



Original Article

Historical discarding in Mediterranean fisheries: a fishers' perception

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Damalas, D., Maravelias, C. D., Osio, G. C., Maynou, F., Sbrana, M., Sartor, P., and Casey, J. Historical discarding in Mediterranean fisheries: a fishers' perception. – ICES Journal of Marine Science, 72: 2600–2608.

Received 21 October 2014; revised 12 July 2015; accepted 17 July 2015; advance access publication 12 August 2015.

Discarding of commercially important fish species in the bottom trawl fisheries in the northern Mediterranean Sea was investigated by soliciting the long-term recollections of fishers engaged or formerly engaged in such fisheries. The main aim of our investigation was to describe the prevalence of discarding and its evolution over the past 70 years using information gathered through individual questionnaire-based interviews with fishers from ports in Spain, Italy, and Greece, following a standardized sampling protocol. Although it proved impossible to derive absolute estimates of the volume of discarded catches over the period investigated, we conclude that over the past 70 years, discarding as a practice has gradually increased in the northern Mediterranean trawl fisheries and has been accompanied by a shift in the species composition of the discarded catch. While discarding can occur for a number of reasons, our investigations indicate that discarding in the past was mostly driven by market demand, but recent legal and regulatory constraints have led to changes in fishing strategies and became a significant reason for discards.

Keywords: discards, landing obligation, Mediterranean, minimum landing size, trawl.

Introduction

Discards constitute that portion of the catch, which for whatever reason, is not retained on board during fishing operations and which is returned to the sea. Discards may constitute a large proportion of the total catch (Alverson *et al.*, 1994) and may include species that have or do not have any commercial value. The most recent estimate indicates that worldwide, over the period 1992–2001, ~7.3 million tonnes of organic material of animal origin were discarded annually, representing ~8% of the annual global catch (Kelleher, 2005). For the Mediterranean Sea, the most recent estimate of discards is on average around 230 000 tonnes annually or 18.6% of the average annual catches (Tsagarakis *et al.*, 2013). The reasons for discarding are numerous and include legal [e.g. species smaller than the minimum legal size (MLS), catches exceeding quotas,

etc.], economic (low market value and highgrading), technical (e.g. characteristics of fishing gears and vessel hold capacity), biological (e.g. species composition and recruitment period), and environmental aspects (e.g. weather conditions affecting sorting practices) (Alverson *et al.*, 1994; Stratoudakis *et al.*, 1998; Rochet and Trenkel, 2005; Tsagarakis *et al.*, 2013).

Despite the introduction of technical and tactical measures to reduce unwanted bycatch (STECF, 2013), discarding has remained prevalent in many EU fisheries for decades. While the term discarding may have different interpretations, in this study, we refer to discarding as the unwanted fraction of the catch of species of commercial value discarded from bottom trawl fisheries. In semi-industrial fisheries (purse-seine and otter trawl), discarding is mainly due to market reasons, for example in periods when

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catches exceed market demand thereby driving down fish prices (Leonart and Maynou, 2003). In small-scale fisheries (fishing vessels <12 m not using a towed gear—EC, 2006), spoiled and damaged specimens are also routinely discarded. In recent years, increased enforcement of minimum landing size regulations has also led to an increase in discarding of undersized commercially important species, such as hake (*Merluccius merluccius*) and sardine (*Sardina pilchardus*). Discarding may have important consequences for the ecological functioning of marine ecosystems. There are indications that discarding has altered the ecosystem functioning of some seabird communities and has negative effects on charismatic and endangered species (Alverson *et al.*, 1994). Discarding has been practised for as long as fishing has taken place. There are early accounts of high discarding in the 18th century Mediterranean sail pair trawl fishery (Osio, 2012). However, for the period before the 1980s, very little information is available (Kelleher, 2005).

The absence or scarcity of discard information compromises the stock assessment process, and can result in inaccurate estimates of fishing mortality, which in turn can affect the quality of scientific advice (Diamond and Beukers-Stewart, 2011). In general, reducing or eliminating discards is most complex in mixed-species demersal trawl fisheries where discard mitigation measures are difficult to develop and implement. On average, most of the discards in the Mediterranean Sea (>35% by weight of the total catch) are attributable to such fisheries (Tsagarakis *et al.*, 2013). It has been argued that as a consequence of changes in market demand for smaller sizes of certain species (the so-called poor fish, previously kept for fisher's own consumption) by local consumers and tourists, discarding practices aboard trawlers fishing in the Mediterranean have also changed over time (Sacchi, 2008). Strengthening of monitoring, control, and surveillance to enforce established minimum landing sizes may have also been a significant driver for discarding (Borges, 2015).

Sampling programmes to estimate discards are a relatively recent innovation and most cover only relatively short time-series. In the EU Mediterranean waters, monitoring of discards has only been regularly undertaken since 2002 within the framework of the EU data collection programmes (DCF EU Regulation 199/2008; formerly DCR EU Regulation 1543/2000). Consequently, historical data on discarding are scarce. In an attempt to gain an understanding of how discarding in Mediterranean fisheries has evolved over time, we employed techniques that make use of Local and Traditional Knowledge (Neis *et al.*, 1999; Lavidés *et al.*, 2010; Thornton and Maciejewski Scheer, 2012) and Traditional Ecological Knowledge (Sáenz-Arroyo *et al.*, 2005). Such approaches make use of fishers' life-long experiences observing the marine system and with appropriate scientific analysis, have the potential to detect changes over several decades. Our approach was to solicit the long-term recollections of fishers from ports in Spain, Italy, and Greece, using information gathered through individual questionnaire-based interviews following a standardized sampling protocol. The main focus of our research was to describe the historical prevalence and evolution of discarding of commercially valuable fish species in the northern Mediterranean bottom trawl fisheries over the past 70 years.

It must be emphasized to note that we have not attempted to derive quantitative historical estimates of the absolute volume of fish discarded. While interviewees were able to recollect how much fish they had landed in the past, they were unable to recall the volumes (weight or numbers) of fish that had been discarded. Hence, the trends in discarding we discuss relate to (i) the total

number of fishers reporting discards and (ii) the species composition of discards. The geographical and temporal dynamics underlying the resulting trends are also discussed.

Material and methods

Historical information on discarding was gathered by individual questionnaire-based interviews following a standardized sampling protocol with fishers from ports on the Catalan Sea (Spain), Ligurian, Tyrrhenian and central Adriatic Seas (Italy), and the Ionian and Aegean Seas (Greece; Figure 1). The sampling protocol is the one officially adopted as part of a CIESM international basin-wide monitoring programme (Azzurro *et al.*, 2011). A similar version has been also employed in the FP 6 AFRAME Project (Wilson and Becker-Jacobsen, 2009). Interviews were carried out during 2009 and 2010, and the questionnaire was designed to elicit information relating to vessels, fishing gears deployed, fishing practices (duration of fishing trips, on-board activity, etc.), location of main fishing grounds, main target species, estimation of catches (the usual catch, memories of exceptional captures, sizes of specimen caught, etc.), and species composition of discards. The choice of interview localities in each country was based on: (i) the national importance of the local fisheries in terms of total production, number of crew, and full time equivalent; (ii) the historical context; the existence of experienced/retired skippers to interview, and (iii) the existence of a mutually respectful relationship between the local fishing associations/individual fishers and the researchers. In total, 96 elderly or retired trawler fishers (50 Italians, 23 Spanish, and 23 Greeks) from 26 different fishing ports provided responses covering almost 80 years of observations. Interviewees had a median age of 70 years. The median year in which individuals commenced fishing activities was 1955, although some individuals commenced fishing as early as 1932. All potential interviewees willingly agreed to participate in the survey and several were very enthusiastic. Details of the protocol followed and the structure of the questionnaires are available in Sartor (2011) and Damalas *et al.* (2015) who carried out an integral study of fishers' perceptions during the 20th century. The results presented here are based on a subset of the information collected therein and which related solely to discarding. Such information relates to: three periods (1940–1959, 1960–1979, and 1980–2008), commercial species/taxon discarded, reasons for discarding, and details of fishing operations.

The accuracy of recollections about past experiences will always be susceptible to the limitations of the individual's memory (Bradburn *et al.*, 1987). Such recollections depending entirely on memory can often be imperfect and thereby unreliable (Hassan, 2006). This systematic error is referred as "Recall bias" and is caused by differences in the accuracy or completeness of the recollections retrieved by study participants regarding events or experiences from the past. To avoid or minimize recall bias, a number of methodological approaches have been suggested (Sabatella and Franquesa, 2003; Hassan, 2006). How we applied some of these methodological approaches is described in Supplementary Appendix.

Statistical analyses

All taxa reported as discards during each interview were structured in a presence/absence matrix, interviews being the samples (rows), and taxa the variables (columns). Each sample was accompanied by the following corresponding factors: Country, geographical area fished, period, minimum, maximum, and average depths fished. Temporal differences in the presence or absence of discarding of

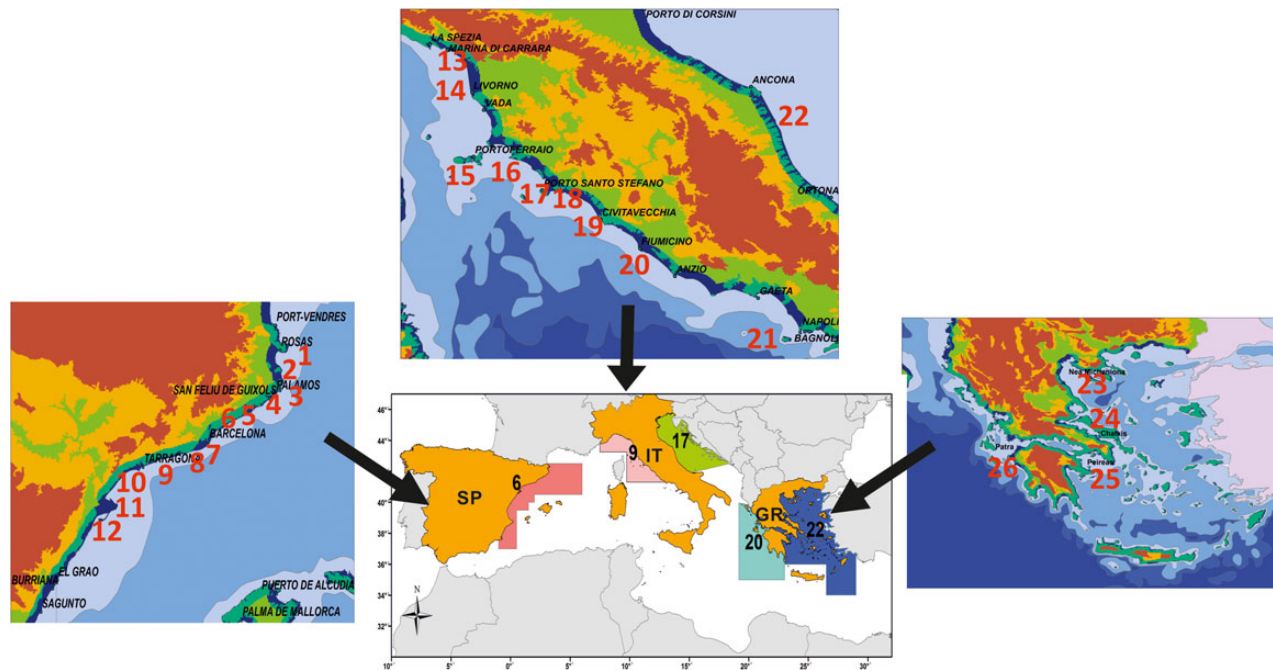


Figure 1. Map showing the ports and geographical subareas (GSAs) where the interviews with the fishers were carried out. Spain (GSA 6): 1: Port de la Selva; 2: Roses; 3: Palamos; 4: Blanes; 5: Arenys de Mar; 6: Mataro; 7: Barcelona; 8: Vilanova i la Geltrú; 9: Tarragona; 10: Cambrils; 11: L'Ametlla de Mar; 12: San Carles de la Rapita; Italy (GSAs 9 and 17): 13: Viareggio; 14: Livorno; 15: Elba Island; 16: Castiglione della Pescaia; 17: Porto Santo Stefano; 18: Porto Ercole; 19: Civitavecchia; 20: Fiumicino; 21: Ponza Island; 22: Civitanova Marche; Greece (GSAs 20 and 22): 23: Nea Michaniona; 24: Chalkis; 25: Peireas; 26: Patra. Country maps. Source: European Environmental Agency - Data and Maps. (<http://www.eea.europa.eu/data-and-maps/data/elevation-breakdown>).

each taxon between regions were investigated by non-parametric multivariate permutational analysis of variance (PERMANOVA; Anderson, 2001). Similarity Percentages Procedure (SIMPER; Clarke, 1993) identified the taxa that characterized discarding practices in each period. Visualization of geographical patterns in discarding was realized through non-metric multi-dimensional scaling (nMDS) ordination.

To understand the changes in the presence/absence of species in the reported discards, the species composition of discards in each period was compared with the species composition of the reported landings for the equivalent period. From such a comparison, it is possible to see whether the absence of a species from the reported discards is because that species was not caught at all in the period concerned, or that all catches of that species were landed. After carrying out such a comparison using data from Maynou *et al.* (2011) and Damalas *et al.* (2015), it was apparent that one species, *Gadiculus argenteus* (silvery pout), was discarded in the recent (1980–2008) period but not in earlier periods; this was due to the fact that before 1980, *G. argenteus* was never caught. Furthermore, since 1980, all catches of *G. argenteus* have been discarded. *Gadiculus argenteus* was therefore excluded from the analysis on the grounds that its appearance in the reported discards in the recent period did not signify any change in discarding practice. The comparison also confirmed that other species for which there were no discards reported in any of the periods were caught and landed.

Finally, to ensure that “suspicious observations” or “potential outliers” did not influence the results, taxa reported less than three times were eliminated from the statistical analyses (R library

Table 1. Proportion (%) of interviewees reporting discarding, as usual practice, by period and country (total numbers of interviewees are given in parentheses).

Period	Greece	Italy	Spain	Average ^a
1940–1959	29 (14)	58 (26)	43 (14)	47
1960–1979	36 (22)	55 (47)	70 (23)	54
1980–2008	35 (23)	83 (48)	91 (11)	71
Average ^a	34	67	67	58

^aAverage is weighted arithmetic mean.

vegan—Community Ecology Package ver. 2.0-10). The rationale for doing so is statistically valid and is explained in Barnett and Lewis (1994).

Results

Table 1 summarizes, by period and country, the proportion of fishers for whom discarding was normal practice. The results indicate an overall increase in the prevalence of discarding expressed as the proportion of fishers reporting discarding over time (Table 1). Such an increase is particularly striking in the responses from Spanish fishers, which indicate that in the 1940s and 1950s, the most trawler skippers (57%) did not discard, whereas in the most recent period (1980–2008) 9 out of 10 did so routinely. The responses from Italian fishers show a similar trend with a marked increase in the prevalence of discarding, especially in the most recent period. The information collected from interviews with Greek fishers indicated that the increase in discarding in the bottom

trawl fisheries in the Ionian and Aegean Seas has been much less. In all countries, the main reason for discarding was attributed to “non-marketable” (low value) species (Table 2). The second most important reason for discarding was attributed to “damaged” specimens in all areas for the earlier periods. In the most recent period, discarding of damaged specimens in all fisheries is reported to have decreased and to no longer take place in the Spanish bottom trawl fisheries in the Catalan Sea. Although negligible in the past, discarding for “other” reasons is reported to have increased significantly during the period 1980–2008 in the Italian and Spanish fisheries.

The responses from fishers in relation to which species have been discarded indicate that over the entire period of the study, a total of 36 species/taxa have been subject to discarding (Figure 2). Eleven species/taxa were mentioned by > 10 interviewees; the three most common being European hake (*M. merluccius*), horse mackerels (*Trachurus* spp.), and bogue (*Boops boops*). More than half of the species/taxa reported as discards were discarded throughout all periods (Figure 2). A comparison of the responses from interviewees for the different periods clearly indicates that there was a marked increase in the prevalence of discarding between the early (1940–1959) and subsequent periods (1960–1979 and 1980–2008). In terms of the species composition of the discards in different periods, some notable changes can be identified. For example, it appears that anglerfish were discarded by more fishers in the past compared with the most recent period, whereas the converse is true for red mullet. Sardines are reported to have been discarded by more fishers during the 1960s and 1970s than in the previous or subsequent periods.

The PERMANOVA indicated that discarding practices differed significantly by country and period (Table 3). nMDS ordinations, visualizing the level of similarity of the individual cases in our dataset, demonstrated the geographical structure of discards' species composition during the three periods (1940–1959, 1960–1979, and 1980–2008; Figure 3). The results of the SIMPER analysis (Table 4) classified each period according to the discard species' composition. It also gave the percentage contribution of each species that explains the classifications expressed from highest to lowest. The cumulative percentage contribution indicates which species explain *n*% of the resulting classifications. Furthermore, the overall percentage dissimilarity between periods was estimated from pairwise comparisons. The results for each period are given below.

1940–1959

In total, 21 species/taxa were reported to have been discarded. The most frequently reported included some of the most valuable commercial species, such as European hake. The nMDS ordination plot (Figure 3, top), suggests almost complete separation between the three countries, indicating a very dissimilar composition of discards. The SIMPER analysis (Table 4), when sorting species/taxa in a decreasing order of importance, indicated that discarding

practices in the three countries during the 1940s–1950s were characterized largely by Norway lobster, Mediterranean parrotfish, various rays, red mullets, and blue and red shrimps.

1960–1979

Compared with the 1940s–1950s, an increase in the number of species/taxa discarded was reported for the period 1960–1979 (28 species/taxa). The nMDS ordination plot (Figure 3, middle) indicates a partial overlap between countries; however, it is evident that discarding practices in the different countries remained rather distinct. As indicated by SIMPER analysis (Table 4), the species that characterize discards in the three countries during the 1960s and 1970s were various rays, various sea breams, blue and red shrimps, silver scabbardfish, and anchovy.

1980–2008

The results indicate that 29 different species/taxa were discarded during the period 1980–2008. The nMDS ordination plot (Figure 3, bottom) indicates significant overlap between all countries, implying that discarding practices in the fisheries in the different regions in terms of the species, being discarded at that time, were more similar than hitherto. The SIMPER analysis (Table 4) indicates that the five most important species that characterize the three regions during this period were picarel, poor cod, red mullet, horse mackerels, and European hake. As mentioned earlier, silvery pout, a species frequently discarded during 1980–2008, was excluded from the SIMPER analysis since it was not reported as being caught in earlier periods and no evaluation of discarding trend was possible. Silvery pout was the only species in the dataset showing such an inconsistency.

Discussion

From an ethical point of view, discards can be considered as a waste of natural resources and from an ecological perspective they impact the marine ecosystem in various ways (Diamond and Beukers-Stewart, 2011). Discards are also considered to be inconsistent with responsible fishing (Bellido *et al.*, 2011). Seen from the perspective of fishery managers, discards pose a huge problem to solve and a balance needs to be found between improving fleet selectivity by minimizing unwanted catches and bring an end to a wasteful practice, while ensuring profitability and well-being of the fishing sector (Bellido Millán *et al.*, 2014). From a fishers' standpoint, discards constitute a burden and incur increased costs in terms of both time and money (Macher, 2008). In recent years, the desire to find solutions to reduce or eliminate discards in marine fisheries has become of major concern to conservation organizations and the wider public (Catchpole and Gray, 2010). Such a desire has been instrumental in the adoption of the obligation to land all catches (of species subjected to quota or minimum landing size) enshrined in Article 15 of the 2013 reform of the EU Common Fisheries Policy (EU, 2013), which aspires to gradually phase out discards by 2019.

Table 2. Reasons for discarding by period and country (numbers of interviewees giving this response are given in parentheses).

Reason for discarding (in %)	1940–1959			1960–1979			1980–2008			Overall
	GRC	ITA	SPN	GRC	ITA	SPN	GRC	ITA	SPN	
Damaged specimens	25 (1)	38 (9)	14 (1)	12 (1)	34 (13)	18 (3)	12 (1)	7 (3)	0 (0)	21
Non-marketable species	75 (3)	62 (15)	86 (6)	88 (7)	66 (25)	47 (8)	88 (7)	81 (33)	50 (5)	69
Other (MLS, handling costs)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	35 (6)	0 (0)	12 (5)	50 (5)	10

MLS: minimum landing size; GRC: Greece; ITA: Italy; SPN: Spain.

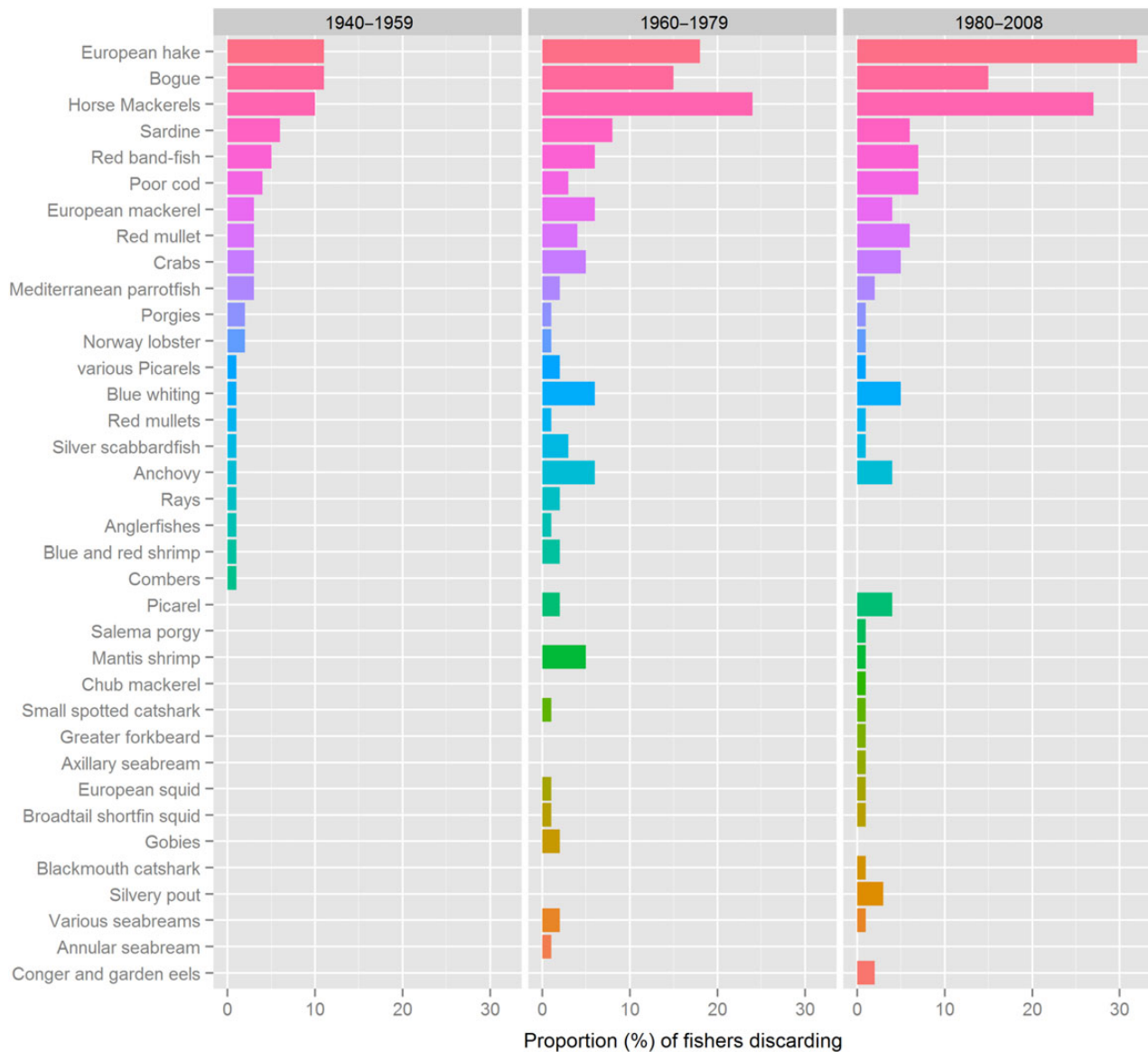


Figure 2. Proportion (%) of fishers discarding by species/taxon and period in the Mediterranean bottom trawl fisheries during 1940–2008.

Table 3. Results of the PERMANOVA.

	d.f.	Sums of Sqs	MeanSqs	F model	R ²	Pr (>F)
Country	2	3.521	1.76039	5.7903	0.08264	0.001
Period	2	1.078	0.53916	1.7734	0.02531	0.045
Residuals	125	38.003	0.30402	0.89204		
Total	129	42.602	1			

Sqs, squares; MeanSqs, mean squares.

Based on information gathered through structured interviews with individuals with long-term experience, we conclude that discarding in the northern Mediterranean bottom trawl fisheries has increased over the past 70 years, both in terms of the proportion of interviewees reporting that discarding took place and in the number of species/taxa being discarded. There are many potential factors that could have led to such an increase including inter alia increase in fishing power, changes in market demand for different species, changes in environmental conditions affecting fish community

structure, progressive introduction of regulatory measures, and changes in the selectivity of fishing gears.

Promoted by increases in engine power, during the past century, the range of fishing activities extended from coastal/shelf areas to deeper waters offshore and at the same time improvements to the design of fishing gears took place (Osio, 2012). Such factors have affected catchability and selectivity patterns (Sartor, 2011). The emergence of silvery pout in the catches after the early 1980s reflects the expansion of fishing activity to offshore deep-water areas. Silvery pout is a species that inhabits depths between 100 and 1000 m; in the Mediterranean Sea, its highest abundance is typically at depths greater than 200 m (Damalas et al., 2010).

Discarding patterns also seem to be depth-dependent and there are several studies indicating that discarding increases with increasing fishing depth (Machias et al., 2001; D'Onghia et al., 2003). One of the few deep-sea trawl fisheries in the Mediterranean (deep-sea crustacean fishery) is often characterized by high discards (e.g. Castriota et al., 2001). Furthermore, the recent regulation (EU,

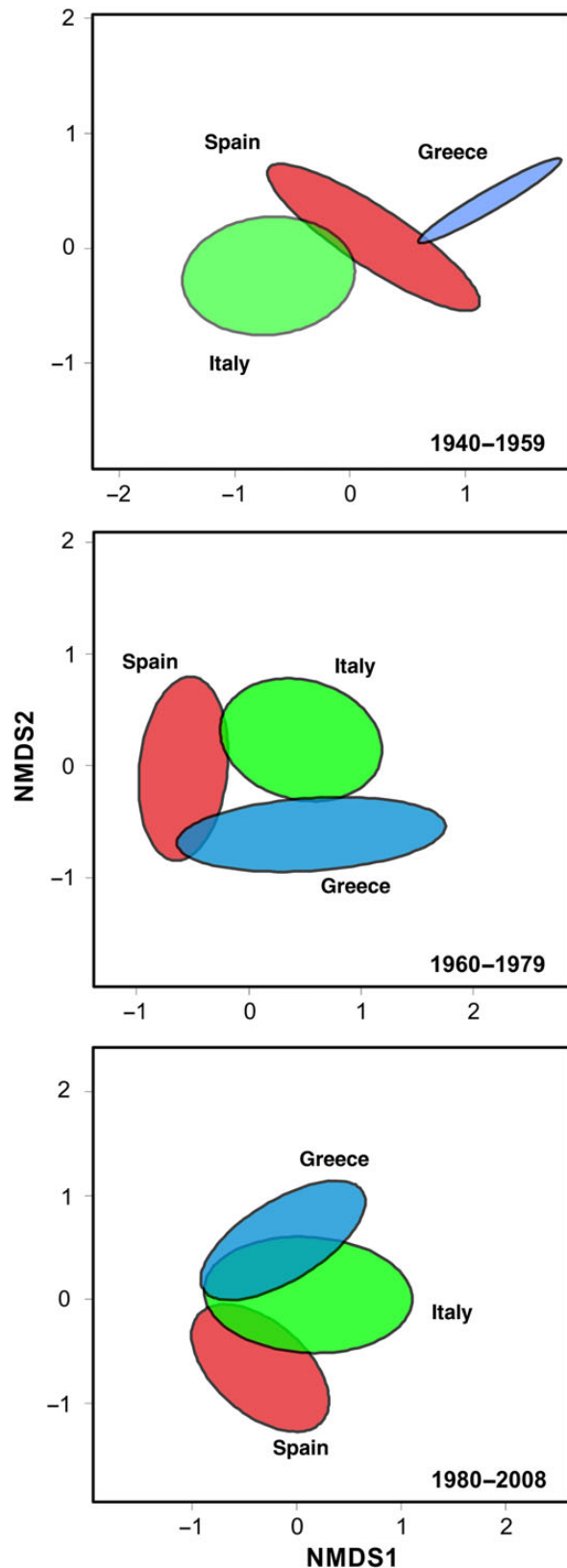


Figure 3. nMDS ordination comparing discarding by species/taxon across the different regions (country).

Table 4. Discarding: most important species/taxa typifying each period as suggested by SIMPER analysis.

Period	Taxon	Contribution (%)	Cumulative (%)	
1940–1959	<i>Nephrops norvegicus</i>	9.44	9.4	
	<i>Sparisoma cretense</i>	7.93	17.4	
	<i>Raja</i> spp.	6.51	23.9	
	<i>Mullus</i> spp.	6.51	30.4	
	<i>Aristeus antennatus</i>	6.51	36.9	
	<i>Sardina pilchardus</i>	5.36	42.3	
	<i>Trisopterus minutus capelanus</i>	5.35	47.6	
	<i>Cepola rubescens</i>	5.13	52.7	
	1960–1979	<i>Raja</i> spp.	6.71	6.7
		<i>Diplodus</i> spp.	6.71	13.4
<i>A. antennatus</i>		6.71	20.1	
<i>Lepidopus caudatus</i>		6.01	26.1	
<i>Engraulis encrasicolus</i>		5.36	31.5	
<i>Spicara</i> spp.		5.07	36.6	
Sparidae		5.07	41.6	
1980–2008	<i>Micromesistius poutassou</i>	4.96	46.6	
	<i>Spicara smaris</i>	8.26	8.26	
	<i>T. minutus capelanus</i>	6.24	14.50	
	<i>Mullus barbatus</i>	5.82	20.32	
	<i>Trachurus</i> spp.	5.49	25.81	
	<i>Merluccius merluccius</i>	5.39	31.20	
	<i>M. poutassou</i>	5.32	36.52	
	<i>C. rubescens</i>	5.02	41.54	

Species/taxa characterizing discarding practices in each period are ranked in a decreasing order of importance. Overall between group dissimilarities: "1940–1959" vs. "1960–1979" 79.28; "1940–1959" vs. "1980–2008" 76.24; "1960–1979" vs. "1980–2008" 76.71.

2011) specifying the permissible size and geometry of trawlnets was introduced with the specific aim to reduce discards (Bellido Millán *et al.*, 2014). However, Sala *et al.* (2015) after conducting a series of experimental gear trials argue that more sophisticated alternative gear designs may be needed to achieve the required selectivity changes to reduce discards.

In general, in Mediterranean fish markets, the first sale prices are not fixed and fluctuate according to market demand. The demand for quality fresh fish requires that storage on board needs to be limited to a maximum of 1 d. Moreover, nutritional habits, tastes, and culinary practices have changed in the last half century, largely altering market demand (Essid, 2012).

The attitudes of Mediterranean societies have also altered during the past century. In the period immediately following World War II, people would eat virtually anything brought to the market and hence, the prevalence of discarding was low at that time. It has also been demonstrated that increased per capita gross domestic product (GDP) leads to increased discarding. Wealthier societies also seem to be more selective in resource use, whereas in times of poverty more species and possibly wider size ranges are accepted and sold (Tsagarakis *et al.*, 2013). The differences in national GDPs (IMF, 2014) may also explain the generally lower levels of discarding observed in Greek fisheries, compared with fisheries in Italy and Spain.

The geographical distribution and timing of fishing in relation to the seasonal distribution of the life history stages of the populations

being exploited and the demand for different species and sizes can also influence discarding. Increased discarding has been associated with spawning periods (Tzanatos *et al.*, 2007) and time of recruitment (Sánchez *et al.*, 2004). Periods of low fishing activity have also been associated with an increase in discarding in the Adriatic and Catalan Seas (Sanchez *et al.*, 2007). Adverse weather conditions can also influence discarding. For instance, because of reduced catches as a result of periods of bad weather in the winter and concomitant increases in first sale prices, discarding is usually lower in winter than at other times of the year (Machias *et al.*, 2004). In addition, the availability of different species may also influence discarding and in one reported case, discards of Adriatic sardine were affected by the available size and quantity of anchovy (Santojanni *et al.*, 2005).

The introduction of regulatory measures to protect juveniles (MLS), without accompanying measures or changes in fishing tactics to avoid catching undersized individuals, has also meant that fishers must discard at sea, individuals that they formerly brought to the market. Most of the MLS restrictions were imposed with the implementation of the EU Common Fisheries Policy by the Mediterranean Member States and the first so-called Mediterranean Regulations (EC, 1994, 2006b). The list of species therein, regulated under an MLS, includes at least 10 of the species reported by the interviewees. Our results indicate that discarding of European hake, horse mackerel, and red mullet has increased during the most recent period (Figure 2) and there is evidence to indicate a change in fishers' behaviour in recent years. For example, in the northern Tyrrhenian Sea trawl fishery, the size at which 50% of hake specimens were landed increased from 10 to 11 cm total length (TL) in 1995–1998 (Sartor *et al.*, 2001) to ~18 cm TL in 2013 (De Ranieri, 2014). This may reflect increased compliance with the established minimum landing size (20 cm TL). Abella *et al.* (2005) demonstrated how the enforcement of control measures in the port of Viareggio (Southern Ligurian Sea—W. Mediterranean) has altered the size composition of landings due to a reduction of fishing pressure on hake nursery grounds. Eliassen *et al.* (2014), studying the factors affecting discard behaviour, concluded that the extent of control and enforcement exerted over a fishery was shown to influence fishers' behaviour and observed discard levels. On the other hand, while the introduction of MLSs is often stated as a reason for increased discarding, Mediterranean fisheries have a notorious reputation for their “culture of non-compliance”. Recent studies from Greece suggest that MLSs are largely ignored by the trawler skippers (Damalas and Vassilopoulou, 2013). Furthermore, the reformed EU Common Fisheries Policy regulation (EU, 2013) has identified costs of “handling unwanted catches” as a serious impediment; it is even foreseen that, under certain conditions, a fishery may be eligible for an exemption from the rule to land all catches. The technological developments in trawling have revolutionised trawling operations and many hauls can now be undertaken per day. This, together with the development of on-board refrigeration equipment, means that the quantity of daily catch that can be processed (sorted) and stored has increased dramatically; and so have the associated handling costs. This was confirmed by the interviewed fishers since handling costs as a cause of discarding have been reported only during the recent years.

The average codend mesh size of trawlnets has increased from less than 20 mm in the 1940s to greater than 40 mm currently. Doubling of mesh size should have resulted in more selective fishing and less discarding. However, from the fishers' responses, it can be deduced that selectivity has not improved.

Mediterranean fisheries are currently on the brink of a new era. After introducing almost a hundred technical measures regulations (or amendments) since the 1980s with the aim of improving selectivity and reducing discards (Santurtún *et al.*, 2014), the EU has eventually decided to follow a more aggressive approach in an attempt to solve the discard problem. The landings obligation (or “discard ban”) included under Article 15 of the new CFP basic regulation (EU, 2013) prohibits the discarding of species subject to catch limits (i.e. TAC and quota species) and those subject to minimum size limits in the Mediterranean Sea. Implementation of the landing obligation to different types of fisheries will be undertaken in stages according a timetable (2015–2019) based on “the species that define the fisheries”. Some concerns have already been expressed that due to the absence of catch quotas in the Mediterranean, the landing obligation may lead to an increase in the catch of undersized/juvenile individuals, which will not be counted against any quota (Bellido Millán *et al.*, 2014). Furthermore, transformation of such catches into fishmeal might make them a commercially attractive “target”. García-Rivera *et al.* (2015) investigated the effectiveness of the landings obligation in a Spanish Mediterranean port, and concluded that the landing obligation regulation has more weaknesses and threats (72.6%) than strengths and opportunities (27.4%). They argue that the measure may prove to be ineffective in the Mediterranean Sea resulting in a failure to reduce discards.

In summary, we conclude that over the past 70 years, discarding in the northern Mediterranean bottom trawl fisheries in the Catalan, Ligurian, Tyrrhenian, eastern Ionian, and Aegean Seas has increased. The observed increase has been accompanied by a change in the species composition of the discarded catches. Furthermore, discarding in the past was mostly driven by market demand, but recent legal and regulatory constraints have led to changes in fishing strategies and became a significant reason for discards.

Supplementary data

Supplementary material is available at the ICESJMS online version of the manuscript.

Acknowledgements

We warmly thank all fishers who dedicated valuable time to help us understand the evolution of Mediterranean fisheries in the second half of the 20th century. Special thanks to the three anonymous reviewers and the Editor for extensive corrections and suggestions that improved the manuscript significantly. Data acquisition was supported by the European Commission through the EU project EVOMED (“The 20th Century evolution of Mediterranean exploited demersal resources under increasing fishing disturbance and environmental change”). European Commission, Directorate-General for Maritime Affairs and Fisheries. Open Call for Tenders n° MARE/2008/11, Proposal for Lot 4, (Contract. N° SI2 539097).

References

- Abella, A., Serena, F., and Ria, M. 2005. Distributional response to variations in abundance over spatial and temporal scales for juveniles of European hake (*Merluccius merluccius*) in the Western Mediterranean Sea. Fisheries Research, 71: 295–310.
- Alverson, D. L., Freeberg, M. H., Murawaski, S. A., and Pope, J. G. 1994. A Global Assessment of Fisheries Bycatch and Discards. FAO Fisheries Technical Paper, No. 339. 235 pp.
- Anderson, M. J. 2001. A new method for non-parametric multivariate analysis of variance. Australian Journal of Ecology, 26: 32–46.

- Azzurro, E., Moschella, P., and Maynou, F. 2011. Tracking signals of change in mediterranean fish diversity based on local ecological knowledge. *PLoS ONE*, 6: e24885.
- Barnett, V., and Lewis, T., 1994. *Outliers in Statistical Data*, 3rd edn. John Wiley & Sons, New York, XVII. 582 pp.
- Bellido, J. M., Santos, M. B., Pennino, M. G., Valeiras, X., and Pierce, G. J. 2011. Fishery discards and bycatch: Solutions for an ecosystem approach to fisheries management? *Hydrobiologia*, 670: 317–333.
- Bellido Millán, J., Carbonell Quetglas, A., Garcia Rodríguez, M., Garcia Jimenez, T., and González Aguilar, M. 2014. The Obligation to Land All Catches—Consequences for the Mediterranean—In-Depth Analysis. IP/B/PECH/IC/2013-168. PE 529.055. 52 pp. [http://www.europarl.europa.eu/RegData/etudes/note/join/2014/529055/IPOL-PECH_NT\(2014\)529055_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/note/join/2014/529055/IPOL-PECH_NT(2014)529055_EN.pdf) (last accessed 18 October 2014).
- Borges, L. 2015. The evolution of a discard policy in Europe. *Fish and Fisheries*, 16: 534–540.
- Bradburn, N., Rips, L., and Shevell, S. 1987. Answering autobiographical questions: The impact of memory and inference on surveys. *Science*, 236: 157–161.
- Castriota, L., Campagnuolo, S., and Andaloro, F. 2001. Shrimp Trawl Fishery By-catch in the Straits of Sicily (Central Mediterranean Sea). Scientific Council Research Documents of the Northwest Atlantic Fisheries Organization, Serial No. N4501, No. 01/113.
- Catchpole, T. L., and Gray, T. S. 2010. Reducing discards of fish at sea: A review of European pilot projects. *Journal of Environmental Management*, 91: 717–723.
- Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, 18: 117–143.
- Damalas, D., Maravelias, C. D., Katsanevakis, S., Karageorgis, A. P., and Papaconstantinou, C. 2010. Seasonal abundance of non-commercial demersal fish in the eastern Mediterranean Sea in relation to hydrographic and sediment characteristics. *Estuarine, Coastal and Shelf Science*, 89: 107–118.
- Damalas, D., Maravelias, C. D., Osio, G. C., Maynou, F., Sbrana, M., and Sartor, P. 2015. “Once upon a Time in the Mediterranean” long term trends of mediterranean fisheries resources based on fishers’ traditional ecological knowledge. *PLoS ONE*, 10: e0119330.
- Damalas, D., and Vasilopoulou, V. 2013. Slack regulation compliance in the Mediterranean fisheries: A paradigm from the Greek Aegean Sea demersal trawl fishery, modelling discard ogives. *Fisheries Management and Ecology*, 20: 21–33.
- De Ranieri, S. 2014. Programma nazionale Italiano per la raccolta di dati alieutici 2013. Campionamento biologico delle catture. Sezioni C ed E. Rapporto finale, Consorzio per il Centro Interuniversitario di Biologia Marina ed Ecologia Applicata “G. Bacci”, Italia. 306 pp.
- Diamond, B., and Beukers-Stewart, B. D. 2011. Fisheries discards in the North Sea: Waste of resources or a necessary evil? *Reviews in Fisheries Science*, 19: 231–245.
- D’Onghia, G., Carlucci, R., Maiorano, P., and Panza, M. 2003. Discards from deep-water bottom trawling in the eastern-central Mediterranean Sea and effects of mesh size changes. *Journal of Northwest Atlantic Fishery Science*, 31: 245–261.
- EC. 1994. Council Regulation (EC) No. 1626/94 of 27 June 1994 Laying Down Certain Technical Measures for the Conservation of Fishery Resources in the Mediterranean. OJ L 171, 6.7.1994. p. 1–6. <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1433084768019&uri=CELEX:31994R1626>.
- EC. 2006. Council Regulation (EC) No. 1198/2006 of 27 July 2006 on the European Fisheries Fund. OJ L 223, 15.8.2006. p. 1–44. <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32006R1198>.
- EC. 2006b. Council Regulation (EC) No. 1967/2006 of 21 December 2006 Concerning Management Measures for the Sustainable Exploitation of Fishery Resources in the Mediterranean Sea, Amending Regulation (EC) No. 2847/93 and Repealing Regulation (EC) No. 1626/94. OJ L 409, 30.12.2006. p. 11–85. <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1433161780994&uri=CELEX:32006R1967>.
- Eliassen, S. Q., Papadopoulou, K. N., Vassilopoulou, V., and Catchpole, T. L. 2014. Socio-economic and institutional incentives influencing fishers’ behaviour in relation to fishing practices and discard. *ICES Journal of Marine Science*, 71: 1298–1307.
- Essid, M. Y. 2012. History of Mediterranean food. In *MediTERRA 2012* (English), Presses de Sciences Po, pp. 51–69. www.cairn.info/mediterr-2012-english-9782724612486-page-51.htm.
- EU. 2011. Regulation (EU) No. 1343/2011 of the European Parliament and of the Council of 13 December 2011 on Certain Provisions for Fishing in the GFCM (General Fisheries Commission for the Mediterranean) Agreement Area and Amending Council Regulation (EC) No. 1967/2006 Concerning Management Measures for the Sustainable Exploitation of Fishery Resources in the Mediterranean Sea. OJ L 347, 30.12.2011, p. 44–61. <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1433084061266&uri=CELEX:32011R1343>.
- EU (European Union). 2013. Council Regulation (EU) No. 1380/2013 of 11 December 2013 on the Common Fisheries Policy, Amending Council Regulations (EC) No. 1954/2003 and (EC) No. 1224/2009 and Repealing Council Regulations (EC) No. 2371/2002 and (EC) No. 639/2004 and Council Decision 2004/585/EC. Official Journal of the European Union L 354/22.
- García-Rivera, S., Lizaso, J. L. S., and Millán, J. M. B. 2015. A quantitative and qualitative assessment of the discard ban in European Mediterranean waters. *Marine Policy*, 53: 149–158.
- Hassan, E. 2006. Recall bias can be a threat to retrospective and prospective research designs. *The Internet Journal of Epidemiology*, 3.2: 339–412.
- IMF. 2014. Report for Selected Countries and Subjects. World Economic Outlook. International Monetary Fund. <http://data.worldbank.org/indicator/NY.GDP.MKTP.CD> (last accessed 18 October 2014).
- Kelleher, K. 2005. Discards in the World’s Marine Fisheries. An Update. FAO. Rome. No. 470. 131 pp.
- Lavides, M. N., Polunin, N. V. C., Stead, S. M., Tabaranza, D. G., and Comeros, M. T. 2010. Finfish disappearances around Bohol, Philippines inferred from traditional ecological knowledge. *Environmental Conservation*, 36: 235–244.
- Leonart, J., and Maynou, F. 2003. Fish stock assessments in the Mediterranean: State of the art. *Scientia Marina*, 67(Suppl. 1): 37–49.
- Macher, C. 2008. Joint productions and management measures of mixed fisheries: The case of the Nephrops fishery in the Bay of Biscay. PhD thesis. Economics and Finances. Université de Bretagne Occidentale - Brest (in French). <http://archimer.ifremer.fr/doc/2008/these-4857.pdf> (last accessed 18 October 2014).
- Machias, A., Maiorano, P., Vasilopoulou, V., Papaconstantinou, C., Tursi, A., and Tsimenides, N. 2004. Sizes of discarded commercial species in the eastern-central Mediterranean Sea. *Fisheries Research*, 66: 213–222.
- Machias, A., Vasilopoulou, V., Vatsos, D., Bekas, P., Kallianotis, A., Papaconstantinou, C., and Tsimenides, N. 2001. Bottom trawl discards in the northeastern Mediterranean Sea. *Fisheries Research*, 53: 181–195.
- Maynou, F., Sbrana, M., Sartor, P., Maravelias, C., Kavadas, S., Damalas, D., Cartes, J. E., *et al.* 2011. Estimating trends of population decline in long-lived marine species in the Mediterranean Sea based on fishers’ perceptions. *PLoS One*, 6: e21818.
- Neis, B., Schneider, D. C., Felt, L., Haedrich, R. L., Fischer, J., and Hutchings, J. A. 1999. Fisheries assessment: What can be learned from interviewing resource users? *Canadian Journal of Fisheries and Aquatic Sciences*, 56: 1949–1963.
- Osio, G. C. 2012. Reconstruction of Mediterranean Trawl Fisheries and Stock Recovery: What are the Perspectives? PhD Thesis, University of New Hampshire, USA. 230 pp.
- Rochet, M. J., and Trenkel, V. M. 2005. Factors for the variability of discards: Assumptions and field evidence. *Canadian Journal of Fisheries and Aquatic Sciences*, 62: 224–235.
- Sabatella, E., and Franquesa, R. 2003. Manual of fisheries sampling surveys: Methodologies for estimations of socio-economic

- indicators in the Mediterranean Sea. Studies and Reviews. General Fisheries Commission for the Mediterranean. No. 73. Rome, FAO. 2003. 37 p.
- Sacchi, J. 2008. The use of trawling nets in the Mediterranean. Problems and selectivity options. *Options Méditerranéennes B*, 62: 87–96.
- Sáenz-Arroyo, A., Roberts, C. M., Torre, J., and Cariño-Olvera, M. 2005. Using fishers' anecdotes, naturalists' observations and grey literature to reassess marine species at risk: The case of the Gulf grouper in the Gulf of California, Mexico. *Fish and Fisheries*, 6: 121–133.
- Sala, A., Lucchetti, A., Perdichizzi, A., Herrmann, B., and Rinelli, P. 2015. Is square-mesh better selective than larger mesh? A perspective on the management for Mediterranean trawl fisheries. *Fisheries Research*, 161: 182–190.
- Sánchez, P., Demestre, M., and Martín, P. 2004. Characterisation of the discards generated by bottom trawling in the northwestern Mediterranean. *Fisheries Research*, 67: 71–80.
- Sanchez, P., Sartor, P., Recasens, L., Lígas, A., Martín, J., De Ranieri, S., and Demestre, M. 2007. Trawl catch composition during different fishing intensity periods in two Mediterranean demersal fishing grounds. *Scientia Marina*, 71: 765–773.
- Santojanni, A., Cingolani, N., Arneri, E., Kirkwood, G., Belardinelli, A., Giannetti, G., Colella, S., et al. 2005. Stock assessment of sardine (*Sardina pilchardus*, Walb.) in the Adriatic Sea with an estimate of discards. *Scientia Marina*, 69: 603–617.
- Santurtún, M., Prellezo, R., Arregi, L., Iriondo, A., Aranda, M., Korta, M., Onaindia, I., et al. 2014. Characteristics of multispecific fisheries in the European Union. IP/B/PECH/IC/2013-088. PE 529.053. 102 pp. [http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/529053/IPOL-PECH_ET\(2014\)529053_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/529053/IPOL-PECH_ET(2014)529053_EN.pdf) (last accessed 15 January 2015).
- Sartor, P. (coord.) 2011. The 20th Century Evolution of Mediterranean Exploited Demersal Resources Under Increasing Fishing Disturbance and Environmental Change, EVOMED. Open Call for Tenders No. MARE/2008/11, Proposal for Lot 4 (Contract No. SI2 539097). 513 pp. http://ec.europa.eu/fisheries/documentation/studies/study_evolution_mediterranean/index_en.htm (last accessed 18 October 2014).
- Sartor, P., Sartini, M., Reale, B., and Sbrana, M. 2001. Analysis of the discard practices in the *Merluccius merluccius* (L. 1758) bottom trawl fishery of the northern Tyrrhenian Sea. *Biologia Marina Mediterranea*, 8: 771–774.
- Scientific, Technical and Economic Committee for Fisheries (STECF). 2013. Landing Obligation in EU Fisheries (STECF-13-23). Publications Office of the European Union, Luxembourg, EUR 26330 EN, JRC 86112. 115 pp. doi:10.2788/37460.
- Stratoudakis, Y., Fryer, R. J., and Cook, R. M. 1998. Discarding practices for commercial gadoids in the North Sea. *Canadian Journal of Fisheries and Aquatic Sciences*, 55: 1632–1644.
- Thornton, T. F., and Maciejewski Scheer, A. 2012. Collaborative engagement of local and traditional knowledge and science in marine environments: A review. *Ecology and Society*, 17: 8.
- Tsagarakis, K., Palialexis, A., and Vassilopoulou, V. 2013. Mediterranean fishery discards: Review of the existing knowledge. *ICES Journal of Marine Science*, 71: 1219–1234.
- Tzanatos, E., Somarakis, S., Tserpes, G., and Koutsikopoulos, C. 2007. Discarding practices in a Mediterranean small-scale fishing fleet (Patraikos Gulf, Greece). *Fisheries Management and Ecology*, 14: 277–285.
- Wilson, C. D., and Becker-Jacobsen, R. 2009. Governance Issues in Mixed-Fisheries Management: An Analysis of Stakeholder Views. A Framework for Fleet and Area Based Fisheries Management (AFRAME) Project. EU Sixth Framework Programme Contract No. 044168 Deliverable 6.3. <https://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/5087/200.pdf>.

Handling editor: Sarah Kraak