatistical approaches applied to survey data. The estimation of the temporal persistence of each hot spot can be obtained measuring the relative persistence of the cell *i* as an annual nursery (Fiorentino *et al.,* 2003). Let $\delta_{ik} = 1$ if the grid cell *i* is included in a nursery in year *k*, and $\delta_{ik} = 0$ otherwise. A persistence index *Ii* can be computed as follows:

$$Ii = \frac{1}{n}\sum_{k=1}^{n}\delta_{ik}$$

where n is the number of surveys considered. Ii ranges between 0 (cell i never included in an annual nursery area) and 1 (cell i always included in an annual nursery area) for each cell in the study area.

Different conservation scenarios can be evaluated using different levels of Ii, the area occupied by nurseries and the proportion of recruits included in the nurseries can be calculated (Colloca et al., 2009).

The script along with a manual is available for downloading at http://mareaproject.net/FTPMareaProject/#2.

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R_MEFH_MEDISEH routine for estimating nursery and spawning grounds of demersal species (version 1.0)

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The R_MEFH_MEDISH routine (Modelling Essential Fish Habitat, version 1.0) is written in R language and allows to estimate annual density maps along with annual and persistent hot spots for fish populations, starting from the abundance indices datasets extracted from the JRC data base using the R_RSI_MEDISEH R routine (Facchini *et al.,* 2012). It is a reworking of the hake_juveniles_mapping_aegean script proposed by G. Tserpes and co-authors (2008).

The annual densities of recruits and spawners are modeled as a function of depth with a ZIGAM approach (Liu and Chan, 2009). The routine automatically chooses the higher initial degree of freedom value that should be attributed to the smoothing functions, to guarantee higher estimated degree of freedom value and so better function roughness. For each life stage and species the analysis is performed on a specific polygon, accounting for the known species distribution, and on a grid with a resolution of 1 km^2, generated inside the specific polygon. Contours of islands could be eliminated from the grid. Maps are obtained using the Inverse Distance Weighted interpolation (Schumaker, 1976). Annual hot spots can be identified using two different criteria: the 45° tangent method based on CRFD (Cumulative Relative Frequence Distribution) curves of abundance fitted values (Bartolino et al., 2011) or the 90th percentile of the abundance values of the fitted distribution as threshold value for nursery/spawning grounds definition. In both cases the extensions of the selected zones are computed as percentage of the total polygon area, and printed on the map.

The annual abundance maps are reclassified attributing the value 1 to the points of the grid belonging to an estimated hot spot and 0 to the others. The reclassified binomial maps are overlapped and the persistence indices are computed by arithmetical mean of 0-1 occurrence. The results, partitioned in five classes (0.05-0.20, 0.21-0.40, 0.41-0.60, 0.61-0.80 and 0.81-1), are plotted in the persistence map. Moreover, a csv file is produced reporting the list of the hauls of the time series included inside the most persistence areas.

The routine is available for downloading at http://mareaproject.net/FTPMareaProject/#2

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R_MEFH_MEDISEH routine for estimating nursery and spawning grounds of demersal species (version 2.0)

Angela Martiradonna, Walter Zupa, Isabella Bitetto, Maria Teresa Facchini, Maria Teresa Spedicato, Giuseppe Lembo
COISPA Tecnologia & Ricerca, via dei Trulli 18-20, Bari (Italy)
December 2013

The R_MEFH_MEDISH routine (Modelling Essential Fish Habitat, version 2.0) is written in R language and allows to estimate annual density maps along with annual and persistent hot spots for fish populations, starting from the abundance indices datasets extracted from the JRC data base using the R_RSI_MEDISEH R routine (Facchini *et al.,* 2012).

The annual densities of recruits and spawners are modeled as a function of depth with a ZIGAM approach (Liu and Chan, 2009) and, in order to capture the spatial correlation structure, ordinary kriging is performed on ZIGAM residuals (Rivoirard et al., 2000). Assuming a rather stable spatial correlation structure throughout years, a pooled variogram (Morfin et al., 2012) is estimated and the cross validation index VSE (Variance of Standard Error – Bleines *et al.*, 2000) is computed. Annual abundance maps are produced by predicting the ZIGAM and kriging models on a grid with the resolution of 1 km^2 generated inside a specific polygon, accounting for the known species distribution.

The Getis and Ord statistic (G statistic; Getis and Ord, 1992) is computed on the predicted values and hot spots could be identified with two approaches:

- Getis and Ord test with level of significance 0.95 (Getis and Ord, 2001): the hot spot is composed by all points of the grid whose standardize G statistic value is greater than the quantile of order $1 - 0.\frac{95}{2\ \mathrm{N}}$ of the standard normal distribution, where N is the amount of predicted values on the grid. The script localG.r (Mastrantonio, 2012) was used for this issue.
- Fisher homogeneous classification: the values of the statistic are classified in three classes such that the variance within groups is minimized and the highest class is selected as a nursery or spawning ground. For this purpose the Fisher algorithm (Fisher, 1958) is used.

Annual abundance estimated values are mapped and hot spots are highlighted with a red contour.

The annual abundance maps are reclassified attributing the value 1 to the points of the grid belonging to an estimated hot spot and 0 to the others. The reclassified binomial maps are overlapped and the persistence indices are computed by arithmetical mean of 0-1 occurrence. The results, partitioned in five classes (0.05-0.20, 0.21-0.40, 0.41-0.60, 0.61-0.80 and 0.81-1), are plotted in the persistence map.

The routine is available for downloading at http://mareaproject.net/FTPMareaProject/#2

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Rivoirard J, Simmonds J, Foote KG, Fernandes P, Bez N (2000) Geostatistics for Estimating Fish Abundance. 216 p. Blackwell Science Ltd.

Machine learning techniques

Presented by M. Scardi (CoNISMa) and C. Martin (HCMR)

ENFA: data requirements, software needed, approach to follow, parameters to use, examples, data useful for validation (M. Scardi)

Machine learning techniques were presented and suggested for application in data poor situations. Methods based on both presence and absence data two Machine Learning techniques were presented, namely Neural Networks (multilayer perceptrons) and Random Forests. These methods are already in use in habitat modeling and are available in several software packages. In particular, Random Forests can easily handle missing values, and in many cases provided the best predictive results for binary variables (presence/absence).

Maxent: data requirements, software needed, approach to follow, parameters to use, examples (C. Martin)

Presentation of a first modeling attempt using Maxent software and a basic dataset of bathymetric (bottom depth and bottom slope) and environmental data (SST, euphotoc zone, photosynthetic active radiation) was done. The stand alone Maxent routine was presented.

Details on these approaches can be seen in Task 1.3 and the respective presentations are cited at http://mareaproject.net/FTPMareaProject/#2.

Annex III

Agendas of the Meetings

MEDISEH: Mediterranean Sensitive Habitats

Kick-off Meeting

At Lato Hotel Heraklion (Crete, Greece)

11-13 October 2011

Final AGENDA

Tuesday 11th October

9:00-9:15 Welcome of the Participants, adoption of the agenda

9:15-9:30 Short introduction on MAREA (Maria Teresa Spedicato, COISPA)

9:30-10:00 Outline, General Objectives, Coordination (Marianna Giannoulaki, HCMR)

10:00-10:15 Short Presentation of the Commission Representative on the study expectations

10:15-10:45 WP3: GIS Database and Tools. Introduction. Link to the project needs (Vasilis Valavanis, HCMR)

10:45-11:15 Coffee Break

11:15-12:00 GIS Database and Tools (continue)

12:00-12:30 Link of GIS to Task 1.1 output and needs. (Database, data input and output format, Timeframe to follow, possible problems, issues to discuss)

12:30-13:00 Link of GIS to Task 1.2 output and needs. (Database, data input and output format, Timeframe to follow, possible problems, issues to discuss)

13:00 – 14:30 Lunch break

15:00-15:30 Link of GIS to Task 1.3 input, output and needs. Emphasis on the parameters that can be derived from GIS Databases and used for modeling, possible problems, Issues to discuss, Timeframe to follow)

14:30-15:00 Link of GIS to Task 1.4 output and needs. (Database, data input and output format, Timeframe to follow, issues to discuss)

15:30-15:45 Link of GIS to Task 1.4 output and needs. (Database, data input and output format, Timeframe to follow, issues to discuss)

15:45-16:30 Link of GIS to Task 2.1 output and needs. (Database, data input and output format, parameters that can be derived from GIS Databases and used for modeling, timeframe to follow, issues to discuss)

16:30-16:45 Coffee Break

16:30-17:15 Link of GIS to Task 2.2 output and needs. (Database, data input and output format, parameters that can be derived from GIS Databases and used for modeling, timeframe to follow, issues to discuss)

17:15-17:45 Presentation of an example online GIS tool presenting sensitive habitats, spawning and nursery grounds

17:45-18:30 General discussion, Day Briefing

Wednesday 12th October

WP1. Protected Habitats (Room A, Chairing: Andrea Belluscio, Simonetta Franscetti)

9:00-9:20 Task 1.1. Seagrass beds distribution along the Mediterranean coasts. Introduction, Objectives, Deliverables, Timeframe (Task Coordinators Andrea Belluscio CIBM)

9:20-9:35 Task 1.1 Overview of the available information for seagrass beds in the Mediterranean, the associated information and possible gaps in knowledge (Andrea Belluscio, CIBM and Panayiotis Panayiotidis HCMR)

9:35-9:50 Task 1.1 Seagrass beds in part of Italian waters: Introduction to the area, data availability, format of available data, associated information (e.g. bathymetric distribution, density, accompanied information) possible gaps in knowledge (Andrea Belluscio, CIBM)

9:50-10:05 Task 1.1 Seagrass beds in Greek waters: Introduction to the area, data availability, format of available data, associated information (e.g. bathymetric distribution, density, accompanied information) possible gaps in knowledge (Panayiotis Panayiotidis, Maria Salomidi HCMR)

10:05-10:20 Task 1.1 Seagrass beds in the Adriatic Sea: Introduction to the area, data availability, format of available data, associated information (e.g. bathymetric distribution, density, accompanied information) possible gaps in knowledge (Gianna Fabi, CNR-ISMAR)

10:20-10:40 Task 1.1 Seagrass beds in the Sicily Channel: Introduction to the area, data availability, format of available data, associated information (e.g. bathymetric distribution, density, and accompanied information) gaps in knowledge (Michele Gristina or Giovanni D'Anna CNR-IAMC)

10:35-11:00 Discussion and agreement on a common protocol for data collection, revision, presentation, GIS database input to cover the needs of other tasks.

11:00-11:30 Coffee Break

11:30-12:00 Continue discussion session.

12:00-12:30 Task 1.2 Coralligenous and mäerl beds along the Mediterranean coasts. Introduction, Objectives, Deliverables, Timeframe (Task Coordinator Simonetta Franscetti, CONISMA)

12:30-12:50 Task 1.2 Overview of the available information for the spatial distribution of coralligenous and mäerl beds in Greek waters and the Eastern Mediterranean basin, the associated information (e.g. bathymetric distribution, density, accompanied information, format of available data) and possible gaps in knowledge (Maria Salomidi, HCMR)

12:50-13:10 Task 1.2 Overview of the available information for the spatial distribution of coralligenous and mäerl beds in Italian waters, the associated information (e.g. bathymetric distribution, density, accompanied information, format of available data) and possible gaps in knowledge (Simonetta Franscetti, CONISMA)

13:10 – 14:40 Lunch break

14:40-15:00 Task 1.2 Overview of the available information for the spatial distribution of coralligenous and mäerl beds in the Adriatic Sea, the associated information (e.g. bathymetric distribution, density, accompanied information, format of available data) and possible gaps in knowledge (Gianna Fabi, CNR-ISMAR)

15:00-15:20 Task 1.2 Overview of the available information for the spatial distribution of coralligenous and mäerl beds in the Strait of Sicily, the associated information (e.g. bathymetric distribution, density, accompanied information, format of available data) possible gaps in knowledge (Michele Gristina or Giovanni D'Anna CNR-IAMC)

15:20-15:40 Task 1.2 Overview of the available information for the spatial distribution of coralligenous and mäerl beds in the Maltese waters, the associated information (e.g. bathymetric distribution, density, accompanied information, format of available data) possible gaps in knowledge (Leyla Knittweis, FCD (MSDEC))

15:40-16:00 Task 1.2 Discussion and agreement on a common protocol for data collection, revision, presentation, GIS database input to cover the needs of other tasks.

16:00-16:30 Coffee Break

16:30-17:00 Task 1.2 Continue from previous session

17:00-17:30 Task 1.3 Modeling of protected habitats with environmental variables. Introduction, Objectives, Deliverables, Timeframe (Task Coordinator Giacomo Chiato Osio, CIBM)

17:30-18:00 Brief overview of available habitat suitability statistical models. What do they need based on what there is available (Giacomo Chiato Osio CIBM, Marianna Giannoulaki HCMR)

18:00-19:00 Discussion on the suitable habitat modeling for *Posidonia*, coralligenous and mäerl beds based on environmental data. Input required from Task 1.1. Input required from WP3. Possible gaps, problems, issues on the appropriate spatial resolution for data analysis.

Wednesday 12th October

WP2. Mapping of nursery and spawning grounds of demersal and small pelagic fish. (Room B, Chairing: Francesco Colloca, Marianna Giannoulaki)

Task 2.1 Small pelagic fish

9:00-9:20 Task 2.1. Mapping of nursery and spawning grounds of small pelagic fish in the Mediterranean. Introduction, Objectives, Deliverables, Timeframe (Task Coordinator Marianna Giannoulaki, HCMR)

9:20-9:30 Task 2.1 Overview of the available information for the analysis of the spatial distribution of the nursery grounds of small pelagic fish in Greek waters (e.g. time series of data available, data quality, possible gaps in knowledge) (Marianna Giannoulaki, Athanassios Machias, HCMR)

9:30-9:45 Task 2.1 Overview of the available information for the analysis of the spatial distribution of the spawning grounds of small pelagic fish in Greek waters (e.g. time series of data available, data quality, possible gaps in knowledge) (Stylianos Somarakis, Apostolos Siapatis, HCMR)

9:45-10:00 Task 2.1 Overview of the available information for the analysis of the spatial distribution of the nursery grounds of small pelagic fish in the Adriatic Sea (e.g. time series of data available, data quality, possible gaps in knowledge) (Iole Leonori, CNR-ISMAR)

10:00-10:30 Task 2.1 Overview of the available information for the analysis of the spatial distribution of the nursery and spawning grounds of small pelagic fish in the Sicily Channel (e.g. time series of data available, data quality, possible gaps in knowledge) (Bernando Patti, CNR-IAMC)

10:30-11:00 Task 2.1 Overview of the available information for the analysis of the spatial distribution of the nursery and spawning grounds of small pelagic fish in Spanish Mediterranean waters (e.g. time series of data available, data quality, possible gaps in knowledge) (Magdalena Iglesias, Pilar Tugores, IEO)

11:00-11:30 Coffee Break

11:30-13:00 Task 2.1 Discussion on the standardization of the analysis, adaption of a common protocol, modeling approaches to follow based on available data, Deliverables, Timeframe

13:00 – 14:30 Lunch break

14:30-19:00 Continue from previous session, discussion on issues related to data availability, common scripts for data analysis, common protocol for data analysis

16:00-16:30 Coffee Break

Task 2.2 Demersal fish

9:00-9:30 Task 2.2. Mapping of nursery and spawning grounds of demersal fish in the Mediterranean. Introduction, Objectives, Deliverables, Timeframe (Task Coordinator Francesco Colloca, CIBM)

9:30-10:00 Task 2.2 Overview of the available information for the analysis of the nursery and spawning grounds of demersal fish that it is up to the responsibility of HCMR (e.g. time series of data available, summary of related past projects, data quality, possible gaps in knowledge, possible problems encountered) (George Tserpes, Eugenia Lefkaditou, Kostas Kapiris)

10:00-10:30 Task 2.2 Overview of the available information for the analysis of the nursery and spawning grounds of demersal fish that it is up to the responsibility of COISPA (e.g. time series of data available, summary of related past projects, data quality, possible gaps in knowledge, possible problems encountered) (Pino Lembo, COISPA)

10:30-11:00 Task 2.2 Overview of the available information for the analysis of the nursery and spawning grounds of demersal fish that it is up to the responsibility of CNR (e.g. time series of data available, summary of related past projects, data quality, possible gaps in knowledge, possible problems encountered) (Germana Garofalo CNR-IAMC)

11:00-11:30 Coffee Break

11:30-11:45 Task 2.2 Overview of the available information for the analysis of the nursery and spawning grounds of demersal fish that it is up to the responsibility of FCD - MSDEC(e.g. time series of data available, summary of related past projects, data quality, possible gaps in knowledge, possible problems encountered) (Leyla Knittweis, FCD (MSDEC))

11:45-12:30 Task 2.2 Overview of the available information for the analysis of the nursery and spawning grounds of demersal fish that it is up to the responsibility of CIBM (e.g. time series of data available, summary of related past projects, data quality, possible gaps in knowledge, possible problems encountered) (Francesco Colloca, CIBM)

12:30-13:00 Task 2.2 Overview of the available information for the analysis of the nursery and spawning grounds of demersal fish that it is up to the responsibility of CONISMA (e.g. time series of data available, summary of related past projects, data quality, possible gaps in knowledge, possible problems encountered) (Angelo Tursi, Roberto Carlucci, CONISMA)

13:00 – 14:30 Lunch break

14:30-15:00 Task 2.2 Overview of the available information for the analysis of the nursery and spawning grounds of demersal fish that it is up to the responsibility of IEO (e.g. time series of data available, summary of related past projects, data quality, possible gaps in knowledge, possible problems encountered) (Luis Gil De Sola, IEO)

15:00-19:00 Discussion on the standardization of the analysis, adaption of a common protocol for data analysis, suggested modeling approaches to follow based on available data, definition of the working team for scripts development, Timeframe.

16:00-16:30 Coffee Break

Thursday 13th October

WP1. Sensitive Habitats (Room A, Chairing Christopher Smith)

9:00-9:30 Task 1.3. Continue from previous day discussion if necessary (Discussion on the suitable habitat modeling for *Posidonia*, coralligenous and mäerl beds based on environmental data. Input required from Task 1.1. Input required from WP3. Possible gaps, problems, issues on the appropriate spatial resolution for data analysis.)

9:30-10:00 Task 1.4: Reviewing and mapping of all types of existing marine protected areas in different GSAs in the Mediterranean basin. Introduction, Objectives, Deliverables, Timeframe (Task Coordinator Christopher Smith, HCMR).

10:00-10:30 Review of available information in the Eastern Mediterranean basin (Christopher Smith/ Nadia Papadopoulou, HCMR)

10:30-11:00 Review of available information in the Western Mediterranean basin (Michele Gristina or Giovanni D'Anna CNR-IAMC)

11:00-11:30 Coffee Break

11:30-13:00 Issues for Discussion, Gaps in knowledge, possible problems to encounter in order to meet the deliverables

13:00 – 14:30 Lunch break

WP2. Nursery and Spawning grounds (Room B)

9:00- 11:00 Continue from previous day discussion if necessary. Agreement on common protocols for analysis

11:00-11:30 Coffee Break

11:30 – 13:00 Issues for discussion concerning GIS databases and applications in relation to WP2

13:00 – 14:30 Lunch break

15:00-18:30 General discussion, Overall Briefing (Joint Session, 10 minutes presentations from Task leaders summarising work and common protocols agreed are required to initiate discussion), Planning for 2nd meeting, finalizing, timeframe for work and reporting (Chairing: Marianna Giannoulaki, Maria Teresa Spedicato)

16:00-16:30 Coffee Break

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MEDISEH: Mediterranean Sensitive Habitats

2nd Meeting

Falkensteiner - Hotel Palazzo Sitano

Palermo 6-8 February 2012 (Sicily, Italy)

Final AGENDA

Monday 6th February (Room A, joined session)

9:00-9:15 Welcome of the Participants, adoption of the agenda

9:15-9:25 Short overview of current status of the project (Marianna Giannoulaki, HCMR)

9:25-9:45 Short Presentation of the Commission Representative (Antonio Cervantes)

9:45-10:00 Task 1.1 Overview of the revised information for seagrass beds in the western Mediterranean, possible gaps in knowledge, approach to follow to cover gaps, timeframe for reporting and deliverables (Andrea Belluscio, CIBM)

10:00-10:15 Task 1.1 Seagrass beds in central Mediterranean: possible gaps in knowledge, approach to follow to cover gaps, timeframe for reporting and deliverables (Michele Gristina CNR-IAMC)

10:15- 10:30 Task 1.1 Seagrass beds in eastern Mediterranean: possible gaps in knowledge, approach to follow to cover gaps, timeframe for reporting and deliverables (Panayiotis Panayiotidis HCMR)

10:30- 10:45 Task 1.2 Coralligenous and mäerl beds along the western Mediterranean coasts, possible gaps in knowledge, approach to follow to cover gaps, timeframe for reporting and deliverables (Simonetta Franscetti, CoNISMa)

10:45 – 11:00 Task 1.2 Coralligenous and mäerl beds along the central Mediterranean coasts, possible gaps in knowledge, approach to follow to`cover gaps, timeframe for reporting and deliverables (Simonetta Franscetti, CoNISMa, Michele Cristina CNR-IAMC, Gianna Fabi CNR-ISMAR)

11:00-11:30 Coffee Break

11:30 – 11:45 Task 1.2 Coralligenous and mäerl beds along the eastern Mediterranean coasts, possible gaps in knowledge, approach to follow to cover gaps, timeframe for reporting and deliverables (Maria Salomidi HCMR)

11:45-12:15 Discussion on the work that remains to be done in Tasks 1.1 and 1.2.

12:15-12:45 WP1. Task 1.4 Overview of the work done in the Mediterranean (Chris Smith – Nadia Papadopoulou HCMR)

12:45-13:00 Discussion on protected areas and sensitive habitats

13:00 – 14:30 Lunch break

14:30-14:45 WP1. Task 1.3 Overview of the work done (Michele Scardi CoNISMa)

14:45- 15:30 Workshop on Sensitive Habitat Modeling. 1) ENFA: data requirements, software needed, approach to follow, parameters to use, examples, data useful for validation (Michele Scardi, CoNISMa)

15:30-16:00 2) Maxent: data requirements, software needed, approach to follow, parameters to use, examples (Corinne Martin – Marianna Giannoulaki)

16:00-16:30 Coffee Break

16:30-18:00 Discussion on the modeling approach on sensitive habitats, environmental variables to use, possible problems to encounter, timeframe for work and reporting

Tuesday 7th February

WP1 (ROOM A)

9:00 – 13:00 Reviewing MPA database and potential data gaps (Task 1.4.) as well as working with data on habitat modeling (Task 3.2)

11:00-11:30 Coffee Break

13:00 – 14:30 Lunch break

16:00-16:30 Coffee break

16:30 - 18:00 Discussion on the modeling approach on sensitive habitats, environmental variables to use, possible problems to encounter, timeframe for work and reporting

WP2 (ROOM B)

Mapping of nursery and spawning grounds of demersal and small pelagic fish. (Chairing: Francesco Colloca, Marianna Giannoulaki)

Session 1: Overview of the progress of work

9:00-9:10 Task 2.2. Mapping of nursery and spawning grounds of demersal fish in the Mediterranean. Introduction, Objectives, Deliverables, Timeframe (Task Coordinator Francesco Colloca, CIBM)

9:10-9:20 Task 2.2 Revised information on nursery and spawning grounds of demersal fish in GSAs 20, 22, 23 that it is up to the responsibility of HCMR (e.g. progress of work, issues related to availability, possible in the scheduled activities) (George Tserpes, HCMR)

9:20-9:30 Task 2.2 Revised information on nursery and spawning grounds of demersal fish in GSAs 10, 18 that it is up to the responsibility of COISPA (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Pino Lembo, COISPA)

9:30-9:40 Task 2.2 Revised information on nursery and spawning grounds of demersal fish in GSAs 15, 16, 25 that it is up to the responsibility of CNR (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Germana Garofalo CNR-IAMC, Giussepe Scarcella)

9:40-9:50 Task 2.2 2 Revised information on nursery and spawning grounds of demersal fish in GSAs 9, 7, 8 that it is up to the responsibility of CIBM (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Francesco Colloca, CIBM)

9:50-10:00 Task 2.2 Revised information on nursery and spawning grounds of demersal fish in GSAs 17, 19, 11 that it is up to the responsibility of CoNISMa (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Angelo Tursi, Roberto Carlucci, CoNISMa)

10:00-10:10 Task 2.2 Revised information on nursery and spawning grounds of demersal fish in GSAs 1, 5, 6 (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Enric Massuti, Luis Gill De Sola, IEO)

10:10 -10:20 Revised information on nursery and spawning grounds for small pelagic in the eastern Mediterranean (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Marianna Giannoulaki, HCMR)

10:20 -10:30 Revised information on nursery and spawning grounds for small pelagic in the central Mediterranean (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Bernando Patti, CNR IAMC)

10:20 -10:30 Revised information on nursery and spawning grounds for small pelagic in the Adriatic (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Iole Leonori, CNR ISMAR)

10:30-10:40 Revised information on nursery and spawning grounds for small pelagic in the western Mediterranean (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Pilar Tugores, IEO)

10:40 – 11:00 Discussion, quick overview timeframe for deliverables and interim report

11:00-11:30 Coffee Break

Session 2: Methodology related to data analysis, scripts, spatial analysis approaches

11:30-12:00 ROME: R Script for checking MEDITS data. Practical examples (Maria Teressa Spedicato, Pino Lembo, Isabella Bitetto, COISPA).

12:00 – 12:30 R-RSI: R routine for the estimation of mean length of Recruits and Spawners and for the calculation of Indices from scientific survey data, practical examples (Maria Teressa Spedicato, Pino Lembo, Isabella Bitetto, COISPA)

12:30 – 13:00 GLMs for spatial analysis, scripts, data requirements, practical examples (George Tserpes, HCMR)

13:00 – 14:30 Lunch break

14:30 – 15:00 GAMs for modeling the spatial distribution of demersals, scripts, practical examples (George Tserpes, HCMR)

15:00 – 15:30 GAMs for spatial analysis using environmental variables, scripts, data requirments, practical examples (Marianna Giannoulaki, HCMR)

15:30 – 16:00 Mixed models for spatial analysis scripts, practical examples (Francesco Colloca, CIBM)

16:00-16:30 Coffee break

16:30 – 17:00 Data poor situations (Michele Scardi, CoNISMa)

17:00 – 17:30 Operational approach on spatial indicators, how can they be useful (Maria Teressa Spedicato, COISPA)

17:30 – 18:00 Discussion on script application, possible improvements. Needs for additional scripts

Wednesday 8th February (Rooms A, B, C)

9:00 – 16:00 Practical session, working with data on WP2 (Task 2.1 and Task 2.2, Rooms B and C) and on WP1 (Room A)

13:00 – 14:30 Lunch break

16:00-16:30 Coffee Break

16:30 – 18:00 Plenary Session (Room A)

General discussion, Overall Briefing (Joint Session, 10 minutes presentations from Task leaders summarising work done. Planning for 3nd meeting by month 12, finalizing, timeframe for work and reporting (Chairing: Marianna Giannoulaki, Maria Teresa Spedicato).

List of participants

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MEDISEH: Mediterranean Sensitive Habitats

3rd Meeting

Orto Botanico

Rome 26-28 September 2012 (Italy)

Final AGENDA

Wednesday 26th September (Room A, Joint session, Chaired Marianna Giannoulaki HCMR, Simonetta Fraschetti CoNISMa, Andrea Belluscio, CIBM)

9:15-9:30 Welcome of the Participants, adoption of the agenda

9:30-9:45 Short overview of current status of the project, interim report, Commission comments for the final report (Marianna Giannoulaki, HCMR)

9:45-10:00 WP1, Task 1.1 Quick overview of the revised information for seagrass beds in the Mediterranean. Update following the previous meeting, Problems encountered after 2nd meeting and additional data collected, timeframe for reporting and deliverables, issues raised from the interim and should be considered for the final report (Andrea Belluscio, CIBM; Panayotidis Panayotis HCMR)

10:15- 10:30 WP1, Task 1.2 Quick overview of the revised information on coralligenous and mäerl beds along the Mediterranean coasts. Update following the previous meeting, Problems encountered after 2nd meeting and additional data collected, timeframe for reporting and deliverables, issues raised from the interim and should be considered for the final report (Simonetta Fraschetti, CONISMA).

10:30- 10:45 WP1. Task 1.3 Overview of the work done concerning *Posidonia* using the Random Forest approach, difficulties encountered, issues for discussion with the experts (Michele Scardi CoNISMa)

10:45 – 11:00 WP1. Task 1.3 Overview of the work done concerning *Posidonia* using the Maxent approach, difficulties encountered, issues for discussion with the experts (Corinne Martin, Vasilis Valavanis HCMR)

11:00-11:30 Coffee Break

11:30 – 11:45 Discussion on the modeling results for *Posidonia*, experts input, ideas for validation and improvement, timeframe for work and reporting

WP1. Task 1.3 Overview of the work done concerning coralligenous using the Maxent approach, difficulties encountered, issues for discussion with the experts (Corinne Martin HCMR)

11:45-12:15 WP1. Task 1.3 Overview of the work done concerning mäerl using the Maxent approach, difficulties encountered, issues for discussion with the experts (Corinne Martin HCMR)

12:15-13:00 Discussion on the modeling results for coralligenous and mäerl, experts input, ideas for validation and improvement, timeframe for work and reporting

13:00 – 14:30 Lunch break

14:30-14:45 WP1, Task 1.4 Overview of the work done, progress after the interim report, timeframe for reporting and deliverables, problems encountered (Chris Smith – Nadia Papadopoulou HCMR)

14:45- 15:30 Overall discussion on the work that remains to be done in Tasks 1.1, 1.2., 1.3, 1.4, timeframe for deliverables, needs for the GIS Viewer

15:30-16:00 WP3. Progress of the GIS viewer, problems encountered (Vasilis Valavanis HCMR)

16:00-16:30 Coffee Break

16:30-18:00 WP3. Discussion on emerging needs of the viewer on data input and formatting, data accessibility, timeframe for deliverables

Thursday 27th September (Rooms A, B, C)

WP1 (ROOM A)

9:00 – 18:00 Continue discussion and work on the modeling approach on sensitive habitats, possible problems to encounter, timeframe for work and reporting. Working with data on habitat modeling.

11:00-11:30 Coffee Break

13:00 – 14:30 Lunch break

16:00-16:30 Coffee break

WP2 Mapping of nursery and spawning grounds of demersal and small pelagic fish (Rooms B and C).

Task 2.1 Mapping of nursery and spawning grounds of small pelagic fish (ROOM B)

9:00 -13:00 Group discussion on the progress of modeling, modeling approaches applies, scripts, working with data

Task 2.2 Mapping of nursery and spawning grounds of demersal fish (ROOM C)

9:00 -13:00 Group discussion on the progress of modeling, modeling approaches applied, scripts, working with data.

11:00-11:30 Coffee Break

13:00 – 14:30 Lunch break

Task 2.1 Mapping of nursery and spawning grounds of small pelagic fish (ROOM B) Chairing Marianna Giannoulaki (HCMR)

Joint session for WP2

14:30 – 14:50 Modeling results for sardine (Iole Leonori, Fabio Campanella, Claudio Vassapollo CNR-ISMAR)

14:50 – 15:10 Modeling results for anchovy (Iole Leonori, Fabio Campanella, Claudio Vassapollo CNR-ISMAR)

15:10 – 15:30 Modeling results for *Trachurus mediterraneus* juvenile grounds (Magdalena Iglesias, Pilar Tugores IEO)

15:30 – 15:50 Modeling results for *Trachurus mediterraneus and Scomber japonicus* spawning grounds (Apostolis Siapatis HCMR)

15:50 – 16:10 Modeling results for *Scomber japonicus* and *Scomber scombrus* (Maria Myrto Pyrounaki HCMR)

16:10-16:40 Coffee break

16:40 – 17:00 Modeling results for *Trachurus trachurus* juvenile grounds (Marianna Giannoulaki HCMR)

17:00 – 18:00 Discussion on modeling results

Friday 28th September (Rooms A, C)

Task 2.2 Mapping of nursery and spawning grounds of demersal fish (ROOM C, Chairing Francesco Colloca CNR-IAMC)

9:00-9:30 Task 2.2 Modeling work on nursery and spawning grounds of demersal fish in GSAs 20, 22, 23 that it is up to the responsibility of HCMR (e.g. progress of work, issues related to availability, possible in the scheduled activities) (George Tserpes, Nikos Nikolioudakis HCMR)

9:30-10:00 Task 2.2 Modeling work on nursery and spawning grounds of demersal fish in GSAs 10, 11, 18, 19 that it is up to the responsibility of COISPA (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Pino Lembo, Isabella Bitetto, Maria Teressa Facchini, Maria Teresa Spedicato COISPA)

10:00-10:30 Task 2.2 Modeling work on nursery and spawning grounds of demersal fish in GSAs 15, 16, 17, 25 that it is up to the responsibility of CNR (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Germana Garofalo CNR-IAMC, Giussepe Scarcella CNR-IAMC, Marie Louise Pace FCD (MSDEC))

10:30-11:00 Task 2.2 Modeling work on nursery and spawning grounds of demersal fish in GSAs 9, 7, 8 that it is up to the responsibility of CIBM (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Francesco Colloca, CNR IAMC)

11:00-11:30 Coffee Break

11:30-12:00 Task 2.2 Modeling work on nursery and spawning grounds of demersal fish in GSAs 1, 5, 6 (e.g. progress of work, issues related to availability, possible in the scheduled activities) (Enric Masutti, Magdalena Iglesias, Francisco Ordinas, Pilar Tugores, Luis Gill De Sola IEO)

12:00 – 13:00 Discussion on modeling results

13:00 – 14:30 Lunch break

14:30 – 15:30 Continue discussion on modeling results

15:30 - 18:00 Plenary Session (Room A) (Chairing: Marianna Giannoulaki, Maria Teresa Spedicato)

General discussion, Overall Briefing

Joint Session, 10 minutes presentations from Task leaders summarising work done.

Planning for 4th meeting by month 16, finalizing, timeframe for work and reporting

16:00-16:30 Coffee Break

	Wed 26/10	Thu 27/10			Fri 28/10	
	Room A	**Room A**	**Room B**	**Room C**	**Room A**	**Room C**
Morning	Joint session WP1 9h15-13h	WP1 9h-13h	WP2 Task 2.1 9h-13h	WP2 Task 2.2 9h-13h		WP2 Task 2.2 9h-13h
Afternoon	Joint session WP1 14h30-15h30 WP3 15h30-18h	WP1 14h30-18h	Joint session WP2 Task 2.1 14h30-18h			WP2 Task 2.2 14h30-15h30
					Plenary 15h30-18h	

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MEDISEH: Mediterranean Sensitive Habitats

4th Meeting

Astoria Capsis Hotel

Heraklion 8-10 January 2013 (Greece)

Final AGENDA

Tuesday 8th January (Chaired Marianna Giannoulaki HCMR, Simonetta Fraschetti CoNISMa)

9:15-9:30 Welcome of the Participants, adoption of the agenda

9:30-9:45 Short overview of current status of the project, expectations from the final meeting (Marianna Giannoulaki, HCMR)

9:45-10:15 WP1, Task 1.1 Overview of the Task deliverables, presentation of the database and shp files, final status of the Task (Andrea Belluscio- CIBM, Luca Telo- CIBM, Panos Panayiotidis – HCMR)

10:15- 10:45 WP1, Task 1.2 Overview of the Task deliverables, presentation of the database and shp files, final status of the Task (Simonetta Fraschetti, CONISMA).

10:45- 11:15 WP1. Task 1.3 Presentation of the work done concerning *Posidonia* using the Random Forest approach, final modeling results, difficulties encountered, and issues for discussion with the experts (Michele Scardi CoNISMa, Corinne Martin HCMR)

11:15-11:45 Coffee Break

11:45 – 12:30 WP1. Task 1.3 Overview of the work done concerning coralligenous and mäerl beds using the Maxent approach, final modeling results, difficulties encountered, issues for discussion with the experts (Corinne Martin, Marianna Giannoulaki, Vasilis Valavanis HCMR)

12:30 – 13:00 Discussion on the modeling results. Timeframe for reporting, GIS viewer needs.

13:00 – 14:30 Lunch break

14:30-15:00 WP1, Task 1.4 Overview of the Task deliverables, presentation of the database and shp files, final status of the Task, issues for reporting (Chris Smith – Nadia Papadopoulou HCMR)

14:45- 15:00 Overall discussion on the work that remains to be done in WP1, timeframe and template for reporting, remaining needs (if any) for the GIS Viewer

15:00-15:30 WP2 Mapping of nursery and spawning grounds of demersal and small pelagic fish

Task 2.1 Mapping of nursery and spawning grounds of small pelagic fish

15:30-16:00 Task 2.1 Deliverables for sardine and anchovy, needs for viewer and reporting (Iole Leonori, Fabio Campanella, Andrea De Felice CNR-ISMAR)

16:00-16:30 Coffee Break

16:30-17:00 Task 2.1 Deliverables for *Trachurus mediterraneus* juveniles, needs for viewer and reporting (Magdalena Iglesias, Pilar Tugores, IEO)

17:00-17:30 Task 2.1 Deliverables for *Trachurus mediterraneu*s spawners and *Trachurus trachurus* juveniles, needs for viewer (Marianna Giannoulaki, Myrto Pyrounaki HCMR)

17:30-18:00 Task 2.1 Deliverables for *Scomber scombrus* and *Scomber japonicus* juveniles, needs for viewer and reporting (Myrto Pyrounaki, Marianna Giannoulaki HCMR)

18:00-18:30 Task 2.1 Deliverables for *Scomber japonicus* and *Trachurus mediterraneus* eggs, needs for viewer and reporting (Apostolos Siapatis HCMR)

Wednesday 9th January

Task 2.2 Mapping of nursery and spawning grounds of demersal fish (Chairing Francesco Colloca, CNR-IAMC)

9:00-9:30 Task 2.2 Bubble plots and modeling work on nursery and spawning grounds of demersal fish in GSAs 20, 22, 23, results and deliverables, viewer needs and reporting, justification for species or life stages not modelled (George Tserpes, Nikos Nikolioudakis HCMR)

9:30-10:00 Task 2.2 Bubble plots and modeling work on nursery and spawning grounds of demersal fish in GSAs 10, 11, 18, 19, results and deliverables, viewer needs and reporting, justification for species or life stages not modelled (Pino Lembo, Isabella Bitetto, Maria Teressa Facchini, Maria Teresa Spedicato COISPA)

10:00-10:30 Task 2.2 Bubble plots and modeling work on nursery and spawning grounds of demersal fish in GSAs 15, 16, 17, 25, results and deliverables, viewer needs and reporting, justification for species or life stages not modelled (Germana Garofalo CNR-IAMC, Giussepe Scarcella CNR-IAMC, Leyla Knittweis FCD (MSDEC))

10:30-11:00 Task 2.2 Bubble plots and modeling work on nursery and spawning grounds of demersal fish in GSAs 9, 7, 8, results and deliverables, viewer needs and reporting, justification for species or life stages not modelled (Francesco Colloca, CNR IAMC)

11:00-11:30 Coffee Break

11:30-12:00 Task 2.2 Bubble plots and modeling work on nursery and spawning grounds of demersal fish in GSAs 1, 5, 6, results and deliverables, viewer needs and reporting, justification for species or life stages not modelled (Enric Masutti, Magdalena Iglesias, Francisco Ordinas, Pilar Tugores, Luis Gill De Sola IEO)

12:00-13:00 Discussion on modeling results and deliverables by each partner

13:00 – 14:30 Lunch break

14:30-15:30 Continue discussion on modeling results and deliverables by each partner

16:00-16:30 Coffee break

15:30 – 18:00 Discussion on final report: templates for each Task and timeframe

Thursday 10th January

WP3 GIS Viewer

9:00-13:00 Detailed presentation of the GIS viewer regarding input from each Task and in terms of project deliverables. Discussion on common formatting and presentation needs within the viewer. Discussion on queries to include in the GIS viewer.

13:00 – 14:30 Lunch break

14:30 – 16:00 General discussion, Overall Briefing, 10 minutes presentations from Task leaders summarising work done (if necessary).

16:00-16:30 Coffee Break

	Tue 8/1	**Wed 9/1**	**Thu 10/1**
Morning	WP1 9h15-13h	WP2, Task 2.2 9h15-13h	WP3 9h-13h
Afternoon	WP1 14h30-15h30 WP2, Task 2.1 15h30-18h	WP2, Task 2.2 14h30-15h30 Plenary 15h30-18h	Plenary 14h30-16h

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Annex IV

List of abbreviations mentioned in the report

AIS	Atlantic Ionian Stream
APA	Archaeological Protection Area
CHAID	CHi-squared Automatic Interaction Detection
CIBM	Centro Interuniversitario di Biologia Marina ed Ecologia Applicata "Guido Bacci" , Consortium of 6 Universities and the Municipality of Livorno
CNR-IAMC	Consiglio Nazionale delle Ricerche, Instituto per l' Ambiente Marino Costiero
CNR-ISMAR	Consiglio Nazionale delle Ricerche, Instituto di Scienze Marine
COISPA	COISPA, Tecnologia and Ricerca, Stazione Sperimentale per lo Studio delle Risorse del Mare
CoNISMa	Consorzio Nazionale Interuniversitario per le Scienze del Mare
COZIGAM	Zero-Inflated Generalized Additive Models
CRT	Classification and Regression Trees
DCF	Data Collection Framework
DG	Directorate General
EC	European Council
EDSU	Elementary Distance Sampling Unit
EEA	European Environmental Agency
EFH	Essential Fish Habitat
EFZ	Excusive Fisheries Zone
EMODNET	European Marine Observation Data Network
EU	European Union
FMZ	Fisheries Management Zone
FP	Framework Programme
FRA	Fishery Closure Area or Fisheries Restricted Area defined as a fishery closed or restricted by a government entity or a regional authority. A Fisheries Restricted Area is an area closed to fishing permanently, temporary or seasonally and this closure may apply to one or more gears. (http://www.protectplanetocean.org/introduction/introbox/glossary/glossary/introduction-item.html#mpa)
GAM	Generalised Additive Models
GEF	Global Environment Facility
GIS	Geographic Information Systems
GSA	Geographical Sub-Area amending the Resolution GFCM/31/2007/2
GSHHS	Global Self-consistent, Hierarchical, High-resolution Shoreline Database
GSI	GonadoSomatic Index
HCMR	Hellenic Centre for Marine Research

IBA	Important Bird Area
IEO	Instituto Espanol De Oceanografia
Ifremer	Institute Francais de Recherche pour l' Exploration de la Mer
INSPIRE	Infrastructure for Spatial Information in the European Community
ISF	Ionian Slope Front
IUCN	International Union for Conservation of Nature
MAP	Mediterranean Action Plan
MAREA	Mediterranean hAlieutic Resources Evaluation and Advice
FCD (MSDEC)	Ministry for Resources and Rural Affair, Fisheries Research Unit (Malta)
MEDISEH	MEDIterranean SEnsitive Habitats
MEDITS	Mediterranean Trawl Survey
MedPan	Network of Managers of Marine Protected Areas in the Mediterranean
MLIW	Modified Levantine Intermediate Waters
MPA	Marine Protected Area
MR-MPA	Marine Reserve - Marine Protected Area
NFP	National Focal Points
NGO	Non Governmental Organisation
TL	Total (body) Length
TOR	Terms Of Reference
RAC/SPA	Regional Activity Centre for Specially Protected Areas
ROV	Remotely Operated Vehicle
S-MAP	Sanctuary Marine Protected Area
SEPA	Special Environmental Protected Areas
SFM	Size at First Maturity
SPAMI	Specially Protected Areas of Mediterranean Importance
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
UNEP	United Nations Environment Programme
WACC	Western Adriatic Coastal Current
WDPA	World Database on Protected Areas
WP	Work Package
ZTB	Zona di Tutela Biologica

Annex V

Kick off MEDISEH meeting minutes

Available at the MAREA ftp under http://mareaproject.net/FTPMareaProject/#1/Specific Projects/Specific Project 2 MEDISEH/ final report/ documentation for the Commission

Annex VI

2nd MEDISEH meeting minutes

Available at the MAREA ftp under http://mareaproject.net/FTPMareaProject/#1/Specific Projects/Specific Project 2 MEDISEH/ final report/ documentation for the Commission

Annex VII

3rd MEDISEH meeting minutes

Available at the MAREA ftp under http://mareaproject.net/FTPMareaProject/#1/Specific Projects/Specific Project 2 MEDISEH/ final report/ documentation for the Commission

Annex VIII

4th MEDISEH meeting minutes

Available at the MAREA ftp under http://mareaproject.net/FTPMareaProject/#1/Specific Projects/Specific Project 2 MEDISEH/ final report/ documentation for the Commission

Deliverables and Milestones description and location

Annex 1.1.1

D1.1.1	Georeference database covering all revised information on seagrass beds spatial distribution	Available in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#12/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission /wp1/task 1.1/ Annex 1.1.1/D 1.1.1 & 1.1.2 Database_Bibliographic references.xlsx
D1.1.2	Integrated maps presenting the known spatial distribution of Posidonia and other seagrass species across the Mediterranean	Description and comments can be found in the final report under Task 1.2 session

Associated Milestones:

M 1.1.1	Revision of existing information of past seagrass beds along the Mediterranean coast	Description and comments can be found in the final report under Task 1.1 session
M 1.1.2	Revision of existing information of current seagrass beds along the Mediterranean coast	Description and comments can be found in the final report under Task 1.1 session

Annex 1.1.2

D1.1.3	GIS compatible files	GIS compatible files in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#16/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission /wp1/task 1.1/Annex 1.1.2/

Associated milestone:

M 1.1.3	Production of GIS files indicating the position of past and current seagrass beds along the Mediterranean coast	GIS compatible files in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#16/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission /wp1/task 1.1/Annex 1.1.2/ Deliverable 1.1.3 shapefiles

Annex 1.2.1

D1.2.1	Georeference database covering all revised information on coralligenous beds spatial distribution	In the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#15/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.2/ Annex 1.2.1/Deliverables 1.2.1_1.2.2.xls
D1.2.2	Georeference database covering all revised information on maerl beds spatial distribution	In the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#15/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.2/ Annex 1.2.1/Deliverables 1.2.1_1.2.2.xls
D1.2.3	Integrated maps presenting the known spatial distribution of coralligenous habitats and maerl beds across the Mediterranean	Description and comments can be found in the final report under Task 1.2 session

Associated milestones and files

M 1.2.1	Revision of existing information of past coralligenous and maerl beds along the Mediterranean coast	Description and comments can be found in the final report under Task 1.2 session. See also http://mareaproject.net/FTPMareaProject/#15/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.2/ Annex 1.2.1/ Species list on coralligenous and maerl (Supplementary material) .xls
M 1.2.2	Revision of existing information of current coralligenous and maerl beds along the Mediterranean coast	Description and comments can be found in the final report under Task 1.2 session See also http://mareaproject.net/FTPMareaProject/#15/Specific Projects/Specific

		Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.2/ Annex 1.2.1/ Species list on coralligenous and maerl (Supplementary material) .xls

Annex 1.2.2

D1.2.4	GIS compatible files	In the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#18/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.2/ /Annex 1.2.2/Deliverable 1.2.4 shapefiles

Associated milestones

M 1.2.3	Production of GIS files indicating the position of past and current coralligenous and maerl beds along the Mediterranean coast	See http://mareaproject.net/FTPMareaProject/#15/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.2/ Annex 1.2.1/ Species list on coralligenous and maerl (Supplementary material) .xls GIS compatible files in the MAREA ftp folder http://mareaproject.net/FTPMareaProject/#18/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.2/ /Annex 1.2.2/Deliverable 1.2.4 shapefiles

Annex 1.3.1

D1.3.4	GIS files with the predicted habitat layers	GIS compatible files in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#21/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ /task1.3/Annex 1.3.1/ Deliverable 1.3.4 shapefiles

Associated deliverables also at:

D1.3.1	Habitat suitability models concerning Posidonia beds	Description and comments can be found in the final report under Task 1.3 session
D1.3.2	Habitat suitability models concerning coastal coralligenous beds	Description and comments can be found in the final report under Task 1.3 session
D1.3.3	Habitat suitability models concerning maerl beds	Description and comments can be found in the final report under Task 1.3 session

Annex 1.4.1

D1.4.1	Database with GIS information on existing MPAs	Available in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#22/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/task1.4/Annex 1.4.1/ Deliverable 141_142.xlsx Shapefiles are also available under in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#22/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.4/ Annex 1.4.1/ Deliverables 1.4.1 & 1.4.2 Shapefiles
D1.4.2	Database with GIS information on habitat areas subjected to particular protective fishing measures in the Mediterranean mainly enforced by national legislation	In the MAREA ftp folder http://mareaproject.net/FTPMareaProject/#22/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/task1.4/ Annex 1.4.1/ Deliverable 141_142.xlsx Shapefiles are also available under http://mareaproject.net/FTPMareaProject/#22/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp1/ task1.4/ Annex 1.4.1/ Deliverables 1.4.1 & 1.4.2 Shapefiles
D1.4.3	Report with a synthesis map reviewing the existing information on Mediterranean MPAs, results of WP1and proposed areas	Synthesis on the existing information on Mediterranean MPAs, results of WP1and proposed areas can be found in the report under Task 1.4 session

Annex 2.1.1

D2.1.1	Mean probability maps for nurseries and spawning grounds at a regional and wider spatial scale e.g. the Mediterranean level	GIS compatible files in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#23/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp2/task 2.1/Annex 2.1.1/Deliverable 2.1.1 (Mean probability maps shp files)

Associated milestones

M 2.1.1	Revision on existing information on spawning and juvenile grounds of the target small pelagic species (i.e., ***Engraulis encrasicolus, Sardina pilchardus, Scomber spp., Trachurus trachurus***) all over the Mediterranean basin	Short description and comments can also be found in the final report under Task 2.1 and each target species section Details on M 2.1.1 can be found in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#24/Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.1/Annex 2.1.1/Milestone 2.1.1.doc Associated shp files can be found in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#24/Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.1/Annex 2.1.1
M 2.1.2	Analysis of survey data concerning the target small pelagic species in order to identify juveniles and spawners in a standardized way. Collection of environmental data. Standardization of environmental data layers. Data transformation for modeling	Details on M 2.1.2 can be found in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#29/Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.1 /Annex 2.1.2/Milestone 2.1.2/ Milestone 2.1.2.doc The analysis applied for each target species and the environmental data used is described in the final report under Task 2.1 and each target species

		section
M 2.1.3	Species distribution modeling of juvenile and spawning grounds for target small pelagic species. Model fitting and validation	Models applied, fitting and validation is described in the final report under Task 2.1 and each target species section
M 2.1.4	Production of annual maps (i.e., probability maps for nurseries and spawning grounds at a regional and Mediterranean level), estimation of mean probability and persistence maps for target small pelagic species. Production of GIS compatible files with the predicted habitat layers	GIS compatible files available in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#36/Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.1/ Annex 2.1.2/Milestone 2.1.4 (Annual maps shp files)
M2.1	Two days day workshop to take place following the kick off meeting of the project in order to standardize the work among the partners involved, determine the criteria/methods/approaches to discriminate nursery or spawning grounds and will produce specific outputs for the successive work, standardize input data format suitable for modelling as well as standardize modelling techniques to be applied	See Minutes of 1st MEDISEH Meeting under Annex I in the MAREA ftp under /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission
M2.2	One and a half day workshop to define spatial modelling techniques and environmental variables to be examined depending on data availability	See Minutes of 2nd MEDISEH Meeting under Annex II in the MAREA ftp /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission
M2.3	One day workshop to evaluate spatial modelling results before submitted to the GIS tool.	See Minutes of 3nd and 4th MEDISEH Meeting under Annex III and IV in the MAREA ftp /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission

Annex 2.1.2

D2.1.2	Persistence maps of the potential spawning and juvenile habitat of the Mediterranean basin	GIS compatible files in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#7/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp2/task 2.1/ Annex 2.1.2/Deliverable 2.1.2 (persistent maps shp files) In addition a description and comments can be found in the report under Task 2.1 session
D2.1.3	Environmental features of nursery and spawning grounds of the target species	Description and comments can be found in the report under Task 2.1 session per target species and life stage

Annex 2.1.3

D2.1.4	Maps presenting the persistent spawning and nursery grounds of the target small pelagic species along with the locations of protected habitats	A short description and comments can be found in the report under Task 2.1 session GIS compatible files in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#35/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/ wp2/task 2.1/Annex 2.1.3/Deliverable 2.1.4 (Overlapping maps shp files)

Annex 2.2.1

D2.2.1	Annual distribution maps of nursery and spawning grounds of target species indicating density hot spots areas	A short description and comments can be found in the report under Task 2.2 session per species/life stage/GSA GIS compatible files per GSA available in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#26/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp2/task 2.2/Annex 2.2.1/D 2.2.1 annual hot spot maps.

Associated milestones

M2.2.1	Revision on existing information on spawning and juvenile grounds of target demersal species (i.e., ***Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris**, **Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa)*** all over the Mediterranean basin. Collection and standardization of trawl survey data. Database compilation	-Description and comments can be found in the final report under Task 2.2 session. -Details on M2.2.1 can be found in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#37/Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.2/ Annex 2.2.1 Revision of existing information
M2.2.2	Updating of the already existing information about the distribution of nurseries and spawning grounds for (i.e., ***Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris**, **Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa)***. Analysis of survey data concerning the target species in order to identify juveniles and spawners in a standardized way i.e. R scripts will be developed in order to: 1) allocate specimens based on length and maturity and 2) standardize the distribution of the	-Description and comments can be found in the final report under Task 2.2 session. -Description of the identification of common approaches for the spatial analysis of data in Annex I of the final report. -R scipts description is available in Annex II of the final report. Scripts are available in the MAREA ftp folder

	density indices in order to identify the occurrence of "major areas of nursery and spawning aggregations	under http://mareaproject.net/FTPMareaProject/#38/Specific Projects/ Specific Project 2 MEDISEH/final report/ documentation for the Commission/ Scripts -Description of the available information on recruitment and spawning processes of demersal target species are available at http:/mareaproject.net/FTPMareaProject/#1/ /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.2/Supplementary material/Suppl 2.2.1/ Suppl 2.2.1 (M 2.2.2).docx -Spatial analyses description per species/life stage/GSA are available at http:/mareaproject.net/FTPMareaProject/#1/ /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.2/Supplementary material/ Suppl 2.2.2/ Suppl 2.2.2 (M 2.2.2).docx -Bubble plots of density indices of Medits for recruits and spawners of demersal target species for the 1994-2010 are available at http:/mareaproject.net/FTPMareaProject/#1/ /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.2/Supplementary material/Suppl 2.2.3/ Suppl 2.2.3 (M 2.2.2).docx -Annual density hot spots of recruits and spawners of demersal target species are available at

		http:/mareaproject.net/FTPMareaProject/#1/ /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.2/Supplementary material/Suppl 2.2.4/ Suppl 2.2.4 (M 2.2.2).docx

Annex 2.2.2

D2.2.2	Maps indicating an index of persistency for density hot spots nursery and spawning grounds	GIS files compatible in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#25/Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.2/Annex 2.2.2/D2.2.2 maps indicating hot-spots persistence A short description and comments can be found in the report under Task 2.2 session per species/life stage/GSA
D2.2.3	Ecological characterisation of the indicated nursery and spawning grounds	Description in the final report under Task 2.2 session per species/life stage/ GSA

Associated milestone

M2.2.3	Development of spatial analysis using surveys indices of juveniles and spawners to identify density hot spots areas for ***Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris***, ***Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa***. Maps indicating the temporal persistency of these areas will also be produced. Analysis will be standardised by means of common R scripts and algorithms. Maps will be GIS compatible	Description and comments can be found in the final report under Task 2.2 session per GSA, species and life stage, R scipts description is available in Annex II of the final report. Scripts are available in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#38/Specific Projects/ Specific Project 2 MEDISEH/final report/ documentation for the Commission/ Scripts GIS files compatible in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#25/Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.2/Annex 2.2.2/D2.2.2 maps indicating hot-spots persistence Details on the surveys can be found in the MAREA ftp under http://mareaproject.net/FTPMareaProject/#10/Specific Projects/Specific

		Project 2 MEDISEH/final report/documentation for the Commission/wp2/task2.2/ Milestone 2.2.3 (Spatial analyses)
M2.2.4	Ecological characterization of density hot spots areas identified in task 2.2 upon data availability for ***Aristaeomorpha foliacea, Aristeus antennatus, Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Nephrops norvegicus, Parapenaeus longirostris***, ***Pagellus erythrinus, Galeus melastomus, Raja clavata, Illex coindetti, Eledone cirrosa***.	Description and comments can be found in the final report under Task 2.2 session per GSA, species and life stage.
M2.2.5	Report on the gaps in knowledge and in adequate survey data for the identification of spawning and nursery grounds for all target species at certain areas in the Mediterranean basin	Description and comments can be found in the final report under Task 2.1 and Task 2.2 respective session
M2.1	Two days day workshop to take place following the kick off meeting of the project in order to standardize the work among the partners involved, determine the criteria/methods/approaches to discriminate nursery or spawning grounds and will produce specific outputs for the successive work, standardize input data format suitable for modelling as well as standardize modelling techniques to be applied	See Minutes of 1st MEDISEH Meeting under Annex I in the MAREA ftp under /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission
M2.2	One and a half day workshop to define spatial modelling techniques and environmental variables to be examined depending on data availability	See Minutes of 2nd MEDISEH Meeting under Annex II in the MAREA ftp /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission
M2.3	One day workshop to evaluate spatial modelling results before submitted to the GIS tool.	See Minutes of 3nd and 4th MEDISEH Meeting under Annex III and IV in the MAREA ftp /Specific Projects/Specific Project 2 MEDISEH/final report/documentation for the Commission

Annex 3.1

D3.1.2	Web-based GIS data Viewer and maps derived from WP1, WP2	Description in the final report under WP3 session/ a link to viewer at http://mareaproject.net/mediseh/viewer/med.html BaseMap data available in the MAREA ftp folder under http://mareaproject.net/FTPMareaProject/#11/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/wp3/Annex 3.1

See also associated deliverables at:

D3.1.1	Framework for a common GIS database	Description in the final report under WP3 session

Associated milestones:

M3.1.1	Development of common protocol for data standardization, classification, presentation and analysis addressing data of WP1 and WP2	Description and comments can be found in the final report under WP3
M3.2.1	One online GIS seminar on data GIS transformation and GIS mapping tools	Description and comments can be found in the final report under WP3 / link at http://arch.her.hcmr.gr/mediseh/eowebsem/
M3.2.2	Export and standardization of satellite environmental data to be used for modelling mainly within Tasks 1.3 and 2.1	Description and comments can be found in the final report under WP3
M3.3.1	A 1 day workshop to be organised in the framework of this WP order to standardize habitat modelling results for input into GIS systems	See Minutes of 1st MEDISEH Meeting (Annex I)

Annex 3.2

D3.1.3	Synthesis maps presenting the persistent spawning and nursery grounds of the target small pelagic and demersal species along with the locations of protected habitats	GIS compatible files in the MAREA ftp folder http://mareaproject.net/FTPMareaProject/#41/Specific Projects/Specific Project 2 MEDISEH/final report/ documentation for the Commission/ wp3/Annex 3.2/D3.1.3 In addition a short description can be found in the report under WP3 session

Associated milestones:

M3.3.2	Development of GIS database to store the results of WP1 and WP2	Description and comments can be found in the final report under WP3/ a link to the geoserver at http://server.orbisnetwork.net:8080/geoserver/wms?request=GetCapabilities&service=WMS&version=1.0.0
M3.4.1	Development of an online GIS data viewer to facilitate the inspection of project results and provide an integrated picture of sensitive habitats related to fisheries within the Mediterranean basin	A link to viewer at http://mareaproject.net/mediseh/viewer/med.html