Fisheries Research 102 (2010) 123–129

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Elasmobranch bycatch in a trammel net fishery in the Portuguese west coast

Filipa Baeta[a,*], Marisa Batista[a], Anabela Maia[b], Maria José Costa[a], Henrique Cabral[a]

[a] *Universidade de Lisboa, Faculdade de Ciências, Instituto de Oceanografia, Campo Grande, 1749-016 Lisboa, Portugal*
[b] *University of Rhode Island, Department of Biological Sciences, 120 Flagg Road, Kingston, RI, USA*

ARTICLE INFO

Article history:
Received 21 May 2009
Received in revised form 27 October 2009
Accepted 27 October 2009

Keywords:
Elasmobranch
Trammel nets
Bycatch
Discards
Portuguese artisanal fisheries

ABSTRACT

Elasmobranchs are an important bycatch component in Portuguese artisanal fisheries, but there are no management or monitoring programs in place yet. This study analysed elasmobranch catches in a Portuguese west coast trammel net fishery. Thirty-seven sampling surveys were conducted aboard commercial fishing vessels on a seasonal basis between October 2004 and August 2005. A total of 11 elasmobranch species were caught (seven Rajiformes, two Torpediniformes and two Carchariniformes), representing 4% of total catches and 15% of total weight. *Raja clavata* was the most important species in number (7.4 ind 10,000 m^{-1} of net) and *Raja undulata* the most important in weight (8512.4 g 10,000 m^{-1} of net). Discards represented 7.8% of total catch in weight, but 24.8% in number of specimens caught. Seven elasmobranch species were commonly discarded. There was a marked seasonality in elasmobranch catches, with lowest species richness registered in spring (four species) and highest in autumn (11 species). For the most abundant species depth range preferences were assessed.

1. Introduction

Worldwide, there is an increasing concern over the capture of elasmobranchs as bycatch and the need for management. According to FAO statistics, in 2007 global catches of the "sharks, rays and chimaeras" group were 780,000 t. In addition it is thought that unreported bycatches of these species might be very high (Bonfil, 1994). Chondrichthyes bycatch is unmanaged in most fisheries and elasmobranchs are less able to sustain their populations under fishing pressures that are sufficient to sustain target teleost and invertebrate species (Heuter, 1998) due to slow growth, late maturity, long life spans, low fecundity and close relationship between recruitment and parental stock of elasmobranchs (Stevens et al., 2000). These characteristics make them extremely vulnerable to over-exploitation (Stevens et al., 2000). In addition, most elasmobranchs are predators at, or near, the top of marine food webs, playing a fundamental role in the ecosystem trophic relationships (Cortés, 1999; Stevens et al., 2000). Today large predatory fish biomass, including elasmobranchs, is only about 10% of pre-industrial fishing levels (Myers and Worm, 2003). Apex predators' elimination leads to top-down effects in marine trophic webs and to community restructuring (Myers et al., 2007). All these aspects make it very important to increase knowledge and to ensure proper management of these species.

The main problem in the assessment and management of elasmobranch fisheries is the lack of basic biological information and appropriate fisheries databases (Pawson and Vince, 1999). A preliminary evaluation of the status of shark species worldwide showed that there had been severe population declines for almost all the 26 shark species for which catch or landing data had been available for more than 10 years (Castro et al., 1999). Once overfished many elasmobranch populations would take several years to recover (Stevens et al., 2000). One additional difficulty in management is that there are still problems with the correct identification of these less known species, mainly due to their low economic value (Stevens et al., 2000). Less than 15% of total chondrichthyan landings were identified to species level in 1998 and 45% were landed as 'chondrichthyans'; in addition, a total of over 10 million tonnes of world fisheries landings were identified as miscellaneous marine fish, of which some are likely to be sharks (FAO, 2002).

Elasmobranchs are a significant component of bycatches of Portuguese artisanal fisheries (Coelho et al., 2005; Correia and Smith, 2003; Erzini et al., 2002; Machado et al., 2004). Since part of this bycatch is discarded and never accounted for official fisheries statistics, it is very difficult to gather information on the impact of these fisheries on elasmobranch populations. In addition, there are no management or monitoring programs in place yet.

Trammel nets are highly represented in the Portuguese artisanal fisheries. This fishing gear is included in various métiers, which are characterized by different combinations of mesh sizes, fishing grounds, fishing time, season, markets and consequently target species (Borges et al., 2001; Stergiou et al., 2006). Although trammel nets are fairly size selective (FAO, 2000; Fabi et al., 2002), they cap-

* Corresponding author. Tel.: +351 217500826; fax: +351 217500207.
E-mail address: afbaeta@fc.ul.pt (F. Baeta).

0165-7836/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.fishres.2009.10.016

ture a high diversity of species, most of them non-target species (Batista et al., 2009). Among these non-target species, there are both non-commercial discarded species, and commercial species, that are retained and landed.

Discarding can affect biodiversity and community structure (Kelleher, 2005). There is an urgent need to evaluate discarding practices and to quantify discard composition and mortality in order to understand the impacts at the population, community and ecosystem levels (Hall et al., 2000; Borges et al., 2001) and contribute to better technical measures (Gonçalves et al., 2007).

There are not many studies in Portugal on the impact of trammel net fisheries and the existing ones were mainly concentrated on the southern coast of mainland (Erzini et al., 1997, 2002, 2006; Borges et al., 2001; Gonçalves et al., 2007, 2008). As for studies on bycatch and discards of elasmobranchs there are some worldwide (e.g. Carbonell et al., 2003; Fernandez et al., 2005; McKinnell and Seki, 1998; Revill et al., 2005; Shepherd and Myers, 2005), but in Portugal few works have been conducted (Coelho et al., 2005; Coelho and Erzini, 2008). In the past few years elasmobranch catches have been decreasing in Portugal, which might indicate that these species are being over-exploited (Coelho et al., 2005). This article presents the results of the research carried out by observers on board trammel net fishing vessels working in the Portuguese west coast. The main objective of this study was to analyse elasmobranch catches and discards and to increase management-relevant information on species characteristics, abundance and distribution.

2. Materials and methods

Samplings were carried out aboard commercial fishing vessels from two of the most important fishing harbours of the Portuguese west coast, Setúbal and Sesimbra, between October 2004 and August 2005. Data from a total of 37 fishing trips, 18 in Sesimbra and 19 in Setúbal, were collected in a seasonal basis—9 in autumn, 8 in winter, 10 in spring and 10 in the summer. The sampling area is located off the Portuguese central coast, within 38° and 39° North and 8° and 10° West, from 0.25 to 6 nautical miles off the coast, at depths ranging between 10 and 115 m, approximately (Fig. 1).

Ten trammel net vessels were chosen randomly and sampled: four from Sesimbra and six from Setúbal (overall length between 10 and 14 m). In each survey, observers accompanied commercial fishers during one full-day fishing trip (ca. 10 h). Vessels left the fishing harbour before sunrise, heading for the fishing grounds, where the nets had been set during the last fishing trip, and usually began to retrieve their nets at sunrise. A total of 136 bottom trammel net sets were sampled, which corresponded to 204 km in length. All trammel nets sampled had the same characteristics: 3 panels made of polyethylene, 1.5–2.5 m deep and ca. 40 m long and mesh size of the inner panel equal to 100 mm (minimum allowed by Portuguese legislation). Trammel net sets were usually composed of a large number of these sheets (usually more than 2000 m long), with a gap of ca. 1 m between consecutive sheets. Net sets were anchored at each end on the sea bottom. Senegalese sole, *Solea senegalensis* Kaup, 1858, common sole, *Solea solea* (Linnaeus, 1758) and cuttlefish, *Sepia officinalis* Linnaeus, 1758 are the target species of this fishery. After retrieving each net, specimens are untangled from the net by fishermen who decide whether they are retained or discarded. Those retained were identified and their total length, width of disc of skates and rays (to the nearest millimetre) and weight (to the nearest 5 g). The specimens were separated accordingly if they were to be marketed or for fishermens' personal consumption. As most of the individuals were dead when they were untangled from the nets, discards were preserved in ice and brought to the laboratory to be identified, measured and weighed. The discarded individuals that remained alive were processed on board and returned to the sea. Additional data, as net length, haul location and depth, soak time and number of sheets in each set was also recorded.

For elasmobranch species, total catches and CPUE (Capture Per Unit of Effort, number and weight per 10,000 m of net) per species were determined. Estimates were made of the discards, retained portion of catches for sale and for the fishermen's own consumption at the species level. For the most important species in number (*Raja brachyura*, *Raja undulata*, *Raja clavata* and *Raja miraletus*), the existence of significant differences among lengths of the individuals retained and discarded was analysed using the *t*-test or Mann–Whitney test ($\alpha = 0.05$).

The total annual amount of elasmobranch discards from this trammel net fishery was estimated as the sum of the four seasons elasmobranch discards in each fishing harbour. The amount of elasmobranchs discarded in each season was estimated based on mean number of individuals and mean weight discarded per vessel in each fishing day combined with fishing effort in the sampled area (fishing days per year and total number of vessels).

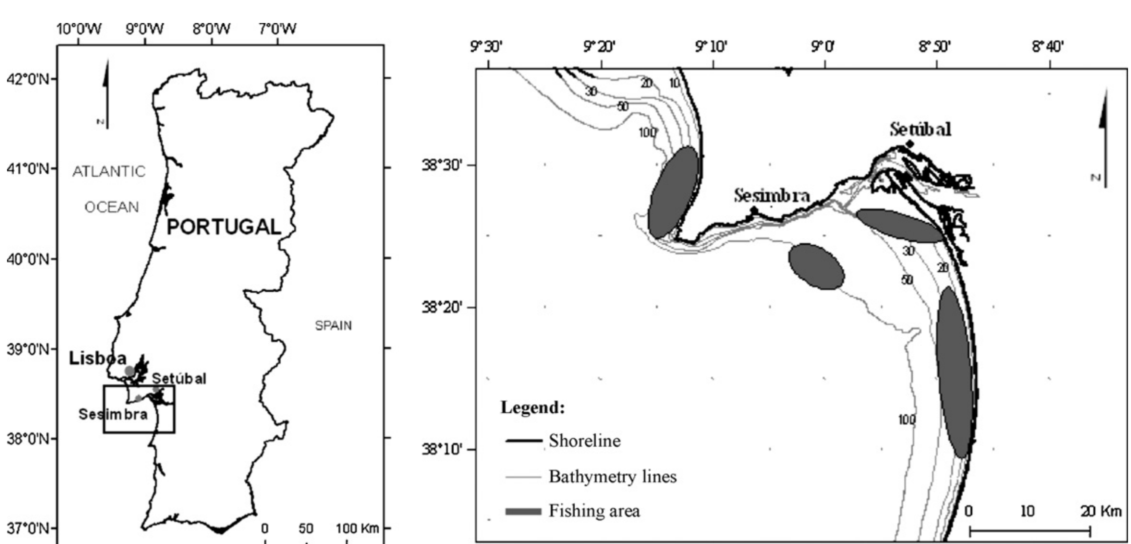

Fig. 1. Map of the study area with the location of the fishing sites surveyed.

CPUE by season (autumn, winter, spring, summer) and by depth intervals (0–25 m, 25–50 m, >50 m) were estimated for the most abundant elasmobranch species (*R. undulata*, *R. brachyura* and *R. clavata*). The depth range considered was limited to 0–125 m, the maximum depth sampled in this study. Analyses of variance (Kruskal–Wallis statistic, with Dunn's test as a posteriori statistics) were performed to test the significance between CPUE at different depths ($\alpha = 0.05$) and to test differences in CPUE among seasons ($\alpha = 0.05$).

3. Results

A total of 11 elasmobranch species (428 specimens; 479 kg) were caught, seven Rajiformes, two Torpediniformes and two Carchariniformes, accounting for 4% of the total catches in number and 15% in weight. All elasmobranchs caught were identified to the species level, except for three individuals that could only be identified as *Raja* spp., due to advanced decomposition. *R. clavata* Linnaeus, 1758 was the most abundant species comprising 35.0% of all elasmobranchs (7.4 ind 10,000 m^{-1} of net), followed by *R. undulata* Lacepède, 1802 (20.1%; 4.2 ind 10,000 m^{-1}) and *R. miraletus* Linnaeus, 1758 (19.4%; 4.1 ind 10,000 m^{-1}), as described in Table 1. However, considering values of biomass caught, *R. undulata* was the most important species (comprising 34.9% of total elasmobranch weight; 8512.4 g 10,000 m^{-1}), followed by *R. clavata* (27.2%; 6403.7 g 10,000 m^{-1}) and *R. brachyura* Lafont, 1873 (24.8%; 5846.7 g/10,000 m^{-1}) (Table 1).

The main fraction of elasmobranchs caught was retained (75.5% in number; 92.3% in weight) (Table 1). Among retained captures, a small part was for fishermen's own consumption (3.1% in number; 3.6% in weight), with the remainder landed. Elasmobranchs discarded represented 24.8% of total number of individuals caught, but only 7.8% in weight, with seven of the eleven species caught being consistently discarded (Table 1). *Dasyatis pastinaca* (Linnaeus, 1758), *Mustelus mustelus* (Linnaeus, 1758), *Raja montagui* Fowler, 1910 and *Torpedo marmorata* Risso, 1810 were always retained, while species with low or no commercial value, such as *Myliobatis aquila* (Linnaeus, 1758) and *Torpedo torpedo* (Linnaeus, 1758) were always discarded. More than a half of *Scyliorhinus canicula* (Linnaeus, 1758) individuals were also discarded.

The main reasons for discards were damage condition when disentangled (52.9%), low or null commercial value (25.5%) and size (21.5%). Captures with poor condition, i.e., individuals entangled showing advanced decomposition, were found especially after stormy days (which lead to higher soak times since fishermen failed to retrieve nets during those periods). Although less important, fish size also seemed to contribute to discards: specimens discarded had in general lower dimensions than the ones retained (Table 2). The statistical tests for the most abundant species showed that *R. brachyura* ($U = 55.50$, $p = 0.001$) and *R. undulata* ($U = 46.50$, $p = 0.004$) had significant differences among lengths of the individuals retained and of the individuals discarded, presenting the latter smaller dimensions. These differences were not statistically significant in *R. clavata* ($t = 1.29$; $p = 0.199$) and *R. miraletus* ($U = 703.5$; $p = 0.388$). Estimates of total annual discarded elasmobranchs from this trammel net fishery were ca. 9900 kg per year, which corresponds to 4250 individuals.

We noticed a marked seasonality, with the lowest value of species CPUE registered in spring (4 species; 70 individuals) and the highest in autumn (10 species; 233 individuals) (Table 3). *R. clavata* presented the highest abundance in autumn, showing considerable lower values in the remaining seasons, especially in winter. *R. undulata* abundance had a slight increasing trend between coldest and warmer months. *R. miraletus* was present in the study area only during colder months, with the highest abundance in winter. *M. aquila* was more abundant in summer, whereas *T. torpedo* was captured only in winter (Table 3). Statistical analyses showed that for *R. brachyura* there were significant differences between seasons ($H = 11.92$; $p = 0.008$), with higher CPUE in spring over the remaining seasons. For *R. undulata* ($H = 1.02$; $p = 0.80$) and *R. clavata* ($H = 1.55$; $p = 0.67$) differences in CPUE between seasons were not statistically significant.

Fig. 2 shows the distribution of most abundant species by depth intervals in the various seasons. *R. clavata* were captured within the entire depth range analysed (5–120 m depth). However, this species seemed to prefer deeper water during the coldest months. For *R. undulata*, which appeared down to about 50 m depth, a decreasing trend in captures was noticed with increasing depth. For this species there was no clear relationship between depth and season. For *R. brachyura*, which was captured within the same

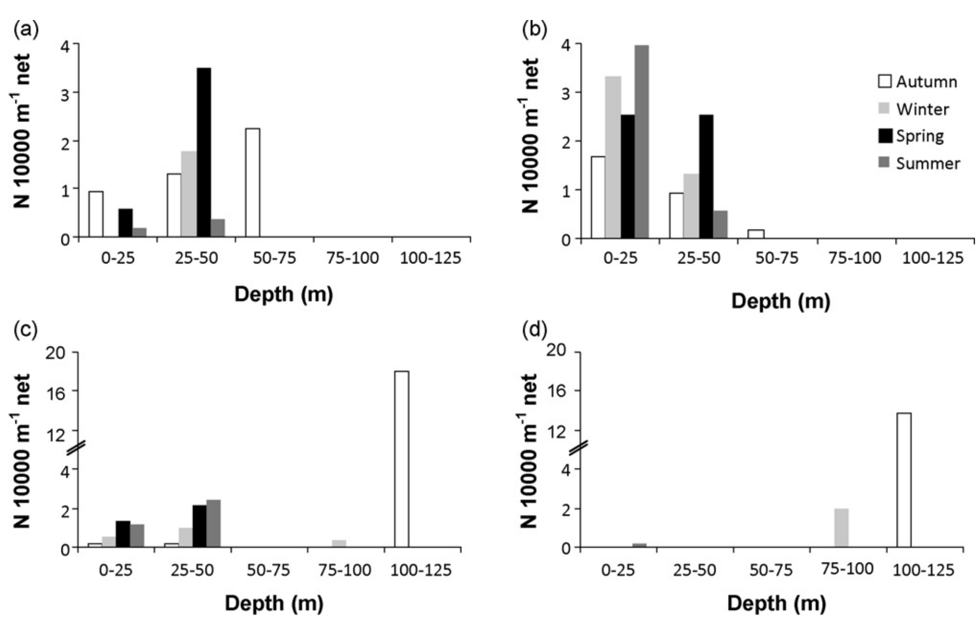

Fig. 2. Catches (in number) of individuals of the most abundant elasmobranchs species according to depth and season: (a) *Raja brachyura*; (b) *Raja undulata*; (c) *Raja clavata* and (d) *Raja miraletus*.

Table 1
Elasmobranchs' catches in a trammel net fishery. Total catches and relative importance of each species in captures (in percentage presented in brackets). CPUE (per 10,000 m of net) and fate (in percentage) in number (*N*) and weight (*W*).

Species	Number				Weight			
	N (%)	*N* 10,000 m^{-1} net	Retained (commercial) (%)	Discarded (%)	*W* (%) (g)	g 10,000 m^{-1} net	Retained (commercial) (%)	Discarded (%)
Dasyatis pastinaca	1 (0.2)	0.05	100.0 (100.0)	0.0	4,400.0 (0.9)	216.54	100.0 (100.0)	0.0
Myliobatis aquila	14 (3.3)	0.69	0.0 (0.0)	100.0	6,449.3 (1.3)	317.39	0.0 (0.0)	100.0
Mustelus mustelus	4 (0.9)	0.20	100.0 (100.0)	0.0	6,975.0 (1.5)	343.26	100.0 (100.0)	0.0
Raja brachyura	56 (13.1)	2.76	83.9 (80.4)	16.1	118,803.3 (24.8)	5846.71	95.9 (94.9)	4.1
Raja clavata	150 (35.0)	7.38	82.0 (80.7)	18.0	130,121.3 (27.2)	6403.70	93.9 (89.1)	6.1
Raja miraletus	83 (19.4)	4.08	63.9 (60.2)	36.1	23,403.8 (4.9)	1151.78	70.0 (65.8)	30.0
Raja montagui	4 (0.9)	0.20	100.0 (100.0)	0.0	1,860.0 (0.4)	91.54	100.0 (100.0)	0.0
Raja undulata	86 (20.1)	4.23	94.2 (90.7)	5.8	167,260.4 (34.9)	8231.44	99.0 (94.6)	1.0
Raja spp.	3 (0.7)	0.15	33.3 (33.3)	66.7	3135.9 (0.7)	154.32	79.7 (79.7)	20.3
Scyliorhinus canicula	14 (3.3)	0.69	42.9 (21.4)	57.1	4,952.4 (1.0)	243.72	57.4 (26.8)	42.6
Torpedo marmorata	2 (0.5)	0.10	100.0 (100.0)	0.0	4,740 (1.0)	233.27	100.0 (100.0)	0.0
Torpedo torpedo	11 (2.6)	0.54	0.0 (0.0)	100.0	6,705.6 (1.4)	330.00	0.0 (0.0)	100.0
Total	428	21.06	75.5 (72.4)	24.8	478,806.81	235,63.68	92.3 (88.7)	7.8

Table 2
Average total lengths, disc widths of Rajiformes and Torpediniformes, respective standard-error and size ranges of retained and discarded elasmobranchs.

Species	Nt	Retained						Discarded					
		Average length (cm)	SE	Size-range (cm)	Average width (cm)	SE	Width-range (cm)	Average length (cm)	SE	Size-range (cm)	Average width (cm)	SE	Width-range (cm)
Dasyatis pastinaca	1	80.0[a]			54.0[a]								
Myliobatis aquila	14							51.86	13.39	19.2–70.0	29.5	7.17	12.2–40.5
Mustelus mustelus	4	74.88	18.14	56.0–99.5	–		–						
Raja brachyura	56	63.35	17.28	36.9–79.0	46.4	12.93	27.0–79.0	43.76	4.26	38.2–50.2	31.6	3.75	26.0–37.0
Raja clavata	150	45.00	12.26	20.4–101.0	34.8	10.07	22.9–66.0	41.79	8.75	30.5–71.0	30.1	10.79	21.0–75.0
Raja miraletus	83	40.22	3.04	35.5–47.5	26.3	2.50	21.4–39.1	39.35	5.28	25.5–49.5	25.6	2.99	20.1–32.4
Raja montagui	4	42.40	5.25	35.0–46.8	29.3	2.39	26.5–31.3						
Raja undulata	86	61.85	17.23	37.0–96.5	43.0	11.78	27.0–77.0	40.36	6.93	28.6–45.5	28.2	5.91	19.4–35.0
Scyliorhinus canicula	14	51.57	2.62	48.9–56.0	–		–	47.46	5.83	40.5–55.9	–		–
Torpedo marmorata	2	45.65	4.74	42.3–49.0	28.5	2.96	26.3–30.5						
Torpedo torpedo	11							32.44	5.50	23.7–40.4	22.5	4.33	17.4–32.2

[a] Only one individual was surveyed.

Table 3
Seasonal catches, in number per 10,000 m of net, of elasmobranchs species according.

Species	Autumn	Winter	Spring	Summer
Dasyatis pastinaca	0.188	–	–	–
Myliobatis aquila	0.188	0.441	–	2.069
Mustelus mustelus	0.188	0.220	–	0.376
Raja brachyura	4.502	1.764	4.088	0.564
Raja clavata	19.322	2.205	3.504	3.574
Raja miraletus	13.694	1.984	–	0.188
Raja montagui	0.750	–	–	–
Raja undulata	2.814	4.630	5.062	4.514
Scyliorhinus canicula	1.313	0.441	0.779	0.188
Torpedo marmorata	0.188	–	–	0.188
Torpedo torpedo	–	2.425	–	–

depth range, the opposite pattern was observed, with the highest catches obtained in deeper waters. Deeper waters also seemed to be preferred during the coldest months. *R. miraletus* were only found at depths greater than 50 m. In addition, statistical tests showed that there were not significant statistical differences of CPUE between the three depth intervals for *R. clavata* ($H = 2.75$; $p = 0.253$). On the contrary, there were significant differences in CPUE between depths for *R. brachyura* ($H = 9.60$; $p = 0.008$) and *R. undulata* ($H = 9.55$; $p = 0.008$). For *R. brachyura*, the highest captures were obtained in the middle depth interval (25–50 m) and *R. undulata* showed higher CPUE in shallower waters (0–25 m), as shown in Fig. 2.

4. Discussion

Most studies on bycatch and discards of elasmobranchs consider trawl and longline fisheries (Carbonell et al., 2003; Clarke et al., 2005; Coelho and Erzini, 2008; Megalofonou et al., 2005; Stobutzki et al., 2002). Erzini et al. (2002) studied discards from the most important fisheries in southern coast of Portugal and found that, despite a great diversity of species caught, including seven chondrichthyan species, trammel nets were those with lower discards. Another study from southern Portuguese coast confirmed that trammel nets had the lower value of mean discard rate per trip of the analysed fisheries (Borges et al., 2001). Also for a trammel net fishery in southern Portugal, Coelho et al. (2005) found that 16 elasmobranch species were caught, accounting for 4.3% of the total catch. Our results showed that 11 elasmobranch species were caught, accounting for 4% of the total catches in number and 15% in weight, similar to results obtained by Coelho et al. (2005).

However, results obtained by Coelho et al. (2005) concerning discards were quite different from those obtained in our study. In trammel net fisheries from southern Portugal discards were low, accounting for only 5.4% of the elasmobranch catch; most of the elasmobranchs were either landed for sale or consumed by the fishermen themselves. In our study, discards were important in terms of the number of elasmobranch species and number of individuals: despite only 7.8% in weight, discards represented 24.8% of specimens caught in number, with seven of the 11 caught species discarded. Differences between discarded rates using the same gear could be related to local species diversity, environmental constrains, social-economic aspects or simply due to random factors (Batista et al., 2009).

Fishermen retained all species that have some commercial value. When few individuals of these species were captured, fishermen usually kept them for personal consumption, due to low selling value. This also happened at a similar fishery in the southern Portuguese coast (Gonçalves et al., 2007). When the principal resources have lower catch rates, fishermen avoid the decline in revenues by trying to take greater advantage of bycatch species, such as skates, which can achieve a high commercial value, thus maintaining their activity economically sustainable. Since 1990, skates and rays annual landings have been around 1500 t with high market price values, ca. 2.5 euros per kg currently.

Apart from some selectivity experiments (e.g. Erzini et al., 2006), there has been no research on trammel net bycatch reduction. Nevertheless, choice of fishing ground, reduction in the number of fleets and soak time as well as the use of larger mesh sizes in the inner panel may reduce bycatches and discards (Gonçalves et al., 2007). If nets soak time was limited to the maximum legal time (in Portuguese legislation 24 h is the maximum soaked time for trammel nets, with some exceptions in case of proven “reason of force majeure” or 72 h when nets are set at more than 300 m depth), the number of damaged individuals would be reduced and thus, the volume of discards. However, to achieve this, existing regulation should be enforced (Gonçalves et al., 2007). A decrease in soak time during the warmer months could also contribute to higher quality of the landings since at higher water temperatures fish and invertebrates degrade faster and this small fleet does not have refrigerated storage on board.

The seasonal variation of species abundance, with lowest species richness registered in spring and highest in autumn, could be related to the reproductive or latitudinal migratory habits of these elasmobranch species, however, our data are insufficient to conclude this. Spawning migrations have been suggested for several rajid species. It is known that females of several species of skates tend to move inshore at shallow depths to lay eggs (e.g. Cox and Koob, 1993; Rydland and Ajayi, 1984; Walker and Hessen, 1996). Also, nursery areas of elasmobranchs are typically in shallower water than adult habitats, an evident pattern for *R. brachyura*, *R. clavata* and *R. montagui* (Ellis et al., 2005). However, despite the economic importance of rajids in the North-east Atlantic, their reproductive behaviour remains poorly known.

Although many species of elasmobranchs co-occur and occupy apparently similar roles as apex predators in marine ecosystems, little is known about resource partitioning and competitive exclusion among them (Papastamatiou et al., 2006). One of the few sources of information is indirect evidence based on data on diet and spatial distribution among potentially competing species (Papastamatiou et al., 2006). Results of this work suggest some degree of depth segregation between the most abundant species (*R. clavata*, *R. undulata*, *R. brachyura*). This might be related to resource (spatial) partitioning and/or competition between them since they are demersal predators and use the same type of resources (Froese and Pauly, 2009). Such habitat partitioning reduces the potential for inter-specific competition for resources. Additional data or experimental work would be necessary to further examine the role of competition and other ecological interactions operating in the assemblage of coastal elasmobranchs.

Juveniles of *R. clavata* tend to remain in deeper waters for several years, whereas adults show seasonal movements, from deeper waters in winter, to shallower waters in the spring, where the reproduction occur (Walker et al., 1997). In this study, this species was captured year round and across the whole depth range, although the highest values of abundance occurred in autumn at higher depths (>100 m). This could indicate a return of the adults to deeper waters after the egg laying season in shallow waters or food or temperature related migrations. *R. miraletus* is also much more abundant in the autumn season and about 100 m depth. Similar reasons might be at play here.

R. undulata occurred in the fishing area throughout the year without major abundance changes. Therefore, no conclusions can be drawn about the breeding season. In Portuguese waters this species has one annual breeding season, with ovulation and mating taking place during the first and second quarters of the year (Moura et al., 2007). *R. undulata* appeared always below 60 m deep and showed a decreasing trend according to depth, which also succeeded in southern Portuguese coast (Coelho et al., 2005).

R. brachyura is a shallow water species (Catalano et al., 2007). In the studied area, this species appeared down to about 60 m depth with the highest catches in the higher depths. In Portuguese waters, reproductive period for this species seems to be quite limited, with sexually active females sampled only in March (Serra-Pereira et al., 2005). In our study, seasonal migrations were not obvious, since *R. brachyura* abundance was as high in autumn as in spring.

In mixed fisheries that lack species discrimination, as the studied trammel net fishery, elasmobranchs may face abundance variations that could put their population in an unstable situation: leading to drastic decline of some species and abnormal increase of others. Thus, the stability on Portuguese commercial landings of the generic group *Raja* spp. could be masking species decline (Figueiredo et al., 2007). In recent years an increase in landed species diversity was obvious with changes in species abundance: *R. brachyura* and *R. clavata* relative importance decreased and at the same time *Leucoraja naevus* relative importance showed a small increase (Figueiredo et al., 2007). This shows that it is urgent to have better identification of elasmobranch species caught in order to obtain more information about such fragile species and to develop protective measures that allow its sustainable management.

Although elasmobranchs captures represent a small percentage of total catches in the studied fishery, trammel nets impact on these species should be taken into account in stock assessments, due to the biological characteristics of these species (Stevens et al., 2000) and the fact that trammel netting is commonly used along the Portuguese coast. Our study pointed out that total annual amount of elasmobranchs discarded from this trammel net fishery was ca. 9900 kg per year, which corresponds to 4250 individuals, which in our view is a very significant amount.

Current conservation measures for elasmobranchs in Portuguese waters consist principally on stipulating a minimum landing size. Since elasmobranchs are mainly caught as bycatch, the establishment of a TAC may result in additional discards without necessarily reducing fishing mortality. The survival rate of discards is a relevant management consideration, which for some species it is believed to be high (e.g. lesser-spotted dogfish), but for other species it is unknown (ICES, 2008).

The study provides additional management-relevant information on the impact of yet another fishery in elasmobranch mortality. We recognize the need for more studies on elasmobranchs bycatch and discards, to further understand the impact of fisheries on these species. In addition, such data would be crucial to develop a management program that ensures sustainability of these resources, especially in multispecies fisheries as trammel net fisheries.

Acknowledgments

We thank the crews of the vessels sampled for their help on board. We are also grateful to all the volunteers that helped with sampling work. This study was co-funded by the European Union through the FEDER - Fisheries Programme (MARE), as well as by Fundação para a Ciência e a Tecnologia (FCT) through the grant attributed to F. Baeta (Grant SFRH/BD/19223/2004). We would also like to thank the anonymous referees for helpful suggestions.

References

Bonfil, R., 1994. Overview of world elasmobranch fisheries. In: FAO Fish. Tech. Pap. 341. Food and Agriculture Organization of the United Nations, Rome.

Batista, M.I., Teixeira, C.M., Cabral, H.N., 2009. Catches of target species and bycatches of an artisanal fishery: the case study of a trammel net fishery in the Portuguese coast. Fish. Res. 100, 167–177.

Borges, T.C., Erzini, K., Bentes, L., Costa, M.E., Gonçalves, J.M.S., Lino, P.G., Pais, C., Ribeiro, J., 2001. By-catch and discarding practices in five Algarve (southern Portugal) métiers. J. Appl. Ichthyol. 17, 104–114.

Carbonell, A., Alemany, F., Merella, P., Quetglas, A., Románc, E., 2003. The by-catch of sharks in the western Mediterranean (Balearic Islands) trawl fishery. Fish. Res. 6, 7–18.

Castro, J.I., Woodley, C.M., Brudek, R.R., 1999. A preliminary evaluation of the status of shark species. In: FAO FisheriesTechnical Paper 380. Food and Agriculture Organization of the United Nations, Rome.

Catalano, B., Dalu, M., Scacco, U., Vacchi, M., 2007. New biological data on *Raja brachyura* (Chondrichthyes, Rajidae) from around Asinara Island (NW Sardinia, Western Mediterranean). Ital. J. Zool. 74, 55–61.

Clarke, M.W., Borges, L., Officer, R.A., 2005. Comparisons of trawl and longline catches of deepwater elasmobranchs west and north of Ireland. J. Northw. Atl. Fish. Sci. 35, 429–442.

Coelho, R., Erzini, K., Bentes, L., Correia, C., Lino, P.G., Monteiro, P., Ribeiro, J., Gonçalves, J.M.S., 2005. Semi-pelagic longline and trammel net elasmobranch catches in southern Portugal: catch composition, catch rates and discards. J. Northw. Atl. Fish. Sci. 35, 531–537.

Coelho, R., Erzini, K., 2008. Effects of fishing methods on deep water shark species caught as by-catch off southern Portugal. Hydrobiologia 606, 187–193.

Correia, J.P.S., Smith, M.F.L., 2003. Elasmobranch landings for the Portuguese commercial fishery from 1986 to 2001. Mar. Fish. Rev. 65, 32–40.

Cortés, E., 1999. Standardized diet compositions and trophic levels of sharks. ICES J. Mar. Sci. 56, 707–717.

Cox, D.L., Koob, T.J., 1993. Predation on elasmobranch eggs. Environ. Biol. Fish. 38, 117–125.

Ellis, J.R., Cruz-Martínez, A., Rackham, B.D., Rogers, S.I., 2005. The distribution of Chondrichthyan fishes around the British Isles and implications for conservation. J. Northw. Atl. Fish. Sci. 35, 195–213.

Erzini, K., Gonçalves, J.M.S., Bentes, L., Moutopoulos, D.K., Casal, J.A.H., Soriguer, M.C., Puente, E., Errazkin, L.A., Stergiou, K.I., 2006. Size selectivity of trammel nets in southern European small-scale fisheries. Fish. Res. 79, 183–201.

Erzini, K., Costa, M.E., Bentes, L., Borges, T.C., 2002. A comparative study of the species composition of discards from five fisheries from the Algarve (southern Portugal). Fish. Manage. Ecol. 9, 31–40.

Erzini, K., Monteiro, C.C., Ribeiro, J., Santos, M.N., Gaspar, M., Monteiro, P., Borges, T.C., 1997. An experimental study of gill net and trammel net 'ghost fishing' off the Algarve (southern Portugal). Mar. Ecol. Prog. Ser. 158, 257–265.

Fabi, G., Sbrana, M., Biagi, F., Grati, F., Leonori, I., Sartor, P., 2002. Trammel net and gill net selectivity for *Lithognathus mormyrus* (L., 1758), *Diplodus annularis* (L., 1758) and *Mullus barbatus* (L., 1758) in the Adriatic and Ligurian seas. Fish. Res. 54, 375–388.

FAO, 2000. Manual on estimation of selectivity for gillnet and longline gears in abundance surveys. FAO Fisheries Technical Paper 397, Rome, 84 p.

FAO, 2002. FAO yearbook—fishery statistics: capture production 2000. In: FAO Fisheries Series 90/1. Food and Agricultural Organization for the United Nations, Rome.

Fernandez, L., Salmerón, F., Ramos, A., 2005. Change in elasmobranchs and other incidental species in the Spanish deepwater black hake trawl fishery off Mauritania (1992–2001). J. Northw. Atl. Fish. Sci. 35, 325–331.

Figueiredo, I., Moura, T., Bordalo-Machado, P., Neves, A., Rosa, C., Gordo, L.S., 2007. Evidence for temporal changes in ray and skate populations in the Portuguese coast (1998–2003)—its implications in the ecosystem. Aquat. Living Resour. 20, 85–93.

Froese, R., Pauly, D. (Eds.), 2009. FishBase. World Wide Web electronic publication. www.fishbase.org, version (04/2009).

Gonçalves, J.M.S., Bentes, L., Coelho, R., Monteiro, P., Ribeiro, J., Correia, C., Lino, P.G., Erzini, K., 2008. Non-commercial invertebrate discards in an experimental trammel net fishery. Fish. Manage. Ecol. 15, 199–210.

Gonçalves, J.M.S., Stergiou, K.I., Hernando, J.A., Puente, E., Moutopoulos, D.K., Arregi, L., Soriguer, M.C., Vilas, C., Coelho, R., Erzini, K., 2007. Discards from experimental trammel nets in southern European small-scale fisheries. Fish. Res. 88, 5–14.

Hall, M.A., Alverson, D.L., Metuzals, K.I., 2000. By-catch: problems and solutions. Mar. Poll. Bull. 41, 204–219.

Heuter, R.E., 1998. Science and management of shark fisheries—introduction. Fish. Res. 39, 105.

ICES, 2008. Report of the ICES Advisory Committee, 2008. ICES Advice, 2008. Book 7, 122 pp.

Kelleher, K., 2005. Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper 470. FAO, Rome.

Machado, P.B., Gordo, L.S., Figueiredo, I., 2004. Skate and ray species composition in mainland Portugal from the commercial landings. Aquat. Living Resour. 17, 231–234.

McKinnell, S., Seki, M.P., 1998. Shark bycatch in the Japanese high seas squid driftnet fishery in the North Pacific Ocean. Fish. Res. 39, 127–138.

Megalofonou, P., Yannopoulos, C., Damalas, D., De Metrio, G., Deflorio, M., de la Serna, J.M., Macias, D., 2005. Incidental catch and estimated discards of pelagic sharks from the swordfish and tuna fisheries in the Mediterranean Sea. Fish. Bull. 103, 620–634.

Moura, T., Figueiredo, I., Farias, I., Serra-Pereira, B., Coelho, R., Erzini, K., Neves, A., Gordo, L.S., 2007. The use of caudal thorns for ageing Raja undulata from the Portuguese continental shelf, with comments on its reproductive cycle. Mar. Freshw. Res. 58, 983–992.

Myers, R.A., Worm, B., 2003. Rapid worldwide depletion of predatory fish communities. Nature 423, 280–283.

Myers, R.A., Baum, J.K., Shepherd, T.D., Powers, S.P., Peterson, C.H., 2007. Cascading effects of the loss of apex predatory sharks from a coastal ocean. Science 315, 1846–1850.

Papastamatiou, Y.P., Bradley, M., Wetherbee, B.M., Lowe, C.G., Crow, G.L., 2006. Distribution and diet of four species of carcharhinid shark in the Hawaiian Islands: evidence for resource partitioning and competitive exclusion. Mar. Ecol. Prog. Ser. 320, 239–251.

Pawson, M., Vince, M., 1999. Management of shark fisheries in the Northeast Atlantic, in: R. Shotton (Ed.) Case studies of the management of elasmobranch fisheries. FAO Fish. Tech. Pap. 378, pp. 1–46.

Revill, A. S., K. Dulvy, N. K., Holst, R., 2005. The survival of discarded lesser-spotted dogfish (*Scyliorhinus canicula*) in the Western English Channel beam trawl fishery. Fish. Res. 71, 121–124.

Rydland, J.S., Ajayi, T.O., 1984. Growth and population dynamics of three species of Rajidae (Batoidei) in Carmarthen Bay, British Isles. ICES J. Mar. Sci. 41, 111–120.

Serra-Pereira, B., Figueiredo, I., Bordalo-Machado, P., Farias, I., Moura, T., Serrano Gordo, L., 2005. Description of Portuguese mixed-fisheries with positive landings of *Raja brachyura* Lafont, 1873 and *Raja montagui* Fowler, 1910. ICES CM 2005/N:18 Theme Session on Elasmobranch Fisheries Science.

Shepherd, T.D., Myers, R.A., 2005. Direct and indirect fishery effects on small coastal elasmobranchs in the northern Gulf of Mexico. Ecol. Lett. 8, 1095–1104.

Stergiou, K.I., Moutopoulos, D.K., Soriguer, M.C., Puente, E., Lino, P.G., Zabala, C., Monteiro, P., Errazkin, L.A., Erzini, K., 2006. Trammel net catch species composition, catch rates and métiers in southern European waters: a multivariate approach. Fish. Res. 79, 170–182.

Stevens, J.D., Bonfil, R., Dulvy, N.K., Walker, P.A., 2000. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. ICES J. Mar. Sci. 57, 476–494.

Stobutzki, I.C., Miller, M., Heales, D.S., Brewer, D.T., 2002. Sustainability of elasmobranch caught as bycatch in a tropical prawn (shrimp) trawl fishery. Fish. Bull. 100, 800–821.

Walker, P.A., Hessen, H.J.L., 1996. Long-term changes in ray populations in the North Sea. ICES J. Mar. Sci. 53, 1085–1093.

Walker, P.A., Howlett, G., Millner, R., 1997. Distribution, movement and stock structure of three ray species in the North Sea and eastern English Channel. ICES J. Mar. Sci. 54, 797–808.