This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 633680

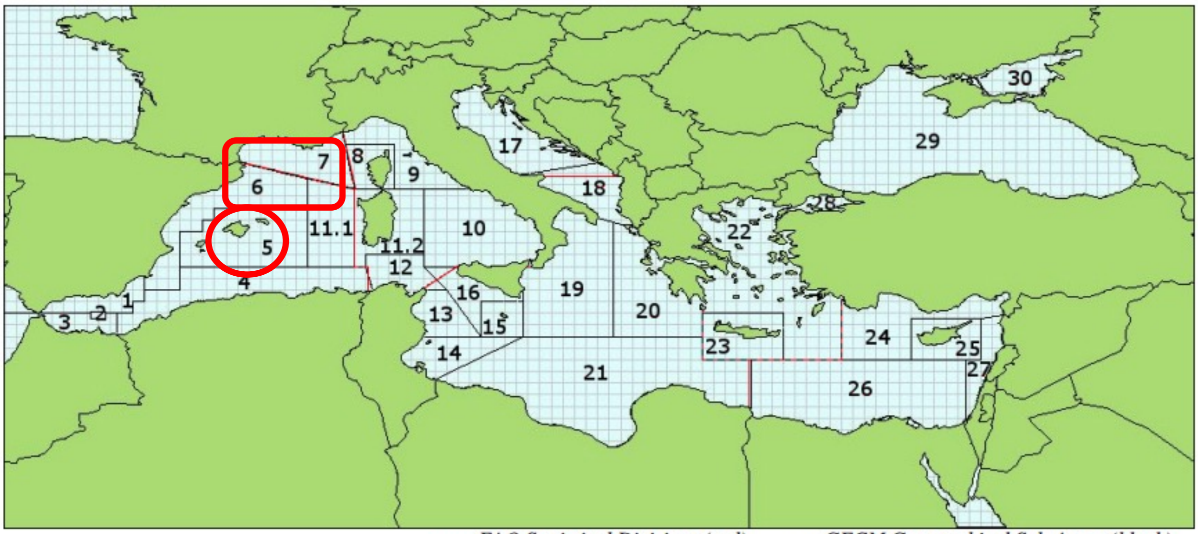
8.3 Western Mediterranean case study

by Antoni Quetglas, Beatriz Guijarro, Enric Massutí (IEO)

8.3.1 Brief presentation of the CS and fisheries concerned

The Western Mediterranean case study will focus on two contrasting areas in terms of the ecosystem productivity, exploitation pattern, and types and rates of discards: the French and Spanish Gulf of Lions-Catalan coast and the Balearic Archipelago. These areas encompass three different geographical subareas (GSAs), defined by the General Fisheries Commission for the Mediterranean (GFCM; www.gfcm.org) for the assessment and management of Mediterranean stocks (Figure 19): 1) Balearic Islands (GSA 5); 2) Northern Spain (GSA 6); and 3) Gulf of Lions (GSA 7).

GFCM Geographical Sub-Areas (GSAs) (GFCM, 2009)



---- FAO Statistical Divisions (red) ---- GFCM Geographical Sub-Areas (black)

01 - Northern Alboran Sea	07 - Gulf of Lions	13 - Gulf of Hammamet	19 - Western Ionian Sea	25 - Cyprus Island
02 - Alboran Island	08 - Corsica Island	14 - Gulf of Gabes	20 - Eastern Ionian Sea	26 - South Levant
03 - Southern Alboran Sea	09 - Ligurian and North Tyrrhenian Sea	15 - Malta Island	21 - Southern Ionian Sea	27 - Levant
04 - Algeria	10 - South and Central Tyrrhenian Sea	16 - South of Sicily	22 - Aegean Sea	28 - Marmara Sea
05 - Balearic Island	11.1 - Sardinia (west) 11.2 - Sardinia (east)	17 - Northern Adriatic	23 - Crete Island	29 - Black Sea
06 - Northern Spain	12 - Northern Tunisia	18 - Southern Adriatic Sea	24 - North Levant	30 - Azov Sea

Figure 19: Map of the Mediterranean Sea showing the thirty geographical sub-areas (GSAs) established by the General Fisheries Commission for the Mediterranean (GFCM). The main study areas covered under the Western Mediterranean Case Study are shown in red: Balearic Islands (GSA 5), Northern Spain (GSA 6) and Gulf of Lions (GSA 7).

The Gulf of Lions is the most productive area in the western Mediterranean owing to the winter upwelling and the discharges of rivers, whereas the Balearic Islands constitute an especially oligotrophic area within the general oligotrophy of the Mediterranean (Estrada, 1996).

In each of these two main areas, two bathymetric strata, middle slope and deep shelf, will be used as parallel 'study systems'. At the deep shelf, the European hake (*Merluccius merluccius*) is the dominant species exploited by different gear types (trawlers, long-liners, gill-netters), while at the middle slope, the red shrimp (*Aristeus antennatus*) dominates the catches and is exploited exclusively by trawlers.

Hake and red shrimp from the Gulf of Lions are shared stocks exploited by the French and Spanish fleets. The French trawler fleet is the largest both in number of boats and landings (41% and 72%, respectively). The second largest fleet is the French gillnetters (41 and 14% respectively), followed by the Spanish trawlers (11 and 8%, respectively), and the Spanish long-liners (6 and 6%, respectively).

Historically, the number of fishing vessels has remained very low in the Balearic Islands compared to nearby areas. The number of trawlers doubled in Mallorca from 35 to 70 units between 1965 and 1977, but has decreased progressively since then to the 28 current vessels. In the rest of the Balearic Islands, the current number of trawlers is even lower: 7 in Menorca, 8 in Ibiza and 2 in Formentera. These values are clearly very far from the total number of vessels in GSA 6, for instance, where the fleet has decreased from 810 trawlers in 1998 to the current 550 units.

Trawl fishing exploitation in GSA 5 is much lower than in GSA 6 and 7; the density of trawlers around the Balearic Islands is one order of magnitude lower than in adjacent waters (Massutí and Guijarro 2004). Due to this lower fishing exploitation, the demersal resources and ecosystems in GSA 5 are in a healthier state than in GSA 6 and 7, which is reflected in the population structure of the main commercial species, and in the higher abundance and diversity of elasmobranch assemblages (Quetglas et al., 2012).

Trawl discards from the shelf constitute up to 55-70% of the catch and are composed mainly of red algae and echinoderms in GSA05, whereas they only represent 23-48% and are dominated by fish in GSA06 (Sánchez *et al*. 2004, Ordines *et al.* 2006).

8.3.2 Causes of discarding

The European Project *Discards of the Western Mediterranean trawl fleets* (Contract Nº MED 94/027), analyzed the composition, both from a quantitative and qualitative point of view, of the trawl fleet discards in different areas of the Western Mediterranean (GSA 1, 5, 6 and 9). This project was carried out during 1995-1996 and included two ports from the Balearic Islands (Palma and Alcudia). On board sampling allowed collecting catch and discard data at three different bathymetric strata: A (<150 m), B (150-350 m) and C (>350 m).

In stratum A, the discarded fraction was composed of species without commercial interest such algae and echinoderms, which represented 52% and 20% of the total catch in Palma (PM) and Alcudia (AL) respectively (Figure 20). In stratum B, discards represented 50% (PM) and 40% (AL) of catch, and included mainly fish; a large bulk of the discard (47% PM, 35% AL) corresponded to marketable species, but of low or almost no commercial value in the study area (e.g. *Boops boops* or *Trachurus* spp.). In stratum C, the discarded fraction was much smaller, less than 20% of the total, and it was composed mainly of species without commercial value, such as macrurids or myctophids.

In conclusion, the discarded biomass always constituted an important fraction of the total catch, but discards principally affected species of no or little commercial interest. The discard of species with a high commercial value (e.g. octopus, shrimp, Norway lobster) was very low or zero.

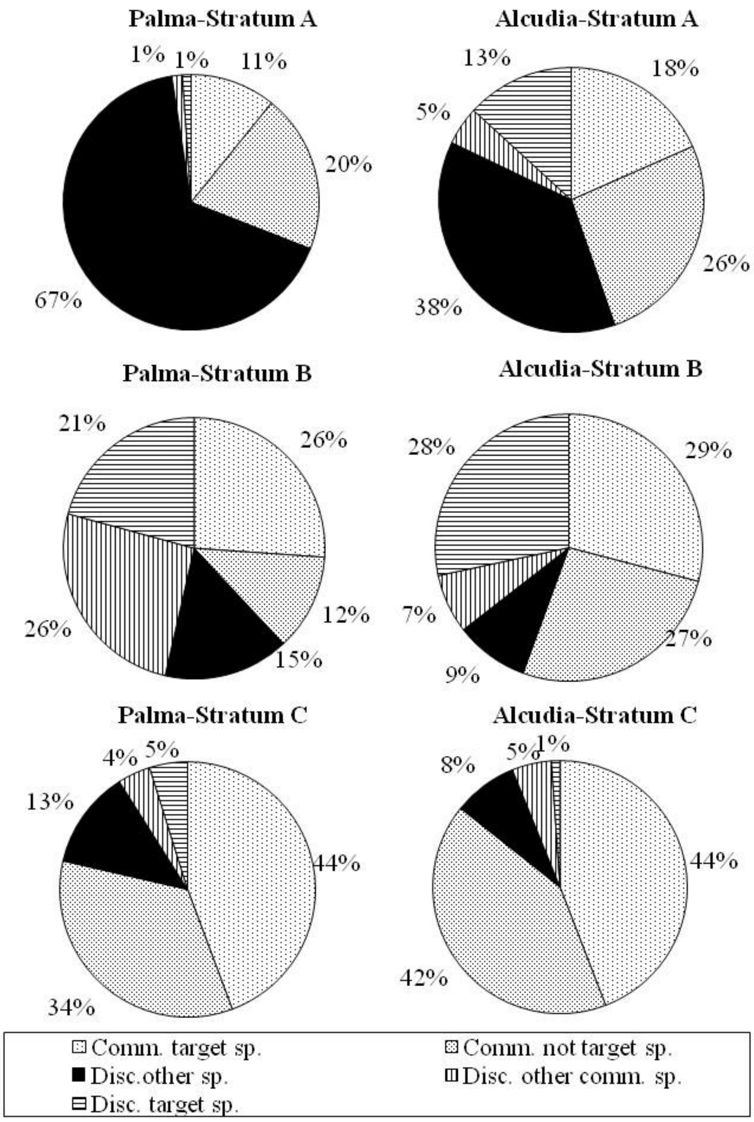


Figure 20: Catch composition (% kg/h) by stratum at Palma de Mallorca and Alcudia (Balearic Islands). From Carbonell et al. (1997).

Using data from this project, Sartor et al. (1998) analyzed the discards of cephalopods in the different areas. In general, discarding of cephalopods was minimal by mass in all bathymetric strata, only 0.06-1.69% of total catch or 0.10-5.23% of the total discarded catch. However, in terms of number of species, the discarded component was notable. In terms of commercial importance of the different species and study areas, three groups were identified: species that are almost entirely of commercial interest, species that are always rejected (mainly bathyal cephalopods) and species for which the discard percentages are variable (e.g. *Alloteuthis* spp., *Sepia orbignyana*).

Bellido et al. (2014) analyzed the consequences of the landing obligation for the Mediterranean; the main findings of this work are summarized in the two following paragraphs. From 300 species caught in the Mediterranean, only around 10% are consistently marketed and 30% are occasionally retained (depending on the sizes and market demands) whereas up to 60% are always discarded.

Total discards in the Mediterranean are estimated at 18.6% of the total catch. Discards differ depending on the country. For regulated species, Italy with more than 40% of landings by weight is followed by Spain (5%) and Slovenia (5%) as countries with the highest discard rates (Figure 21). Reasons for discarding are highly variable and they can be driven by economic, sociological, environmental or biological factors. These factors often act together; it is quite difficult to separate them, especially in multispecies fisheries. In the Mediterranean, discards are characterised by extremely high species diversity with a high percentage of non-commercial catch and high variability in total discard rate due to seasonality.

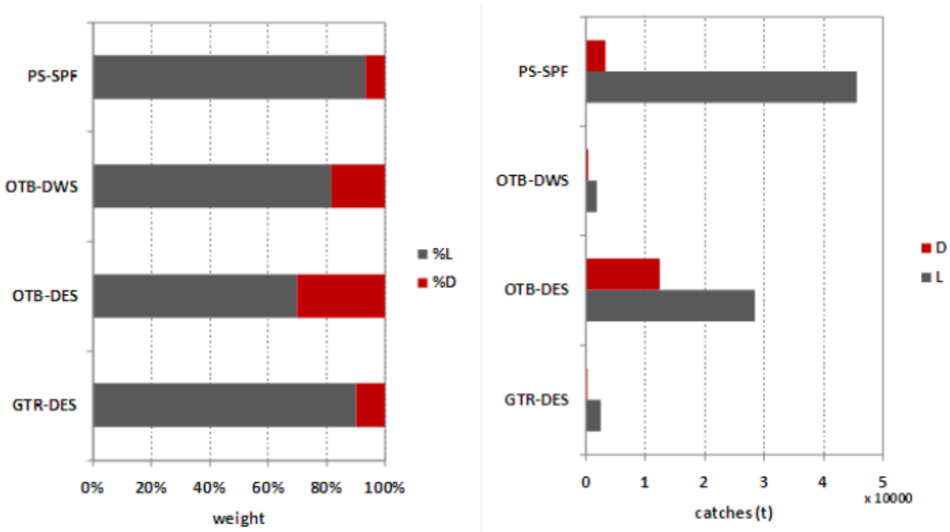


Figure 21: Proportion of commercial (L) and discarded (D) fractions by weight of the catches (a) and total catches (b) taken during the period from year 2009 to 2012 in the Spanish Mediterranean. From Bellido et al. (2014).

For France, Spain and Greece, the highest discard rates for commercial species were associated with 'low value' pelagic species such as sardine and horse mackerel. The length data supplied by Spain suggests that much of the discarding was not only associated with fish below minimum landing size (MLS) but also because of high grading, suggesting that only the larger specimens were retained for marketing purposes. Conversely, high value species such as hake, shrimp and monk/anglerfish all exhibited very low discard rates and examination of the length data suggests that a considerable proportion of the fish landed for sale were below MLS, suggesting that discarding was mainly induced by quality issues and market forces rather than any legal constraints.

Finally, there is a PhD Thesis specifically devoted to the discards from the trawl fleet from the Gulf of Lions (Mallol, 2005). A total of 68 hauls (c.a. 300 h trawling) on board a commercial trawler were carried out between March 1998 and March 2000 (Figure 29). In terms of biomass, discards were represented by fish (88.01%), echinoderms (7.75%), crustaceans (1.50%), cephalopods (0.78%) and other species (1.96%). The discarded biomass was highest on the shelf and lowest on the middle slope;

regarding seasons, discards were significantly highest in summer, coinciding with the recruitment of most commercial species (Figure 23).

Mallol (2005) identified the following main causes of discarding:

1. Compliance with regulations on minimum landing sizes (MLS). This includes species of high commercial value under the MLS (e.g. *M. merluccius, M. poutassou, Z. faber, L. budegassa*), but also some species above the MLS which are, however, below the size considered commercially relevant (e.g. *M. poutassou, P. blennoides, L. caudatus, S. scombrus*).
2. Avoidance of lower fish prices owing to marked saturation, which occur specially in small pelagic species (e.g. *S. pilcharcus, E. encrasicolus, Trachurus* spp.).
3. Non-commercial value, affecting primarily to species or families without commercial interest such as myctophids, macrourids and callyonimids.
4. Accessory catches of low or moderate commercial interest taken in such a low quantities that do not worth packaging. This applies, for instance, to sepiolids and some fish (e.g. *C. macrophthalma, B. boops, M. dypterigia*) and crustacean (e.g. *M. intermedia, S. membranacea*) species.
5. Bad condition of commercial species which are damaged by the effects of trawling or overloaded net.
6. Missed commercial species that are unnoticed during the sorting process.

The last two causes of discarding have been noticed in all the main taxonomic groups: fish (e.g. *Mullus* spp., *P. erythrinus*), crustaceans (e.g. *A. antennatus, N. norvegicus*), cephalopods (*O. vulgaris, E. cirrhosa, L. vulgaris*) and echinoderms (*S. regalis*).

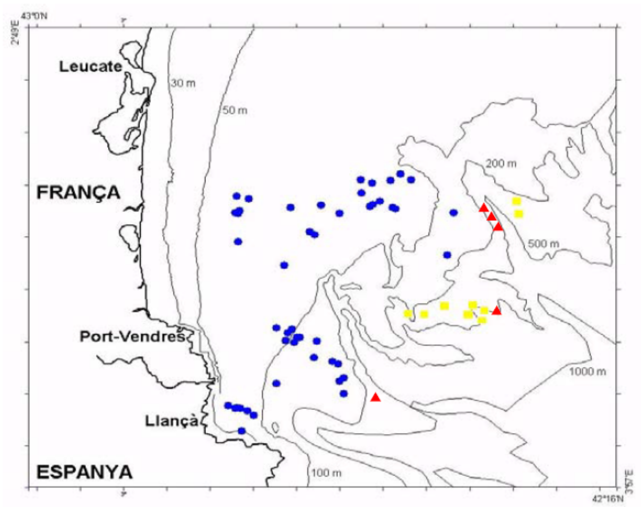


Figure 22: Map of the Gulf of Lions showing the location of the 68 hauls from the continental shelf (blue), upper slope (yellow) and middle slope (red) analysed by Mallol (2005).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 633680

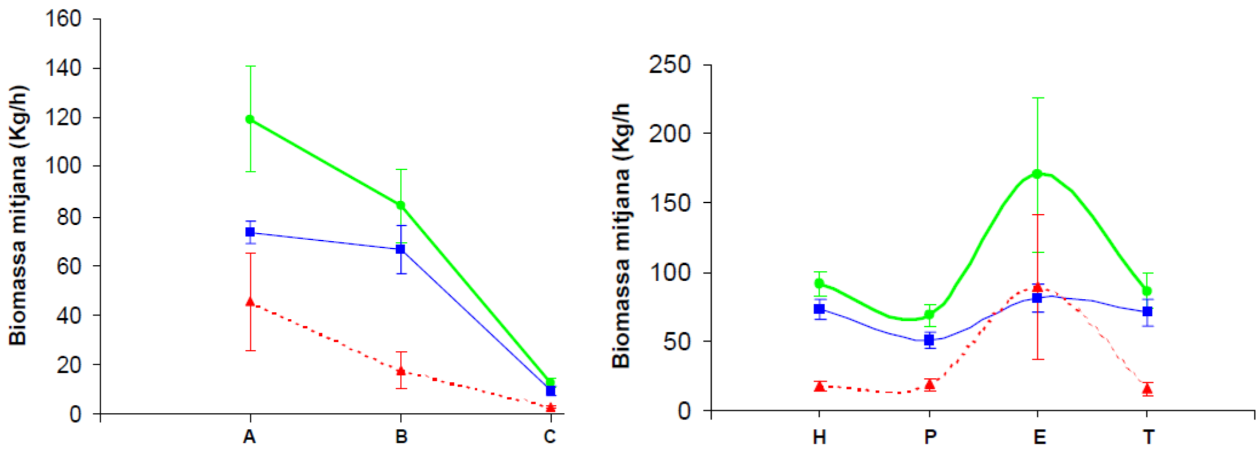


Figure 23: Mean (± S.E.) of biomass (kg·h-1) per depth stratum (A: 50-200 m; B: 200-400; C: >400m) (left) and per season (H: winter; P: spring; E: summer; T: autumn) (right) of a bottom trawler from the Gulf of Lions (Mallol, 2005). Green: total catch; blue: commercial catch; dotted red: discards.

8.3.3 Effects of discarding

The ecological impact of discards goes far beyond single-species demographic effects, since discarded biomass can alter ecosystem structure by favouring scavengers (Tudela 2004). To our knowledge, the only work dealing with this issue in the western Mediterranean is based on photographic surveys carried out off the Catalan coast, and focuses on the estimation of the consumption rate of fishery discards by scavengers (Bozzano and Sardà, 2002). A baited camera set on the sea floor at a depth of 100 and 300 m in areas subjected to trawling with continual discards were used. Discarded material seems to enter demersal food webs quite quickly, as suggested by the high consumption rates recorded. This study showed that fishing can favour a species by both removing its competitors and independently increasing its food availability through discards. At the community level, a continuous supply of discards can alter the diversity and abundance of benthic species, affecting the functionality and distribution of ecological niches (Bellido et al. 2014).

Unaccounted fishing mortality from discards may affect the fisheries assessment and management (Johnsen and Eliasen, 2011), which can even contribute to problems of overfishing (Bellido et al. 2014).

However, discards may also have positive effects on ecosystem productivity (Tsagarakis et al., 2014) and be important food sources for seabirds (Martínez-Abraín et al., 2002) and this can be beneficial for certain populations in oligotrophic areas such as the Mediterranean (Bellido et al. 2014).

There are few works analyzing the economic effects of discarding in the Mediterranean. Bellido et al. (2014) reported that one possible consequence of the new regulation may be the increase in illegal marketing of fish below the minimum size. Landing, storage and transportation of juveniles will be legal and this can simplify commercialization via black market. A SWOT analysis reported the overall balance was detrimental to the implementation of the new CFP, with 72.6% of negative aspects (Weaknesses and Threats) and 27.4% of positive aspects (Strengths and Opportunities).

There is also a lack of works analysing the survival of discards thrown to sea in the present Case Study. Observations derived from experiments on aquaria carried out on board bottom trawlers from the Catalan Sea indicate low mortality of crustaceans, whereas survival rates of fish are highly heterogeneous and vary strongly among species (e.g. 0% for *Trachurus* spp. and 100% in *Scyliorhinus canicula*) (Sánchez, 2000).

8.3.4 Discard Data

8.3.4.1 Discard sampling

Discard data are collected at sea under the Spanish Observers on Board Sampling Programme, funded by the Data Collection Framework (EC, 199/2008). For sampling purposes, only the major metiers are considered, which are selected using a ranking system. Only those metiers whose accumulated shares in landings, value and effort are included in the top 90% are selected. For this reason, the metiers sampled can changed with the years. The best information on discards comes from the following métiers of the bottom trawl fleet (OTB: Bottom otter trawl): OTB_DEF (demersal species), OTB_MDD (mixed demersal and deep water species) and OTB_DWS (deep water species) for the Balearic Islands and OTB_DEF and OTB_DWS for the Spanish fleet operating in the Gulf of Lions.

The sampling design is not probability based, stratified by area (GSA), with port and trip as primary and secondary sampling unit respectively. Information on discards is used as inputs in the stock assessments of the main target species carried out annually in the framework of the GFCM and the STECF. These stocks are: 1) In the Balearic Islands: *Merluccius merluccius*, *Mullus barbatus*, *Mullus surmuletus*, *Aristeus antennatus*, *Nephrops norvegicus* and *Parapenaeus longirostris;* and 2) In the Gulf of Lions: *M. merluccius* and *M. barbatus*. In the case of the Gulf of Lions, these assessments are carried out using datasets from both the Spanish (IEO) and French (IFREMER) fleets.

The sampling coverage for each metier in both areas is summarized inTable 11. The mean coverage in the Balearic Island is around 0.5% for OTB_DEF and OTB_DWS and 0.75% for OTB_MDD. In the Gulf of Lions, the coverage is higher, with a mean around 1% for OTB_DEF and around 2% for OTB_DWS.

Table 11: Sampling coverage by métier, for the two areas included in the Western Mediterranean case study (Balearic Islands and Gulf of Lions) during 2012-2014.

Area	Metier	Year	Total trips	Sampled trips	Coverage (%)
Balearic Islands	OTB_DEF	2012	5140	28	0.54
		2013	5471	18	0.33
		2014	5457	24	0.44
	OTB_DWS	2012	3200	12	0.38
		2013	2767	13	0.47

		2014	2675	14	0.52
	OTB_MDD	2012	2227	12	0.54
		2013	2064	15	0.73
		2014	2170	20	0.92
Gulf of Lions	OTB_DEF	2012	2229	20	0.90
		2013	1923	15	0.78
		2014	2044	18	0.88
	OTB_DWS	2012	541	13	2.40
		2013	726	12	1.65
		2014	666	14	2.10

8.3.4.2 Measuring Discards

Values of total landed and discarded biomass (in tons) for the main species under the minimum landing size (MLS) European Regulation (EC, 1967/2006) by métier are shown in Table 12(Balearic Islands) and Table 13 (Gulf of Lions).

Table 12: Landed and discarded biomass by métier from the Balearic Islands during 2012-2014.

Métier	Species	Landings (t)			Discards (t)		
		2012	2013	2014	2012	2013	2014
OTB_DEF	ANE	0.01	NA	NA	0.00	NA	NA
	DPS	3.56	5.77	4.70	0.41	0.32	0.01
	HKE	43.98	89.79	85.40	6.44	12.65	4.87
	HMM	47.86	38.08	1.00	9.24	0.19	0.77
	HOM	23.64	18.79	82.19	3.80	17.65	15.26
	MUR	69.93	57.55	64.97	5.54	0.08	2.72
	MUT	14.93	12.30	1.13	0.37	0.00	0.00
	NEP	13.04	11.26	19.96	0.06	0.00	0.00
	PAC	14.39	11.43	8.67	0.62	0.68	0.11
	PIL	0.07	0.22	0.05	0.00	19.30	2.38

	RPG	0.78	0.84	0.88	0.00	0.00	0.00
	SBA	8.81	7.02	8.23	0.62	0.00	0.02
	SRG	12.03	3.91	2.52	0.56	0.00	0.09
OTB_DWS	HKE	9.63	9.70	15.69	0.00	0.00	0.00
	NEP	8.42	3.58	4.65	1.19	0.00	0.00
	SBA	0.04	NA	NA	NA	NA	NA
OTB_MDD	DPS	0.61	0.43	0.89	0.00	0.00	0.00
	HKE	7.58	9.22	17.17	0.06	0.40	0.69
	HMM	9.75	7.23	0.29	4.53	0.92	0.04
	HOM	4.82	3.57	23.41	0.03	0.82	11.52
	MUR	15.58	12.13	14.29	0.00	0.00	0.00
	MUT	3.33	2.60	0.25	0.00	0.00	0.00
	NEP	8.04	3.98	6.19	0.87	0.00	0.03
	PAC	3.13	2.26	1.54	0.00	0.07	0.00
	SBA	1.92	1.39	1.47	0.00	0.04	0.01
	SRG	1.33	1.06	0.79	0.01	0.00	0.00

ANE: *Engraulis encrasicolus*; DPS: *Parapenaeus longirostris*; HKE: *Merluccius merluccius*; HMM: *Trachurus mediterranaeus*; HOM: *Trachurus trachurus*; MAZ: *Scomber* spp; MUR: *Mullus surmuletus*; MUT: *Mullus barbatus*; NEP: *Nephrops norvegicus*; PAC: *Pagellus erythrinus*; PIL: *Sardina pilchardus*; RPG: *Pagrus pagrus*; SBA: *Pagellus acarne*; SBG: *Sparus aurata*; SBR: *Pagellus bogaraveo*; SRG: *Diplodus* spp.

Table 13: Landed and discarded biomass by year and metier *of the Spanish OTB fleet from* the *Gulf of Lions.*

Métier	**Species**	**Landings (t)**			**Discards (t)**		
		2012	**2013**	**2014**	**2012**	**2013**	**2014**
OTB_DEF	ANE	3.97	2.00	1.98	45.00	1.40	3.53
	DPS	1.70	2.02	2.76	0.30	0.29	0.03
	HKE	154.40	187.57	184.66	1.16	0.13	2.29
	HMM	2.83	2.21	4.90	0.00	0.00	0.00
	HOM	53.10	41.39	63.76	10.08	2.81	0.20

	MAZ	27.25	36.67	40.76	8.02	0.21	0.13
	MUR	0.20	0.25	9.49	0.00	0.00	0.00
	MUT	28.82	36.89	40.45	0.17	0.01	0.05
	NEP	23.54	18.17	18.94	1.01	0.01	0.06
	PAC	8.54	7.08	7.18	0.02	0.00	0.00
	PIL	1.64	0.66	0.69	1.69	0.00	0.23
	SBA	15.49	8.01	9.74	0.00	0.00	0.38
	SBG	0.88	2.13	0.33	0.00	0.00	0.00
	SBR	2.08	1.88	3.28	0.00	0.04	0.03
	SRG	2.14	1.92	0.87	0.00	0.00	0.00
OTB_DWS	HKE	3.52	6.81	8.38	0.00	0.16	0.00
	MAZ	NA	0.02	NA	NA	0.00	NA
	NEP	1.33	1.73	1.13	0.04	0.33	0.01
	SBR	0.11	0.09	NA	0.00	0.00	0.00

ANE: Engraulis encrasicolus; DPS: Parapenaeus longirostris; HKE: Merluccius merluccius; HMM: Trachurus mediterranaeus; HOM: Trachurus trachurus; MAZ: Scomber spp; MUR: Mullus surmuletus; MUT: Mullus barbatus; NEP: Nephrops norvegicus; PAC: Pagellus erythrinus; PIL: Sardina pilchardus; RPG: Pagrus pagrus; SBA: Pagellus acarne; SBG: Sparus aurata; SBR: Pagellus bogaraveo; SRG: Diplodus spp.

The 2012-2014 average discard biomass rates for the Balearic Islands are shown in Figure 24. The average percentage of discards is in general lower than 10% for most of the species subjected to a regulation, except for three species *T. trachurus* (HOM) and *S. pilchardus* (PIL) in OTB_DEF and *T. mediterraneus* (HMM) in MDD. Small pelagic species are bycatch species for the bottom trawl fleet in this area and their importance is highly variable, both in terms of catches (their catchability shows important oscillations) and in terms of their final destination (they are landed or discarded depending on different factors, including market interest). This can be seen in Table 11, in which their biomass (both landed and discarded) varies significantly among years.

The 2012-2014 average discard biomass rates of the Spanish OTB fleet from the Gulf of Lions are shown in Figure 25. The average percentage of discards is in general lower than 10% for most of the species subjected to a regulation, except again for the case of small pelagic species like *E. encrasicolus* (ANE) and *S. pilchardus* (PIL) in OTB_DEF. Similarly of what happens in the Balearic Islands, their importance is highly variable, as it can be seen in Table 12.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 633680

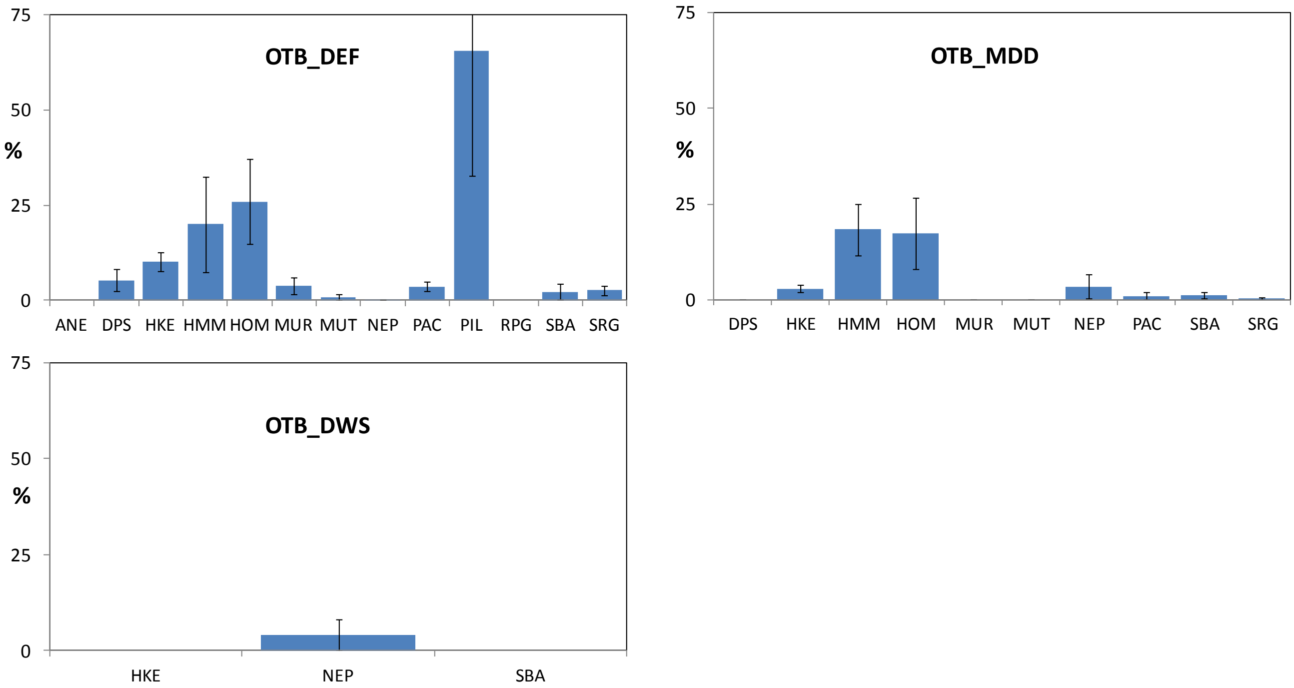


Figure 24: Average percentage of discards, by biomass, for the Balearic Islands (2012-2013) by metier and species. Error bars indicate standard errors. ANE: Engraulis encrasicolus; DPS: Parapenaeus longirostris; HKE: Merluccius merluccius; HMM: Trachurus mediterranaeus; HOM: T. trachurus; MAZ: Scomber spp; MUR: Mullus surmuletus; MUT: M. barbatus; NEP: Nephrops norvegicus; PAC: Pagellus erythrinus; SBA: P. acarne; SBR: P. bogaraveo; PIL: Sardina pilchardus; RPG: Pagrus pagrus; SBG: Sparus aurata; SRG: Diplodus spp.

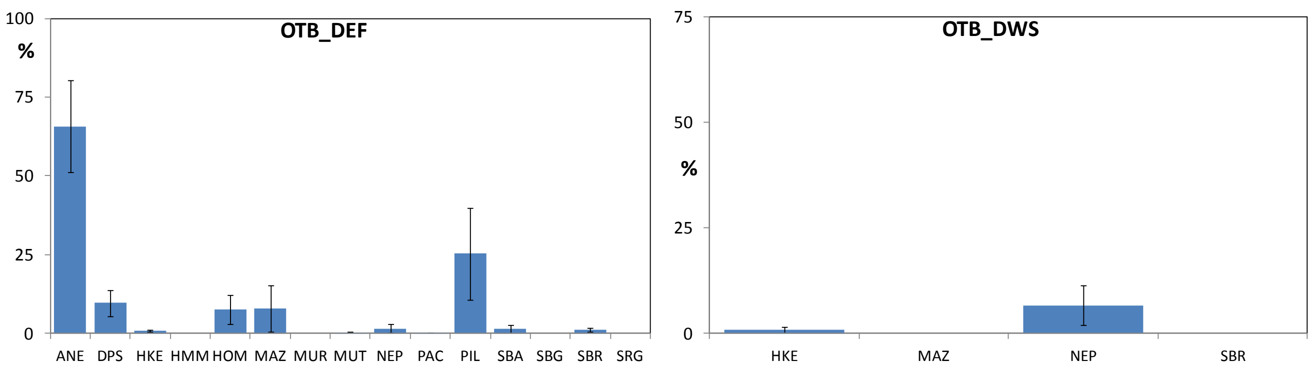


Figure 25: Average percentage of discards, by biomass of the Spanish OTB fleet from the Gulf of Lions (2012-2013) by metier and species. Error bars indicate standard errors. ANE: Engraulis encrasicolus; DPS: Parapenaeus longirostris; HKE: Merluccius merluccius; HMM: Trachurus mediterranaeus; HOM: T. trachurus; MAZ: Scomber spp; MUR: Mullus surmuletus; MUT: M. barbatus; NEP: Nephrops norvegicus; PAC: Pagellus erythrinus; SBA: P. acarne; SBR: P. bogaraveo; PIL: Sardina pilchardus; RPG: Pagrus pagrus; SBG: Sparus aurata; SRG: Diplodus spp.

8.3.5 Methods for reducing discards

During the last decades, the GFCM recommended the improvement of trawl selectivity, stressing also the incongruence that minimum landing size (MLS) established by the European legislation was, for some species, higher than their length of first capture with the gear traditionally used in the Mediterranean (40 mm diamond mesh cod-end). The GFCM encouraged studies, and organized several workshops (GFCM, 2005a, 2007, 2008, 2010), aimed at improving the trawl selectivity in order to reduce discards and overcome that contradiction (GFCM, 2001).

Most of those studies assessed the effects of changing either the size of the diamond mesh (e.g. Dremière, 1979; Aldebert & Carriers, 1990; Sardà *et al.*, 1993; D'Onghia *et al.*, 1998; Mytileneou *et al.*, 1998; Ragonese *et al.*, 2001, 2002, 2006; Carlucci *et al.*, 2006; Tosunoğlu *et al.*, 2008; Aydin *et al.*, 2011) or its geometry from diamond to square mesh (e.g. Stergiou *et al.*, 1997a, 1997b; Petrakis & Stergiou, 1997; Mallol *et al.*, 2001; Mallol, 2005; García-Rodríguez & Fernández, 2005; Sardà *et al.*, 2006; Guijarro & Massutí, 2006; Bahamon *et al.*, 2006, 2007a; Ordines *et al.*, 2006; Baro & Muñoz, 2007; Lucchetti, 2008; Ateş *et al.*, 2010; Sala *et al.*, 2008; Aydin *et al.*, 2011). Sala *et al.* (2006) combined sea trials analyzing the increment of the mesh size with a reduction of the number of meshes in the circumference of the cod-end with computer simulations and Sala et al. (2010, 2011a) assessed the effect of mesh size and configuration and codend circumference. Few studies have analysed the effect of hexagonal meshes in the cod-end (Tosunoğlu *et al.*, 2009; Aydin *et al.*, 2009, 2010). A detailed review of size selectivity performance for different cod-ends has been made recently within the framework of the DISCTACH project[6].

Other studies have explored the efficiency of sorting grid systems (Sardà *et al.*, 2004, 2005, 2006; Bahamon *et al.*, 2007b; Massutí *et al.*, 2009; Sala *et al.*, 2011b). This system was initially used in shrimp fisheries to prevent catching large fish and turtles, but in the Mediterranean it has been tested with the opposite objective, allowing the escapement of juveniles. Information about square mesh panels in the Mediterranean is scarce, being limited to some comments by Sardà *et al.* (2004) and two studies developed in the Tyrrhenian Sea (Belcari *et al.*, 2005) and very recently in the Balearic Islands (Massutí *et al.*, 2014). Lastly, the effect of twine thickness on the size selectivity has also been assessed (Sala *et al.*, 2007; Massutí *et al.*, 2015).

Some of the above mentioned studies were done on the basis of the Council Regulation (EC) Nº 1967/2006, of 21 December 2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea. This Regulation established the replacement of the 40 mm diamond mesh cod-end by a 40 mm square mesh cod-end or, under the duly justified request of the ship owner, by a diamond mesh of 50 mm. This measure was not implemented until 2010, and most vessels (>90% since estimations of the European Commission[7]) benefited from the exceptionality of the 50 mm diamond mesh cod-end, despite the lack of scientific information about the selectivity of this net in the north-western Mediterranean. The only information comparing the

---

[6]Pilot Project on catch and discard composition including solutions for limitation and possible elimination of unwanted by-catches in trawl net fisheries in the Mediterranean (DISCATCH). DG MARE European Commission Contract Nº MARE/2012/24 Lot 2.

[7]Informe de la Comisión al Parlamento Europeo y al Consejo sobre la aplicación del artículo 9, apartado 3, del Reglamento (CE) nº 1967/2006 del Consejo relativo a las medidas de gestión para la explotación sostenible de los recursos pesqueros en el mar Mediterráneo. Bruselas 10.7.2012, COM (2012) 370 final, 8 pp.

selectivity of 40 mm square mesh cod-end with 40 and 50 mm diamond mesh cod-ends has been provided very recently by Zapata (2015). This study has compared catches and size composition, both from landings and discards, obtained by the three types of mesh under commercial conditions, using data from the scientific monitoring of the bottom trawl fleet, developed between 2009 and 2013 in the Balearic Islands.

*Table 14: Length of first capture (L_{50}, with selection range between brackets; fishes: TL in cm; cephalopods: ML in cm; crustaceans: CL in mm) for some of the main commercial species, estimated for different mesh shape cod-ends (40 mm DM and SM; except for ◊, ◊◊ and ◊◊◊, in which 34-35.5, 50 and 60 mm DM were used) and sorting grid (SG15 and SG20; *: with guiding funnel; **: without guiding funnel) by some authors at different areas of the western Mediterranean: (i) BAL (Balearic Islands; present study, Guijarro & Massutí, 2006; Ordines et al., 2006); (ii) NEC (north-eastern Iberian coast; Sardà et al., 2006; Bahamon et al., 2007b); (iii) CEC (central Iberian coast; García-Rodríguez & Fernández, 2005); (iv) GOL (Gulf of Lions; Dremière, 1979; Aldebert & Carriers, 1990; Mallol, 2005). MLS: minimum landing size established by the Council Regulation (EC) Nº 1967/2006, of 21 December 2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea.*

Species	**MLS**	**Area**	**DM**	**SM**	**SG15**	**SG20**
Lepidorhombus boscii	--	BAL	9.9 (2.4)	10.2 (1.5)	9.1 (5.2)	12.1 (5.6)
		GOL	11.7 (5.0)	11.0 (4.0)	--	--
Merluccius merluccius	20	BAL	10.6 (3.3)	15.2 (3.3)	10.9* (5.1)	18.9* (3.4)
		NEC	10.1 (3.1)	16.0 (3.2)	5.9* (3.5)	17.2* (6.2) 13.2** (3.6)
		CEC	10.3 (3.1)	14.6 (4.0)	--	--
		GOL	7.5 (2.5) 10.2-12.8◊ 12.4-13.0 16.3◊◊ 19.5◊◊◊	20.0 (7.4)	--	--
Micromesistius poutassou	--	BAL	--	20.1 (2.5)	--	16.1* (6.0)
		CEC	14.0 (1.7)	18.3 (2.2)	--	--
		GOL	12.1 (1.6)	20.6 (1.8)	--	--
Mullus barbatus	11	NEC	--	--	--	10.4* (3.9)
		CEC	7.8 (2.0)	13.7 (2.2)	--	--
		GOL	9.1 (3.0)	12.4 (2.7)	--	--
Mullus surmuletus	11	BAL	4.5 (5.8)	12.2 (2.1)	--	--
		CEC	8.7 (1.7)	13.2 (2.3)	--	--
Phycis blennoides	--	BAL	12.2 (3.0)	14.4 (4.0)	8.7* (7.9)	10.9* (5.6)
		NEC	9.8 (2.6)	15.0 (3.0)	--	10.9** (6.4)
		GOL	11.4 (2.7)	17.2 (3.6)	--	--
Trachurus mediterraneus	15	BAL	13.7 (2.1)	15.2 (3.0)	7.6 (7.0)	11.2 (7.1)
Nephrops norvegicus	20	BAL	--	26.6 (3.4)	21.2* (6.7)	23.8* (8.6)
		NEC	--	22.0 (6.5)	--	20.5** (9.3)

Parapenaeus longirostris	20	BAL	16.6 (3.7)	20.2 (2.3)	21.4* (13.2)	25.7* (11.4)
Octopus vulgaris	--	BAL	3.5 (2.1)	6.0 (2.2)	--	--

The size selectivity parameters estimated at different areas of the north-western Mediterranean, using 40 mm diamond mesh (DM) and 40 mm square mesh (SM) cod-ends, and sorting grids with a bar spacing of 15 and 20 mm (SG15 and SG20, respectively), show high variability (Table 14). It is probably due to the different conditions (experimental and commercial), methodologies (e.g. covered cod-end and twin trawl methods), characteristics of the tested devices (e.g. grid surface and mounting, net material and mounting), gears, vessels used and areas and seasons surveyed. Trawl selectivity depends on gear (e.g. twine thickness, knotted/non-knotted mesh), vessel, environment and biocenosis, among other factors (Wileman *et al.*, 1996; MacLennan, 1992; Sala *et al.*, 2007). However, it is evidenced a similar tendency, with values of length of first capture (L_{50}) with SM cod-end and SG20 clearly higher than with SG15 and DM cod-end. The comparison between the size selectivity performance of SM cod-end and SG20 shows some differences, being SM cod-end more efficient than SG20 for most species off the Balearic Islands, but not showing marked differences in the north-eastern Iberian coast (Bahamon *et al.*, 2007b). In any case, the results obtained for some species are diverse. For *Merluccius merluccius*, L_{50} estimated in the Balearic Islands (18.9 cm) is very similar to that obtained by Sardà *et al.* (2004) and Bahamon *et al.* (2007b), with similar selectivity devices (18.8 and 17.2 cm, respectively). By contrary, the same authors have also reported values of 14.2 cm and ~13 cm with SG20 (Sardà *et al.*, 2005, 2006). The L_{50} with SM cod-end estimated in our study area (15.2 cm) is smaller than the one reported by Sardà *et al.* (2006) with a SM non-knotted cod-end (18.5 cm). According to these authors, these differences could be due to the use of a knotted net, trawled at a lower speed, in the Balearic Islands. Moreover, it must be also considered that the separation process of the grid is more complex than for normal mesh selection, combining both selection at the grid and the vertical behaviour of the fish. Thus, the behaviour of *M. merluccius*, swimming high in the trawl, could also be on the basis of the high sorting efficiency of the grids assessed, with spaced bars in their upper part. The selection range of sorting grids were substantially wider than those estimated for DM and SM cod-ends (Table 14), indicating that the sorting performance of the grids was not yet fully satisfactory, allowing a higher escapement of big specimens than DM and SM cod-ends.

The increment of the L_{50} observed with 40 mm SM cod-end and SG20, with respect to the traditional 40 mm DM cod-end, increased the percentage of escaped individuals smaller than the MLS for most species (Table 15). The only exception was *Lophius* spp., since in this case both the mesh size and shape and the separation between bars in the grids were clearly not large enough to allow under-sized individuals to escape. This is a typical situation in multi-species fisheries throughout the world (Sainsbury, 1984; Liu *et al.*, 1985) and also in the Mediterranean, where trawl catches are contains many species with contrasting body sizes and shapes (e.g. Petrakis & Stergiou, 1997). Similar results have been obtained by comparing 40 mm DM, 50 mm DM and 40 mm SM cod-ends (Zapata, 2015;Table 16).

Table 15: Percentage of number of undersized specimens retained in the cod-end of the bottom trawl (smaller than minimum landing size; %<MLS) and percentage of number of undersized specimens escaped, in relation to the total number of undersized specimens captured (%<MLS-ESC), by depth strata (SH: shelf; SL: slope), for different 40 mm mesh shape cod-ends (DM and SM) and sorting grids (SG15 and SG20) off Balearic Islands.

Species	MLS	Depth	Device	n	%<MLS	%<MLS-ESC
Lophius spp.	30	SH	DM	47	63.6	0.0
			SM	96	37.5	0.0
			SG15	89	83.2	0.0
			SG20	35	34.3	0.0
		SL	DM	242	70.0	0.0
			SM	146	78.2	0.0
			SG15	26	42.3	0.0
			SG20	30	40.0	0.0
Merluccius merluccius	20	SH	DM	106	26.4	3.6
			SM	129	21.7	39.3
			SG15	8409	56.8	5.9
			SG20	17338	68.7	22.8
		SL	DM	1680	11.7	11.2
			SM	1073	6.8	23.3
			SG15	309	0.6	0.0
			SG20	258	1.5	25
Mullus surmuletus	11	SH	DM	686	13.9	14.6
			SM	2031	9.3	74.7
			SG15	17	0.0	--
			SG20	13	0.0	--
Trachurus spp.	15	SH	DM	2899	19.5	36.2
			SM	3356	13.3	78.3
			SG15	4495	46.3	24.0
			SG20	2801	27.5	37.7
Nephrops norvegicus	20	SL	DM	2605	0.0	--
			SM	3858	0.0	--
			SG15	86	1.2	0
			SG20	95	0.0	--
Parapenaeus longirostris	20	SL	DM	20829	0.23	26.5
			SM	26827	0.0	--
			SG15	525	0.0	--
			SG20	491	0.0	--

Table 16: Percentage of individuals (%) under the Minimum Landing Size (MLS), established by European, National and Regional regulations, and under the length at first maturity (L_{50mat}), estimated in the Balearic Islands, using data from the scientific monitoring of the bottom trawl fleet, developed between 2009 and 2013. 40D: 40 mm diamond mesh cod-end; 50D: 50 mm-diamond mesh cod-end; 40S: 40 mm-square mesh cod-end. Fish: total length in cm; Crustaceans: carapace length in mm; Cephalopods: mantle length in cm. Adapted from Zapata (2015).

Species	MLS	% <MLS			L_{50mat}	% <L_{50mat}		
		40D	50D	40S		40D	50D	40S

Mullus surmuletus	11	1.9	0.6	0.7	15♂; 17♀[1]	52.5	53.9	39.5
Spicara smaris	11	3.7	4.1	0.7	11-13[2]	24.3	45.2	10.4
Merluccius merluccius	20	55.0	31.8	66.6	32[3]	97.8	97.0	98.3
Lepidorhombus boscii	15	42.4	60.5	81.4	11♂; 14♀[4]	33.1	56.8	70.6
Phycis blennoides	--				19♂; 20♀[5]	86.2	76.5	64.8
Scyliorhinus canicula	--				43♂; 44♀[6]	93.9	93.8	95.1
Galeus melastomus	--				44♂; 49♀[7]	99.9	99.5	100
Aristeus antennatus	--				19♂; 25♀[8]	25.4	25.7	25.7
Nephrops norvegicus	20	0.0	0.2	0.0	30[9]	17.9	21.1	10.2
Loligo vulgaris	--				16♂; 19♀[10]	96.4	94.9	97.7
Octopus vulgaris	--				8♂[11]	52.1	54.8	56.8

[1]Reñones et al. (1995); [2]Lozano-Cabo (1953); [3]Oliver (1993); [4]Vassilopoulou et al. (1997); [5]Rotllant et al. (2002); [6]Capapé et al. (2008a, 2008b); [7]Rey et al. (2005); [8]Guijarro et al. (2008); [9]Orsi-Relini et al. (1998); [10]Vila et al. (2010); [11]Minimum length of mature individuals from Quetglas et al. (1998)

On the whole, the change in the mesh geometry of the cod-end (from 40 mm DM to 40 mm SM) should benefit both the environment, by decreasing discards and hence the impact of the trawl gears on the ecosystems, and the trawl fishery. It would recover the exploitation pattern of the main target species in this fishery, which currently show clear symptoms of over-fishing[8], by reducing the fishing pressure on small fish, generating improvements in the state of these resources and benefits in their yield per recruit. Off north-eastern Iberian coast, Bahamon *et al.* (2007a) estimated an immediate reduction up to 20% in the yield per recruit of *M. merluccius* after the implementation, with an increment >50% within the following five years. During the first years of the last decade, this change in the mesh shape cod-end was also estimated as an efficient management measure to reduce the over-exploitation of this species in the Gulf of Lions, Northern Iberian coast and the Balearic Islands (GFCM, 2005b). In addition, the 40 mm SM cod-end has contributed to solve the above mentioned incongruence of the Council Regulation (EC) Nº 1967/2006 with respect to the MLS and the L_{50} for some target species of the bottom trawl fishery. This is the case of *Mullus* spp., *Nephrops norvegicus* and *Parapenaeus longirostris*, which estimated L_{50} with 40 mm SM cod-end (and also with SG20 for both crustaceans) are greater than their MLS (Table 4). However, these positive effects depend on the survival rate of the escaped individuals, but the only study on that topic has been developed in the eastern Mediterranean (Metin *et al.*, 2004) and there is no information in the western basin. In addition, for other target species such as *M. merluccius* the L_{50} with 40 mm SM is still far below its MLS and for most target species both L_{50} and MLS are smaller than their 50% length at first maturity (Table 6). In this sense, a lot of work is still needed to improve the management of the size selectivity of the Mediterranean bottom trawl fishery, which has been described as legally and ecologically unsuccessful (Stergiou *et al.*, 2009). Maybe there is not a single solution suitable for all species, and it could be necessary the use of multiple selection systems. The combination of mesh size/shape in the cod-end with grid systems and square mesh panels should be a potential solution.

[8]Communication from the Commission to the European Parliament and the Council Concerning a consultation on Fishing Opportunities for 2015 under the Common Fisheries Policy. Brussels, 26.6.2014, COM(2014) 388 final, 17pp.

8.3.6 Ecsosytem modelling of the West Mediterranean Case Study

8.3.6.1 Golfe of Lion

An application of the ISIS-Fish model will be developed in the context of the DiscardLess project in order to evaluate the combined impact of the management plan for the Mediterranean sea which is based on effort control and the implementation of the landing obligation. The fishery under study is the demersal trawler fishery targeting hake in the Gulf of Lion. The structure of the model will be defined according to the results of preliminary analyses of the fishery structure and dynamics. The fleets and the set of target species to describe as well as the spatial structuration to adopt will be determined. Then a model of fishing behavior including discard behavior will be developed and coupled to the ISIS-Fish model.

8.3.6.2 Balearic Islands

The Ecopath model covers the geographical sub-area 5 (Balearic Islands;Figure 19) established by the General Fisheries Commission for the Mediterranean (GFCM).

The model describes the three domains (pelagic, demersal and benthic) and the trophic structure and biomass flows from 50 to 800 meters depth. The model is composed of 55 functional groups (Table 17), including primary producers, detritus, sea snow and discards. Each group has species of similar size, habitat, diets, consumptions, mortalities and production. A total of 5 groups of fisheries were included: bottom trawl, small-scale, purse-sine, bottom long-line and surface long-line. The following information has been used for model construction: i) 1691 research papers; ii) 3 databases (24 bottom trawl surveys, sampling on board fishing vessels and daily sales bills); and iii) reports from two stock assessment working groups: GFCM and ICCAT.

According to the model trophic flows (Figure 26), discards are exclusively consumed by turtles, Audouin seagulls and other seabirds.

The Balearic Islands Ecopath model was developed in the framework of the Spanish national projects LIFE+ INDEMARES (LIFE07/NAT/E/000732) and IDEADOS (Plan Nacional; CTM2007-65844-C01-01/MAR). The model has been presented at the IDEADOS Workshop (Palma de Mallorca, Nov-2012; http://www.ba.ieo.es/ideados/index.php/cworkshop2), the XVII SIEBM Symposium (Gijón, Sept-2014; http://www.siebm.org/2012/) and is included in the LIFE+INDEMARES report (Moranta et al. 2014).

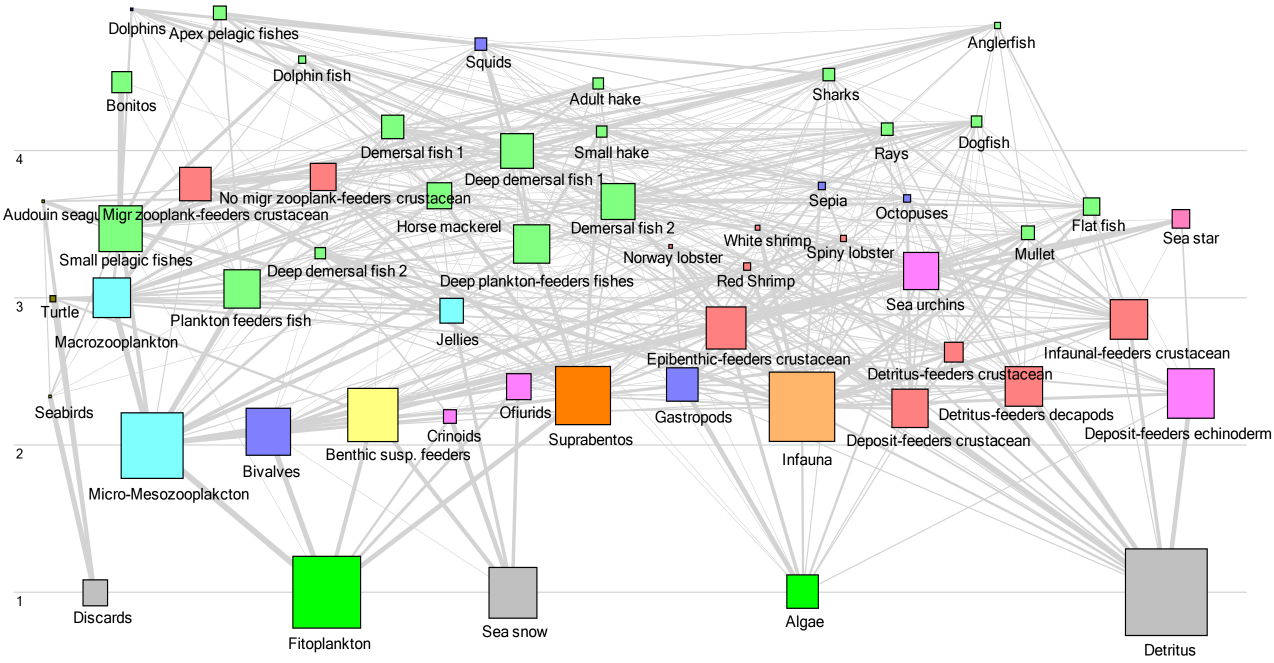


Figure 26: Trophic flows of the Ecopath model from the Balearic Islands.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 633680

1. Dolphins: *Tursiops truncatus, Stenella coeruleoalba*
2. Seabirds: *Calonectris diomedea, Hydrobates pelagicus, Phalacrocorax aristotelis, Puffinus mauretanicus*
3. Audouin seagull: *Larus audouinii*
4. Turtle: *Caretta caretta*
5. Apex pelagic fishes: *Thunnus thynnus, Xiphias glaucus*
6. Bonitos: *Sarda sarda, Auxis rochei*
7. Dolphin fish: *Coryphaena hippurus*
8. Anglerfish: *Lophius budegassa, Lophius piscatorius*
9. Adult hake: *Merluccius merluccius*
10. Small hake: *Merluccius merluccius*
11. Demersal fish 1: *Trisopterus minutus, Scorpaena elongata, Scorpaena porcus, Epinephelus spp., Zeus faber, Pagrus pagrus, Synodus saurus, Conger conger, Scorpaena scrofa, Pagellus acarne, Pagellus bogaraveo, Serranus cabrilla, Trachinus draco, Uranoscopus scaber, Syngnathus acus, Phycis phycis, Ophichthus rufus, Chelidonichthys gurnardus, Chelidonichthys lucerna, Balistes carolinensis, Ophidion barbatum*
12. Deep demersal fish 1: *Chlorophthalmus agassizi, Micromesistius poutassou, Helicolenus dactylopterus, Gadiculus argenteus argenteus, Symbolophorus veranyi, Epigonus spp., Phycis blennoides, Nemichthys scolopaceus, Chauliodus sloani, Stomias boa, Lampanyctus crocodilus, Hoplostethus mediterraneus, Lepidion lepidion, Mora moro, Nettastoma melanurum, Notacanthus bonaparte, Lepidopus caudatus, Trachyrincus scabrus, Molva dypterygia, Gaidropsarus biscayensis, Gnathophis mystax*
13. Demersal fish 2: *Trigla lyra, Lepidotrigla cavillone, Lepidotrigla dieuzeidei, Scorpaena loppei, Scorpaena notata, Dactylopterus volitans, Gobius niger, Odondebuenia balearica, Blennius ocellaris, Callionymus maculatus, Lesueurigobius friesii, Lesueurigobius sanzoi, Diplodus spp., Pagellus erythrinus, Serranus hepatus, Coris julis, Thalassoma pavo, Symphodus cinereus, Serranus scriba, Xyrichthys novacula, Chelidonichthys cuculus, Chelidonichthys lastoviza*
14. Mullet: *Mullus barbatus, Mullus surmuletus*
15. Flat fish: *Arnoglossus imperialis, Arnoglossus laterna, Arnoglossus rueppelii, Arnoglossus thori, Bothus podas, Citharus linguatula, Lepidorhombus boscii, Lepidorhombus whiffiagonis, Microchirus spp., Solea impar, Solea vulgaris, Symphurus nigrescens, Synaptura kleinii*
16. Deep demersal fish 2: *Argentina sphyraena, Nezumia aequalis, Polyacanthonotus rissoanus, Caelorinchus caelorhincus*
17. Plankton-feeders fish: *Capros aper, Macroramphosus scolopax, Deltentosteus quadrimaculatus, Crystallogobius linearis, Pomatoschistus spp., Aphia minuta, Spondyliosoma cantharus, Spicara maena, Spicara smaris, Centracanthus cirrus, Chromis chromis, Anthias anthias, Cepola macrophthalma*
18. Deep plakton-feeders fish: *Mictófidos*
19. Small pelagic fish: *Engraulis encrasicolus, Sardina pilchardus, Sardinella aurita, Boops boops*
20. Horse mackerel: *Scomber scombrus, Trachurus* spp.
21. Rays: *Leucoraja circularis, Leucoraja naevus, Raja asterias, Raja brachyura, Raja clavata, Raja miraletus, Raja montagui, Raja polystigma, Raja radula, Raja rondeleti, Raja undulata, Dipturus oxyrinchus, Myliobatis aquila, Dasyatis pastinaca*
22. Sharks: *Squalus acanthias, Centrophorus granulosus, Dalatias licha, Mustelus mustelus, Torpedo marmorata, Etmopterus spinax, Galeus melastomus*
23. Dogfish: *Scyliorhinus canicula*
24. Squids: *L. forbesi, L. vulgaris, I. coindetii, T. sagittatus, H. reversa, H. bonnellii, A. media*
25. Sepia: *S. officinalis, S. elegans, S. orbignyiana, Sepietta oweniana*
26. Octopuses: *E. cirrhosa, S. unicirrhus, P. tetracirrhus, O. salutii, B. sponsalis, E. moschata, O. vulgaris*
27. Gasteropods: *Aporrhais pespelicani, Aporrhais serresianus, Astraea rugosa, Bolinus brandaris, Calliostoma spp., Cancellaria cancellata, Cassidaria tyrrhena, Cymatium corrugatum, Euspira fusca, Fusinus rostratus, Lunatia sp., Natica spp, Phalium undulatum, Ranella olearia, Turritella spp., Xenophora crispa*
28. Bivalve: *Acanthocardia tuberculata, Aequipecten opercularis, Anadara diluvii, Anomia ephippium, Callista chione, Chlamys oppercularis, Chlamys varia, Glossus humanus, Glycimeris sp., Laevicardium oblongum, Mytilus edulis, Mytilus galloprovincialis, Ostrea edulis, Pecten maximus, Pinna nobilis, Pteria hirundo, Pycnodonte cochlear, Venus verrucosa*
29. Red shrimp: *Aristeus antennatus*
30. Norway lobster: *Nephrops norvergicus*
31. Spiny lobster: *Palinus* spp.
32. White shrimp: *Parapenaeus longirostris*
33. Epibenthic-feeders crustaceans: *Acanthonyx, Bathynectes, Eriphia, Eualus, Gnathophyllum, Herbstia, Homola, Inachus, Lambrus, Ligur, Liocarcinus, Maja, Macropipus, Macropodia, Maja, Paractaea, Paromola, Parthenope, Pilumnus, Pisa, Polycheles, Portunidae, Squilla, Stomatopoda, Xantho*
34. Infaunal-feeders crustaceans: *Acanthonix, Achaeus, Atelecyclus, Calappa, Chlorotocus, Crangon, Corystes, Ebalia, Ethusa, Eucrate, Eurinome, Geryon, Gnathophyllum, Goneplax, Ilia, Lysmata, Medorippe, Monodaeus, Palaemonidae, Palicus, Philocheras, Pontocaris, Pontophilus, Processa, Sicyonia, Solenocera, Thia*
35. Migr. zooplank-feeders crustaceans: *Acanthephyra, Gennades, Oplophoridae, Pasiphaea, Sergestes, Sergia*
36. No migr. zooplank-feeders crustaceans: *Aristaeomorpha, Plesionika*
37. Detritus-feeders decapods: *Dardanus, Diogenes, Dromia, Galathea, Munida, Paguristes, Pagurus*
38. Deposit-feeders crustaceans: *Alpheus, Brachynotus, Callianassa, Thoralus, Upogebia, Calocaris, Jaxea, Thalassinidea*
39. Detritus-feeders shrimps: *Lophogaster, Pandalina, Palaemon, Nebalia*
40. Sea star: *Astropecten, Chaetaster, Anseropoda, Echinaster, Hacelia, Marthasterias, Luidia*
41. Sea urchins: *Centrostephanus, Cidaris, Echinus, Paracentrotus*
42. Ofiurids: *Ophiura, Ophiocomina, Ophioderma…*
43. Deposit-feeders echinoderms: *Holothuria, Stichopus, Spatangus…*
44. Crinoids: *Antedon mediterránea, Leptometra phalangium*
45. Benthic susp. Feeders: Poriphera, Ascidians, cnidarios, briozoos…
46. Infauna: Anfipods, polyquetos, isopods…
47. Suprabenthos: Eufausiaceos, misidaceos, anfipodos…
48. Jellies: Jelly fi
49. Macrozoopla
50. Micro-Mesoz ostracods
51. Phytoplankto
52. Algae: *Cystos*
53. Discards
54. Sea snow
55. Deposit detri

Table 17: Functional groups used in the Balearic Islands Ecopath model.

8.3.7 References

Aldebert Y. and C. Carriers.- 1990. Application des populations virtuelles au stock de merlu du Golf du Lion. Impacte de modifications de regime d'exploitation. *FAO Rapp. Pech.*, 447: 143-150.

Ateş C., Deval M.C., Bök T.and Z. Tosunoğlu.- 2010. Selectivity of diamond (PA) and square (PE) mesh codends for commercially important fish species in the Antalya Bay, eastern Mediterranean. *J. Appl. Ichthyol.*, 26: 465-471.

Aydin C. and Z. Tosunoglu.- 2009. Selectivity of square and hexagonal mesh codends for the deep water rose shrimp, *Parapenaeus longirostris* (Lucas, 1846) (Decapoda, Penaeidae) in the Aegean Sea. *Crustaceana*, 82: 89-98.

Aydın C. and Z. Tosunoglu.- 2010. Selectivity of diamond, square and hexagonal mesh codends for Atlantic horse mackerel *Trachurus trachurus*, European hake *Merluccius merluccius*, and greater forkbeard *Phycis blennoides* in the eastern Mediterranean. *J. Appl. Ichthyol.*, 26: 71-77.

Aydin C., Tokaç A., Ulaş A., Maktay B. and T. Şensurat.- 2011. Selectivity of 40 mm square and 50 mm diamond-mesh codends for five species in the Eastern Mediterranean demersal trawl fishery. *Afr. J. Biotechnol.*, 10: 5037-5047.

Bahamon N., F. Sardà and P. Suuronen.- 2006. Improvement of trawl selectivity in the NW Mediterranean demersal fishery by using a 40 mm square mesh codend. *Fish. Res.*, 81: 15-25.

Bahamon, N., Sardá F. and P. Suuronen.- 2007a. Potential benefits from improved selectivity in the northwest Mediterranean multispecies trawl fishery. *ICES J. Mar. Sci.*, 64: 757-760.

Bahamon N., F. Sardà and P. Suuronen.- 2007b. Selectivity of a flexible size-sorting grid in Mediterranean multi-species trawl fishery. *Fish. Sci.*, 73(6): 1231-1240.

Baro J. and I. Muñoz de los Reyes.- 2007. Comparación de los rendimientos pesqueros y la selectividad del arte de arrastre empleando malla cuadradas y rómbicas en el copo. *Inf. Téc. Int. Eps. Oceanogr.*, 188: 1-23.

Belcari P. and C. Viva.- 2005. Study on the effects of fitting square-mesh sections to the selectivity of demersal trawling in Northern Tyrrhenian Sea (western Mediterranean). In: GFCM Workshop on standardization of selectivity methods applied to trawling in the Mediterranean Sea. *FAO Fish. Rep.*, 820: 28-29.

Bellido J.M., Carbonell A., García-Rodríguez M., García T. and M. González.- 2014. The obligation to land all catches: consequences for the Mediterranean. European Union, 46 pp.

Bozzano A. and F. Sardà.- 2002. Fishery discard consumption rate and scavenging activity in the northwestern Mediterranean sea. *ICES J. Mar. Sci.* 59: 15–28.

Capape C., Vergne Y., Reynaud C., Guelorget O. and J.P. Quignard.- 2008a. Maturity, fecundity and occurrence of the smallspotted catshark *Scyliorhinus canicula* (Chondrichthyes: Scyliorhinidae) off the Languedocian coast (southern France, north-western Mediterranean). *Vie et Milieu*, 58: 47–55.

Capape C., Reynaud C., Vergne Y. and J.P. Quignard.- 2008b. Biological observations on the smallspotted catshark *Scyliorhinus canicula* (Chondrichthyes: Scyliorhinidae) off the Languedocian coast (southern France, northern Mediterranean). *Pan Am. J. Aquat. Sci.*, 3: 282-289.

Carbonell A., Martín P., de Ranieri S. and WEDIS team.- 1997. Discards of the Western Mediterranean Trawl Fleets. Contract Nº MED 94/027. Final Report, 145 pp.

Carlucci G., G. D'Onghia, L. Sion, P. Maiorano and A. Tursi.- 2006. Selectivity parameters and size at first maturity in deep-water shrimps, *Aristaeomorpha foliacea* (Risso, 1827) and *Aristeus antennatus* (Risso, 1816), from the North-Western Ionian Sea (Mediterranean Sea). *Hydrobiologia*, 557: 145-154.

D'Onghia G., F. Mastrototaro, P. Maiorano and M. Basanisi.- 1998. Selettività della rete a strascico utilizzata sui fondi di scarpata (250-750 m) dello Ionio (Mediterranean Centrale). *Biol. Mar. Medit.*, 5: 437-448.

Dremière P.Y.- 1979. Parametres biologiques et dynamiques disponibles sur les principaux stocks halieutiques du Golfe du Lion: sous zone 37-2 du CGPM. *FAO Rapp. Pech.*, 227: 115-122.

Estrada M.- 1996. Primary production in the northwestern Mediterranean. *Sci. Mar.* 60: 55-64.

García-Rodríguez M. and A.M. Fernández.- 2005. Influencia de la geometría de la malla del copo en las capturas, la selectividad y el rendimiento de algunas especies de peces comerciales en el golfo de Alicante (sureste de la península Ibérica). *Inf. Téc. Inst. Esp. Oceanogr.*, 185: 1-26.

GFCM. 2001.- General Fisheries Commission for the Mediterranean. Report of the Twenty-sixth Session. Lacco Ameno (Ischia, Italy), 10-13 September 2001. GFCM Report 26: 1-27.

GFCM.- 2005a. Report on ATSELMED Workshop. Sète (France), 9-11 February 2005, 14 pp.

GFCM.- 2005b. Report of the Meeting of the 7th SAC Sub-Committee on Stock Assessment (SCSA). Rome (Italy), 26-30 September 2005, 44 pp.

GFCM.- 2007. SCSA/SCESS/SCSI Transversal Workshop on Selectivity in the Mediterranean trawl fisheries. Barcelona (Spain), 2-4 April 2007, 34 pp.

GFCM.- 2008. SCMEE/SCESS/SCSA Transversal Working Group on Selectivity. Sète (France), 2-4 July 2008, GFCM:SAC11/2008/Inf.16, 20 pp.

GFCM.- 2010. Transversal workshop on selectivity improvement, by-catch reduction and alternative gears. Alexandria (Egypt), 25-27 October 2010, GFCM:SAC13/2011/..., 16 pp.

Guijarro B. and E. Massutí.- 2006. Selectivity of diamond- and square-mesh codends in the deepwater crustacean trawl fishery off the Balearic Islands (western Mediterranean). ICES J. Mar. Sci. 63, 52-67.

Guijarro B., Massutí E., Moranta J. and P. Díaz.- 2008. Population dynamics of the red shrimp *Aristeus antennatus* in the Balearic Islands (western Mediterranean): Short spatio-temporal differences and influence of environmental factors. *J. Mar. Syst.*, 71: 385–402.

Johnsen J. P. and S. Eliasen.- 2011. Solving complex fisheries management problems: what the EU can learn from the Nordic experiences of reduction of discards. *Mar. Pol.,* 35: 130–139.

Liu H.C., K.J. Sainsbury and T.S. Chiu.- 1985, Trawl cod-end mesh selectivity for some fishes of North-Western Australia. *Fish. Res.*, 3: 105-129.

Lozano-Cabo F.- 1953. Monografía de los cantracántidos mediterráneos, con un estudio especial de la biometría biología y anatomía de *Spicara smaris* (L.). *Boletín del Instituto Español de Oceanografía*, 59: 1-126.

Lucchetti A.- 2008. Comparison of diamond- and square-mesh codends in the hake (*Merluccius merluccius* L. 1758) trawl fishery of the Adriatic Sea (central Mediterranean). *Sci. Mar.*, 72: 451-460.

MacLennan D.N. (Editor).- 1992. Fishing gear selectivity. *Fish. Res.*, 13: 201-352.

Mallol S., M. Casadevall and E. García.- 2001. Comparison of discarded, escaped and landed fish using diamond and square mesh codends. *Rapp. Comm. Int. Mer Médit.*, 36: 296.

Mallol S.- 2005. Anàlisi dels descartaments efectuats per la flota d'arrossegament en el Golf de Lleó. PhD Thesis. Univ. Girona, Spain, 279pp.

Martínez-Abraín A., Maestre R. and D. Oro.- 2002. Demersal trawling waste as a food source for western Mediterranean seabirds during the summer. *ICES J. Mar. Sci.,* 59: 529-537.

Massutí E. and B. Guijarro.- 2004. Recursos demersales en los fondos de arrastre de la plataforma y el talud de Mallorca y Menorca (Illes Balears). Resultados de las campañas BALAR0401 y BALAR0901. *Inf. Tec. Inst. Esp. Oceanogr.,* 182: 132 pp.

Massutí E., F. Ordines and B. Guijarro.- 2009. Efficiency of flexible sorting grids to improve size selectivity of bottom trawl in the Balearic Islands (western Mediterranean), with comparison to a change in mesh cod-end geometry. *Journal of Applied Ichthyology,* 25: 153-161.

Massutí E., M.Á. Zapata, B. Guijarro, E.M. Vidal, J. Sintes, G. Picó, I. Uranga and F. Ordines.- 2014. New selectivity data for Spanish bottom trawl nets (GSA05) with square mesh panels of thinner, lighter and wider netting without knots in the upper plan. Deliverable 3.7 Proyecto DISCATCH (DG MARE European Commission, Contract Nº MARE/2012/24 Lot 2), 40 pp.

Massutí E., M.Á. Zapata, I. Uranga, G. Picó, B. Guijarro and F. Ordines.- 2015. Informe del Instituto Español de Oceanografía a la Confederación Española de Pesca (CEPESCA) sobre la asistencia técnica para el seguimiento científico de las campañas piloto del proyecto TORZAL "Mejora de la selectividad de los artes de arrastre en el Mediterráneo español", financiado por el Fondo Europeo de la Pesca, a través de la Fundación Biodiversidad (Ref: 20124302). Instituto Español de Oceanografía, 82 pp.

Metin C., Tokac A.¸ Ulas A., Düzbastılar F.O., Lök A., Ozbilgin H., Metin G., Tosunoğlu Z., Kaykac H. and C. Aydın.- 2004. Survival of red mullet (*Mullus barbatus* L., 1758) after escape from a trawl codend in the Aegean Sea. *Fish. Res.*, 70: 49-53.

Moranta, J., Barberá, C., Druet, M., Zaragoza, N., (Editores). 2014. Caracterización ecológica de la plataforma continental (50-100 m) del canal de Menorca. Informe final área LIFE+ INDEMARES

(LIFE07/NAT/E/000732). Instituto Español de Oceanografía-Centro Oceanográfico de Baleares (Palma). Coordinación: Fundación Biodiversidad, Palma, 504 pág.

Mytilineou, C., C.-Y. Politou and A. Fortouni.- 1998. Trawl selectivity studies on *Nephrops norvegicus* (L.) in the eastern Mediterranean Sea. *Sci. Mar.*, 62 (Suppl. 1): 107-116.

Oliver P.- 1993. Analysis of fluctuations observed in the trawl fleet landings of the Balearic Islands. *Sci. Mar.*, 57: 219-227.

Ordines F., Massutí E., Guijarro B. and R. Mas.- 2006. Diamond vs. square mesh codend in a multi-species trawl fishery of the western Mediterranean: effects on catch composition, yield, size selectivity and discards. *Aquat. Living Resour.,* 19: 329-338.

Orsi Relini L., Zamboni A., Fiorentino F. and D. Massi.- 1998. Reproductive patterns in Norway lobster *Nephrops norvegicus* (L.), (Crustacea Decapoda Nephropidae) of different Mediterranean areas. *Sci. Mar.*, 62: 25-41.

Petrakis G. and K.I. Stergiou.- 1997. Size selectivity of diamond and square mesh codends for four commercial Mediterranean fish species. *ICES J. Mar. Sci.*, 54: 13-23.

Quetglas A., Alemany F., Carbonell A., Merella P. and P. Sánchez.- 1998. Biology and fishery of *Octopus vulgaris* Cuvier, 1797, caught by trawlers in Mallorca (Balearic Sea, Western Mediterranean). *Fish. Res.*,36: 237-249.

Quetglas A., Guijarro B., Ordines F. and E. Massutí.- 2012. Stock boundaries for fisheries assessment and management in the Mediterranean: the Balearic Islands as a case study. *Sci. Mar.* 76: 17-28.

Ragonese S., M. Zagra, L. Di Stefano and M.L. Bianchini.- 2001. Effect of codend mesh size on the performance of the deep-water bottom trawl used in the red shrimp fishery in the Strait of Sicily (Mediterranean Sea). *Hydrobiologia*, 449: 279-291.

Ragonese, S., M.L. Bianchini and L. Di Stefano.- 2002. Trawl cod-end selectivity for deepwater red shrimp (*Aristaeomorpha foliacea*, Risso, 1827) in the Strait of Sicily (Mediterranean Sea). *Fish. Res.*, 57: 131-144.

Ragonese S. and M.L. Bianchini.- 2006. TRawl selectivity trials on the deep-water rose shrimp (*Parapenaeus longirostris*) in Sicilian waters. *Hidrobiología*, 557: 113-119.

Reñones O., Massutí E. and B. Morales-Nin.- 1995. Life-history of the red mallet *Mullus Surmuletus* from the bottom trawl fishery off the island of Majorca (North-west Mediterranean). *Mar. Biol.*, 23, 411-419.

Rey J., Gil de la Sola L. and E. Massutí.- 2005. Distribution and biology of the blackmouth catshark *Galeus melastomus* in the Alboran Sea (southwestern Mediterranean). *J. Northwest Atl. Fish. Sci.*, 35: 215-223.

Rotllant G., Moranta J., Massutí E., Sardà F. and B. Morales-Nin.- 2002. Reproductive biology of three gadiform fish species through the Mediterranean deep-sea range (147-1850 m). *Sci. Mar.*, 66: 157-166.

Sainsbury K.I.- 1984. Optimal mesh size for tropical multispecies trawl fisheries. *J. Con. Int. Explor. Mer*, 41: 129-139.

Sala A., Priour D. and B. Herrmann.- 2006. Experimental and theoretical study of red mullet (*Mullus barbatus*) selectivity in codends of Mediterranean bottom trawls. *Aquat. Living Resour.*, 19: 317-327.

Sala A., Lucchetti A. and G. Buglioni.- 2007. The influence of twine thickness on the size selectivity of polyamide codends in a Mediterranean bottom trawl. *Fish. Res.*, 83: 192-203.

Sala A., Luchetti A., Piccinetti C. and M. Ferretti.- 2008. Size selection by diamond- and square-mesh codends in multi-species Mediterranean demersal trawl fisheries. Fish. Res., 93: 8-21.

Sala A. and A. Lucchetti.- 2010. The effect of mesh configuration and codend circumference on selectivity in the Mediterranean trawl *Nephrops* fishery. *Fish. Res.*, 103: 63-72.

Sala A. and A. Lucchetti.- 2011a. Effect of mesh size and codend circumference on selectivity in the Mediterranean demersal trawl fisheries. *Fish. Res.*, 110: 252-258.

Sala A., Lucchetti A. and M. Affronte.- 2011b. Effects of Turtle Excluder Devices on bycatch and discard reduction in the demersal fisheries of Mediterranean Sea. *Aquat. Living Resour.*, 24: 183–192.

Sánchez P.- 2000. The impacts of bottom trawling in the Mediterranean. WWF Workshops on Ecosystem Approach & Integrating Fisheries and Conservation Frameworks.

Sánchez P., Demestre M. and P. Martín.- 2004. Characterisation of the discards generated by bottom trawling in the northwestern Mediterranean. *Fish. Res.*, 67: 71-80.

Sardà, F., G.Y. Conan and X. Fusté.- 1993. Selectivity of Norway lobster *Nephrops norvegicus* (L.) in the northwestern Mediterranean. *Sci. Mar.*, 57(2-3): 167-174.

Sardà F., B. Molí and I. Palomera.- 2004. Preservation of juvenile hake (*Merluccius merluccius*, L.) in the western Mediterranean demersal trawl fishery by using sorting grids. *Sci. Mar.*, 68(3): 435-444.

Sardà F., N. Bahamón, F. Sardà-Palomera and B. Molí.- 2005. Commercial testing of a sorting grid to reduce catches of juvenile hake (*Merluccius merluccius*) in the western Mediterranean demersal trawl fishery. *Aquat. Living Resour.*, 18: 87-91.

Sardà F., N. Bahamon, B. Molí and F. Sardà-Palomera.- 2006. The use of a square mesh codend and sorting grids to reduce catches of young fish and improve sustainability in a multispecies bottom trawl fishery in the Mediterranean. *Sci. Mar.*, 70(3): 347-353.

Stergiou K.I., G. Petrakis and C.-Y. Politou.- 1997a. Size selectivity of diamond and square mesh cod-ends for *Nephrops norvegicus* in the Aegean Sea. *Fish. Res.*, 29: 203-209.

Stergiou K.I., C.-Y. Politou, E.D. Christou and G. Petrakis.- 1997b. Selectivity experiments in the NE Mediterranean: the effect of trawl codend mesh size on species diversity and discards. *ICES J. Mar. Sci.*, 54: 774-786.

Stergiou K.I., Moutopoulos D.K. and G. Armentis.- 2009. Perish legally and ecologically: the ineffectiveness of the minimum landing sizes in the Mediterranean Sea. *Fish. Manage. Ecol.*, 16: 368-375.

Tosunoğlu Z., Aydın C. and O. Özaydın.- 2008. Selectivity of a 50-mm diamond-mesh knotless polyethylene codend for commercially important fish species in the Aegean Sea. *J. Appl. Ichthyol.*, 24: 311-315.

Tosunoğlu Z., Aydın C., Salman A. and P. Fonseca.- 2009. Selectivity of diamond, hexagonal and square-mesh codends for three commercial cephalopods in the Mediterranean. *Fish. Res.*, 97: 95-102.

Tsagarakis K., Palialexis A. and V. Vassilopoulou.- 2014. Mediterranean fishery discards: review of the existing knowledge. *ICES J. Mar. Sci.*, 71(5): 1219–1234.

Tudela S.- 2004. Ecosystem effects of fishing in the Mediterranean: an analysis of the major threats of fishing gear and practices to biodiversity and marine habitats. *Studies and Reviews. General Fisheries Commission for the Mediterranean*, 74: 1-44.

Vassilopoulou V., Ondrias I. and C. Papaconstantinou.- 1997. Data on the sexual maturity of the flatfish *Lepidorhombus boscii* (Risso) in the northeastern Mediterranean Sea (Greece). *Proceedings of the American Fisheries Society Annual Meeting*, 127: 42-43.

Vila Y., Silva L., Torres M.A. and I. Sobrino.- 2010. Fishery, distribution pattern and biological aspects of the common European squid *Loligo vulgaris* in the Gulf of Cadiz. *Fish. Res.*, 106: 222-228.

Wileman D.A., R.S.T. Ferro, R. Fonteyne and R.B. Millar (Editors).- 1996. Manual of methods of measuring the selectivity of towed fishing gears. *ICES Coop. Res. Rep.*, 215: 64 pp.

Zapata M. Á.- 2015. A comparative analysis of the bottom trawl fleet catches off Mallorca lsland (western Mediterranean) with three different mesh types. Master Thesis, Universitat de les Illes Balears, 54 pp.