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Research Article

Catch and size selectivity of small-scale fishing gear for the smooth-hound shark *Mustelus mustelus* (Linnaeus, 1758) (Chondrichthyes: Triakidae) from the Aegean Turkish coast

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Abstract

Catch rate, CPUE, biomass ratios and size selectivity from traditional longline and trammel nets of Turkish coastal small-scale fisheries were investigated in order to describe the smooth-hound shark (*Mustelus mustelus*) fishery. The SELECT method was used to estimate the selectivity parameters of a variety of models for the trammel nets inner panel of 150 and 170 mm mesh sizes. Catch composition and proportion of the species were significantly different in longline and trammel nets. While mean CPUE of longline was 119.2±14.3 kg/1000 hooks, these values for 150 and 170 mm trammel nets were 5.3±1.2 kg/1000 m of net and 12.7±3.9 kg/1000 m of net, respectively. Biomass ratios of the by catch to smooth-hound catch were found to be 1:0.32 for 150 mm trammel net, 1:0.65 for longline and 1:0.73 for 170 mm trammel net. The estimated modal lengths and spreads were found to be 91.1 and 16.2 cm for 150 mm and 103.2 and 18.4 cm for 170 mm, respectively. The modal lengths of the species as well as the spread values increased with mesh size.

Keywords: Smooth-hound shark; *Mustelus mustelus;* CPUE; Biomass ratio; Selectivity.

Introduction

Because of their K-selected life-history strategy (characterized by slow growth, late attainment of sexual maturity, long life spans, low fecundity and natural mortality, and a close relationship between the number of young produced and the size of the breeding biomass), sharks and rays appear to be particularly vulnerable to over-exploitation (STEVENS *et al.,* 2000). This results in a low level of recruitment seldom capable of keeping pace with modern fishing technology (HOLTS *et al.,* 1998).

Globally, shark catches are divided into targeted and by-catch fisheries. Few elasmobranchs are subject to directed fisheries in the Mediterranean, with local fisheries mostly landing elasmobranchs as by-catch (FOWLER *et al.,* 2005). A similar situation occurs in Turkey. Targeted fisheries for the sharks have developed, due to the increase in domestic consumption around tourist areas, and export activity. Elasmobranch fisheries have globally been common and traditional with lesser importance around the world (BONFIL, 1994). In Turkish Seas, 64 elasmobranches species were reported (BILECENOĞLU *et al.,* 2002). However, 38 species of these fish have a commercial value (FILIZ and TOĞULGA, 2002). In 2006, the harvested amount of chondrichthyans was 1532 t in Turkey, which is just 0.2% of the total elasmobranch catch in the world (FAO, 2000).

Despite the major socio-economic importance of small-scale fisheries in the whole eastern Mediterranean Sea, many aspects have not been studied comprehensively. In particular there is a lack of information on catch composition, catch rates and size selectivity of the mesh size in trammel net shark fishery. The main objectives of this study were to describe and compare elasmobranch catches, size selectivity for smooth-hound shark (*Mustelus mustelus*) in small-scale coastal fisheries, using trammel nets and longline in the Izmir Bay, Aegean Sea.

Material and Methods

A total of 22 fishing trials with trammel nets were carried out in the same fishing grounds visited by local fishermen from September 2006 to May 2007 in the Izmir Bay, Aegean Sea. In these trials, fishing depths varied from 28 to 55 m. Normal fishing practices were followed, with the setting of the gear during the daytime or afternoon and hauling after sunset. The stretched mesh sizes of the trammel nets were 150 and 170 mm and the total length of the nets were 2000 m and 5000 m, respectively. The hanging ratio was 0.5 for both mesh sizes of nets.

Experimental fishing trials with the longline were carried out by 6 trials in 2007, from July to August. Fishing was carried out by a commercial fishing vessel and took place on traditional fishing grounds. Fishing depths varied from 50 to 60 m. The longline used consisted of a 1 mm diameter monofilament main line with 0.7 mm diameter monofilament at intervals of approximately 9.2 m. These longlines were stored in two baskets each containing 200 hooks. The hook number used was 7, manufactured by Mustad. The total length of the longlines was 4 km.

All captured fishes were sorted, identified and measured (total length and weight) as they came aboard. The specimens of *M. mustelus* were separated by sex. Test for significance ($p<0.05$) between total length and weight between males and females were performed by using Student t-test. Comparisons of differences between sex ratios of smooth-hound shark according to trials of each fishing gear were tested by Kruskal-Wallis H test.

Scientific names for each species were checked and confirmed using Fishbase (FROESE and PAULY, 2007).

Chi-square (χ^2) tests were performed to test variations in actual catches (kg) of species by type of fishing gear.

Fishing effort (f) and CPUE were calculated using following formula, modified from DE METRIO and MEGALOFONOU (1988): $f = (a'/10) \times g$. where $(a'/10)$ represents the average length of the nets and average number of hooks in longline, placed daily in the sea divided by the 10 net units. Therefore, a 10 net unit is equal to 10 x 100 = 1000 m for gillnets and 10 x 100 = 1000 hooks for longline. "g" is the number of fishing days. The CPUE was computed in biomass with the formula, CPUE = kg/f. Means were given with standard error (±SE). Comparisons of differences between CPUEs of the three types of gear were tested by Kruskal-Wallis H test.

The SELECT (share each length class

catch total) method (MILLAR, 1992) was used to estimate the selectivity of the trammel nets. For a given length class, *l*, the numbers of fish, nlj, that encounter trammel net j are assumed to be observations of independent Poisson random variables,

$$n_{lj} \approx \text{Pois}\ (p_j\ \lambda_l\ r_j\ (l))$$

where the expected count, $p_j\ \lambda_l$, is the product of the abundance of length class l fish, λ_l, and the relative fishing intensity of trammel net j, p_j. Relative fishing intensity of a trammel net is a combined measure of fishing effort and fishing power.

The log-likelihood of n_{lj} is

$$\sum_l \sum_j \{n_l \log_e [p_j \lambda_l r_j (1)] - p_j \lambda_l r_j (1)\}$$

An appropriate software (Gillnet, ConStat-DK) was used here for selectivity estimation (equal power over mesh sizes was assumed). How good the fit was was evaluated by comparison of deviances, the lowest deviance value corresponding to the best fitting model (DOS SANTOS *et al.,* 2003; ERZINI *et al.,* 2003), and the analysis of residual plots as in MILLAR and HOLST (1997). A collection of the most commonly used selection curves (HOLST *et al.,* 1996), estimated by this software, is given in Table 1.

Results

A total of 190 specimens of smooth-hound, 110 males and 80 females, were examined. The smallest specimen was 34 cm TL and weighed 350 g. The largest specimen was 141.1

Table 1
Normal (fixed spread), normal (proportional spread), gamma, and log-normal selection curves (*l*= fish length,   =dispersion/variance, m=mean, k= optimum catch length).

Model	Selection Curve
Normal location	$\exp\left(-\dfrac{(l - k_1\cdot m_j)^2}{2\sigma^2}\right)$
Normal scale	$\exp\left(-\dfrac{(l - k_1\cdot m_j)^2}{2k_2^2\cdot m_j^2}\right)$
Log-normal	$\dfrac{m_j}{l\cdot m_l}\exp\left(\mu - \dfrac{\sigma^2}{2} - \dfrac{\left(\log(l) - \mu - \log\left(\dfrac{m_j}{m_j}\right)\right)^2}{2k_2^2\cdot m_j^2}\right)$
Gamma	$\left(\dfrac{l}{(a-1)\cdot k\cdot m_j}\right)^{a-1}\exp\left(a - 1 - \dfrac{l}{k\cdot m_j}\right)$
Bi-normal	$\exp\left(-\dfrac{(l - k_1\cdot m_j)^2}{2k_2^2\cdot m_j^2}\right) + c\cdot\exp\left(-\dfrac{(l - k_3\cdot m_j)^2}{2k_4^2\cdot m_j^2}\right)$

cm TL and weighed 7.5 kg (Table 2). There was no significant relationship between total mass and TL between both sexes (p>0.05).

Sex ratios of smooth-hound were found to be 1:0.59 for longline, 1:0.67 for 170 mm trammel net and 1:0.97 for 150 mm trammel net. (Table 3). No significant differences were identified between the sex ratios of smooth-hound shark according to trials of each fishing gear (KW=1.415, p>0.05).

In the longline fishery, three different elasmobranch species were captured constituting 72% of the total catch. These species were *Mustelus mustelus* (comprising 84% of elasmobranchs), *Myliobatis aquila* (10%) and *Raja clavata* (6%). In the trammel net fishery of 150 mm mesh size, 7 elasmobranch species were caught and their catches accounted for 92% of the total catch. 97% of the total catch was elasmobranchs in the second mesh size of trammel net (170 mm) and smooth-hound shark comprised 58% of the total catch (Table 4). Catch compositions were significantly different among fishing gears (χ^2 =653.573, p<0.001).

Fishing effort (f) was calculated to be 0.4, 5 and 2 for longline, 150 and 170 mm mesh size trammel net, respectively. CPUEs relative to fishing gears are shown in Table 5. Mean CPUE for the longline was 119.2±14.3kg/1000 hooks and mean CPUE for the 150 and 170 mm trammel nets were 5.3±1.2 kg/1000 m and 12.6±3.9 kg/1000 m, respectively. Median CPUE values differed significantly among gear types (KW=16.45, $p<0.05$).

Biomass ratios of the by-catch to smooth-hound were found to be 1:0.32 for 150 mm trammel net, 1:0.65 for longline and 1:0.73 for 170 mm trammel net (Table 6). No significant differences were identified between weight of by-catch species and weight of the smooth-hound shark by fishing gear (KW=2, $p>0.05$).

The estimated results of the SELECT model for the two mesh sizes of trammel nets are given in Table 7. The normal scale mod-

Table 2
The composition of total length and weight of *M. mustelus*.

		TL (mm)			W (g)		
Sex	**N**	**Range**	**Mean**	**SE**	**Range**	**Mean**	**SE**
Male	110	38.85-141.1	106.21	2.31	350-7500	4724.35	190.45
Female	80	34-138.1	102.33	2.63	450-7300	4245.26	211.07
Male+ Female	190	34-141.1	104.58	1.73	350-7500	4522.63	142.29

Table 3
Sex ratio of the smooth-hound by the different gear trials.

	Number of Specimen		
Gear	**Male**	**Female**	**Sex ratio**
Longline	32	19	1:0.59
Trammel net 150 mm	29	28	1:0.97
Trammel net 170 mm	49	33	1:0.67
Σ	**110**	**80**	

Table 4
List of all species, total weight (kg) and weight % of each species captured in all fishing trials.

	Family	Species	Total Weight (kg)	%W
Longline	Triakidae	*Mustelus mustelus* Linnaeus, 1758	286.1	60.4
	Muraenidae	*Muraena helena* Linnaeus, 1758	70.5	14.9
	Congridae	*Conger conger* Linnaeus, 1758	53.5	11.3
	Myliobatidae	*Myliobatis aquila* Linnaeus, 1758	33.6	7.1
	Rajidae	*Raja clavata* Linnaeus, 1758	19.9	4.2
	Sparidae	*Dentex dentex* Linnaeus, 1758	4.2	0.9
		Dentex gibbosus Rafinesque, 1810	3.2	0.7
	Triglidae	*Trigla lyra* Linnaeus, 1758	2.6	0.5
		∑=	473.6	100
Trammel net 150 mm	Triakidae	*Mustelus mustelus* Linnaeus, 1758	176.8	75.5
	Dasyatidae	*Dasyatis pastinaca* Linnaeus, 1758	20.2	8.6
	Lophiidae	*Lophius piscatorius* Linnaeus, 1758	9.0	3.9
	Zeidae	*Zeus Faber* Linnaeus, 1758	6.1	2.6
	Myliobatidae	*Myliobatis aquila* Linnaeus, 1758	5.0	2.1
	Scyliorhinidae	*Scyliorhinus stellaris* Linnaeus, 1758	4.0	1.7
	Uranoscopidae	*Scyliorhinus canicula* Linnaeus, 1758	3.5	1.5
		Uranoscopus scaber, Linnaeus, 1758	3.6	1.6
	Rajidae	*Dipturus oxyrinchus* Linnaeus, 1758	1.9	0.8
		Raja clavata Linnaeus, 1758	1.9	0.8
		Rostroraja alba Lacepède, 1803	1.1	0.5
	Pleuronectidae	*Pleuronectes platessa* Linnaeus, 1758	0.9	0.4
		∑=	234.0	100.0
Trammel net 170 mm	Triakidae	*Mustelus mustelus* Linnaeus, 1758	396.4	8.0
	Squalidae	*Squalus acanthias* Linnaeus, 1758	156.2	3.2
	Dasyatidae	*Dasyatis pastinaca* Linnaeus, 1758	54.9	2.8
	Scyliorhinidae	*Scyliorhinus stellaris* Linnaeus, 1758	22.2	2.1
		Scyliorhinus canicula Linnaeus, 1758	19.3	0.4
	Rajidae	*Rostroraja alba* Lacepède, 1803	14.4	1.6
		Raja asterias Delaroche, 1809	2.7	1.3
	Lophiidae	*Lophius piscatorius* Linnaeus, 1758	10.8	0.4
	Zeidae	*Zeus faber* Linnaeus, 1758	8.8	0.0
	Uranoscopidae	*Uranoscopus scaber* Linnaeus, 1758	3.0	0.4
	Pleuronectidae	*Pleuronectes platessa* Linnaeus, 1758	0.3	0.0
		∑=	688.9	20.2

Table 5
Fishing effort and CPUE by gear type.

Gear	Total weight of catches (kg)	CPUE
Longline	54.1	135.25
	36.8	92
	36.9	92.25
	57.7	144.25
	33.2	83
	67.4	168.5
Trammel net 150 mm	7	3.5
	18.8	9.4
	8.4	4.2
	17.1	8.55
	40.2	20.1
	65.1	32.55
	20.2	10.1
Trammel net 170 mm	0.6	0.12
	16.7	3.34
	7.3	1.46
	32.1	6.42
	7.3	1.46
	19.9	3.98
	23	4.6
	52	10.4
	28.1	5.62
	19.4	3.88
	43.2	8.64
	23.1	4.62
	10.9	2.18
	16.4	3.28
	96.4	19.28

el had the lowest model deviance as bi-normal model. In fact, the bi-normal model provided the best fit, based on the residual diagnostic plots. The fitted selectivity curves of the two trammel net (150 and 170 mm) are shown in Figure 1, as well as the corresponding deviance residuals for smooth-hound shark. The estimated modal lengths and spreads for the two trammel net mesh sizes for the best model are shown in Table 8. The modal lengths and spread values increased with mesh size.

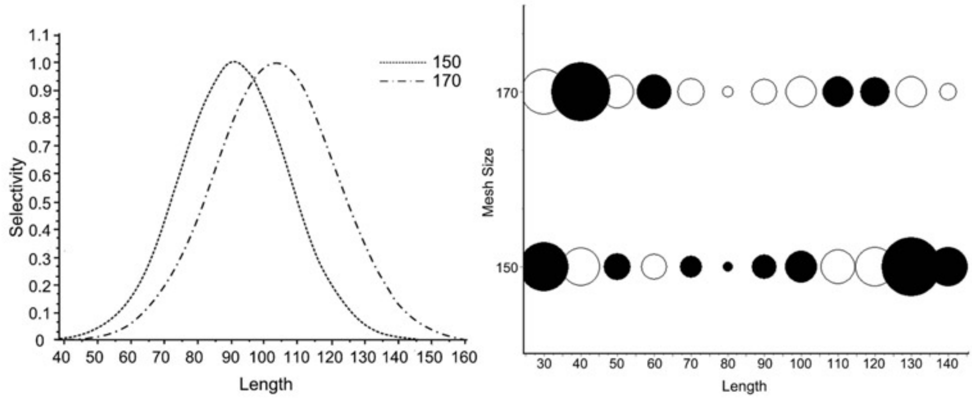

Fig. 1: Selectivity curves of trammel net for the smooth-hound shark and deviance residual plots. Full circle indicates a positive residual and an open circle a negative residual.

Table 6
Summary of total catch and by-catch ratios by gear.

Gear	Total landings	Total catch (kg)	Smooth-hound shark (kg)	By-catch (kg)	By catch ratio
Longline	6	473.6	286.1	187.5	1:0.65
Trammel net 150 mm	7	234.0	176.8	57.2	1:0.32
Trammel net 170 mm	15	688.9	396.4	292.5	1:0.73

Table 7
Summary of total catch and by-catch ratios by gear.

Model	Equal Fishing Power		d.f	P value
	Parameters	Model Deviance		
Normal Location (Fixed spread)	(k. s)= (0.559. 1817)	14.37	10	0.1570
Normal scale (Spread α mj)	(k1 .k2) = (0.607. 0.108)	12.17	10	0.2740
Gamma (Spread α mj)	(α. k) = (0.023. 25.245)	14.37	10	0.1570
Log normal (Spread α mj)	(μ1. s) = (4.419. 0.219)	17.08	10	0.0726
Bi-Normal (Spread α mj)	(a1. b1. a2. b2. w) = (0.607 0.108. 1.648. 0.082. 0.552)	12.17	7	0.0952

Table 8
Modal length and spread values for the best-fitting model of gill net selectivity model curves.

Trammel net	Model Length	Spread
150 mm	91.1	16.2
170 mm	103.2	18.4

Discussion

Analysis of the catch compositions and catch rates of both types of fishing gear showed that catches of smooth-hound shark in longline are very high. COELHO *et al.* (2005) reported that catches of elasmobranchs were high in the longline fishery of the coasts of Southern Portugal, owing to setting in deeper waters than the trammel nets. This results from the fact that longlines with baited hooks attract fish from considerable distances (BJORDAL and LØKKEBORG, 1996), whereas trammel nets depend on the normal movements of fish.

In this study, mean CPUE of the longline was 119.2±14.3kg/1000 hooks and mean CPUEs of the trammel nets 150 and 170 mm were 5.3±1.2 kg/1000m and 12.6±3.9kg/1000m, respectively. MEGALOFONOU *et al.* (2005), studying large pelagic sharks in the surface drifting longline fishery, emphasized that CPUEs were 3.8 fish/1000 hooks in the Alboran Sea and 1 fish/1000 hooks in the Adriatic Sea. They also reported that shark CPUE peaked during late spring and summer. Furthermore, thresher shark CPUE in the driftnet fishery ranged from 0.13 to 1.92 fish/fishing set (HOLTS *et al.* 1998). These results are not directly comparable and can only be regarded as informative data. To begin with, the catch rates are expressed in different units. Secondly, these types of fishing gear operate in different types of habitats (different depths), and lastly the shark species are different. SERENA and VACCHI (1997) reported that large elasmobranchs are often caught incidentally as by-catch in artisanal fisheries, especially in longline fisheries and trammel nets set near the bottom. However, there is lack of data about the CPUE of deep longlines and trammel nets for deep water fisheries.

Despite the importance of gillnet selectivity in fisheries assessment and management, there are few estimates for sharks. Gillnet selectivity models were also estimated for *Mustelus antarcticus* (KIRKWOOD and WALKER, 1986), *Carcharhinus tilstoni* and *Carcharhinus sorrah* (MCLOUGHLIN and STEVENS, 1994), *Carcharhinus obscurus* (SIMPFENDORFER and UNSWORTH, 1998), *Carcharhinus plumbeus* (MCAULEY *et al.* 2007) and *Scyliorhinus canicula* (FONSECA *et al.,* 2005). Furthermore, gillnet selectivity parameters for the Atlantic sharpnose *Rhizoprionodon terraenovae,* blacknose *Carcharhinus acronotus,* finetooth *Carcharhinus isodon,* and bonnethead *Sphyrna tiburo,* sharks were estimated in multi-panel gillnets off the southeastern United States (CARLSON and CORTÉS, 2003). No selectivity estimates are available for smooth-hound shark caught by trammel nets. In this study, the estimated modal lengths and spreads of the trammel nets increased with mesh size. Our results are higher than the estimated first maturity size of 80 cm for female and 70-74 cm for male (COMPAGNO, 1984; GOOSEN and SMALE, 1987). However, first maturity size for the Mediterranean was 971 and 1172 mm for males and females, respectively (SAÏDI *et al.,* 2008). Because of that, mesh size for trammel nets targeting *M. mustelus* should be larger than 170 mm since there is good evidence that selective fishing mortality can lead to changes in growth and juvenile survival for both sharks and batoids, leading to changes in population dynamics (STEVENS *et al.,* 2000). Furthermore, JENNINGS and KAISER (1998) note that fishing acts as a selective force and life-history traits such as growth that are at least partly inheritable may be expected to evolve under sustained exploitation.

CAPAPEÉ *et al.* (2006) reported male specimens were ranging between 39 cm and 139 cm TL and weighing 195 g and 11 kg. The female smooth-hounds fluctuated within 39 cm and 150 cm TL, weighing between 201g and 8.1 kg for the coast of Senegal. In this study, male smooth-hound examined ranged between 38.85 cm and 141.1 cm TL and weighed between 350g and 7.5 kg. The females examined ranged between 34 cm and 138.1 cm TL and weighed between 450g and 7.3 kg. Because of the environment differences, the disagreements between minimum and maximum measurements in CAPAPEÉ *et al.* (2006) and this study are more or less an expected result.

Many coastal fishers are facing the dilemma of fisheries' collapse, the search for income, and the difficulty in sustaining fishing livelihoods (BERKES, 2001). BONFIL (1994) emphasized that fisheries for sharks and rays were common throughout the world and differ in both the species taken and in the type of gear and vessels used. This diversity has contributed to the difficulty in studying the fisheries and to the problems of collecting accurate data on yields and fishing effort. Statistics for elasmobranchs around the world need to be improved. Much data compilation and reviewing must be done on a country and regional basis to enable appraisal of exploitation levels and to make assessments of the status of elasmobranch stocks. In this study, we have put forth the fisheries and the selectivity data for the first time to develop management strategies for the smooth-hound shark. Further studies on animal removals (landing/discards as well as some key factors of the species biology (age, growth, reproductive biology) of smooth-hound and other sharks in the region are essential.

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