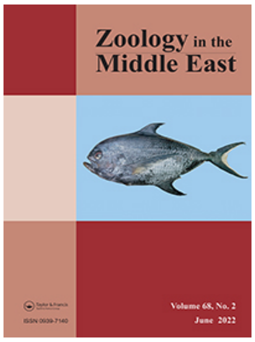

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Fisheries bycatch and conservation priorities of young sharks (Chondrichthyes: Elasmobranchii) in the Eastern Mediterranean

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Sharks are one of the most threatened groups of marine animals because of high exploitation rates coupled with low resilience to fishing pressure. We provide information on the current status of the young sharks caught in fishing nets in Iskenderun and Mersin Bays in the eastern Mediterranean, based on fishery-dependent surveys conducted between 2010 and 2021. Sharks were found in bycatches in trawling nets, trammel nets, bottom longlines and fishing lines. Incidental captures of young-of-the-year or juvenile specimens (n=269) included 15 species and the data indicate that İskenderun and Mersin Bays may serve as a nursery ground for the new-born and young individuals especially for the Blackmouth Catshark (*Galeus melastomus*), the Lesser Spotted Dogfish (*Scyliorhinus canicula*), and the Velvet Belly (*Etmopterus spinax*). If necessary measures are taken, bycatch can be reduced to a certain limit, or even eliminated for shark species in the Mediterranean Sea.

Keywords: Turkey; cartilaginous fish; Blackmouth Catshark; Lesser Spotted Dogfish; Velvet Belly; neonate; fishing pressure, conservation

Introduction

Elasmobranchs constitute an essential group in marine ecosystems, and most elasmobranchs invest more into juvenile survival and growth (Frisk et al., 2001) rather than fecundity (Cortés, 2002). Being apex predators, sharks play an essential role in the structure and function of marine ecosystems, from higher to lower trophic levels (Camhi et al., 1998). They are characterised by a *k*-selected life-history with slow growth rates, late sexual maturity, low fecundity and a long life, resulting in low population increase rates (Holden, 1974; Casey et al., 1985).

Generally, sharks are one of the most threatened groups of marine animals, as high exploitation rates coupled with low resilience to fishing pressure have resulted in population declines throughout the world. In many species, it can take years to recover when their population decreases. Overfishing, habitat degradation, and slow recovery rates are known potential factors that lead to dramatic declines of shark species (Dulvy et al., 2014), especially in areas such as the Mediterranean Sea, where fishing activities have long been a way of life and continue to be intense.

The ability to recover after population depletion depends on a combined effect of size and preferred habitat. It was reported to be highest for small coastal sharks, intermediate for pelagic, and minimal for large coastal species (Smith et al., 1998). From this perspective, the conservation of nursery areas are widely considered to be essential

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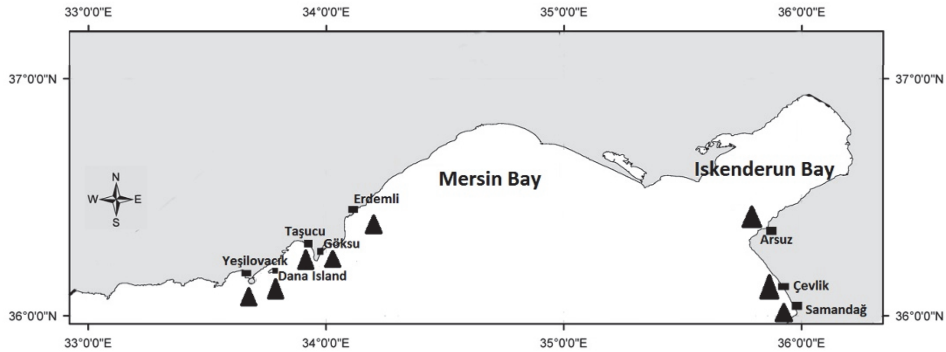

Figure 1. Locations (black triangle) of the occurrences of young shark specimens in Iskenderun and Mersin bays.

(Heithaus, 2007; Heupel et al., 2007). Since shark nurseries have been defined as essential habitats for breeding of a given shark species (Heithaus, 2007), the development of appropriate management for nursery areas relies on the ability to accurately identify areas of most significant importance (Heupel et al., 2007).

Since commercial or recreational fisheries are a major concern in some areas, particularly in nursery grounds, and there is a need for greater awareness that such bycatch should be returned to the water alive (Fowler et al., 2005), identification and mapping of such nursery grounds is of great significance before initiating efforts to raise public awareness and implementation of conservation measures. Furthermore, according to Fowler et al. (2005), due to the magnitude of the elasmobranch catch in commercial fisheries, there is a critical need for assessments to understand the multi-species nature of multiple gear types. Therefore, this study is a first attempt to provide data both for understanding the implications of commercial fisheries on young populations of regional sharks and the distribution of such individuals in Iskenderun and Mersin bays in the eastern Mediterranean. We also attempt drawing attention to possible nurseries of shark species in the region. This information should help understanding the fishing pressure on these species and developing practical management plans for their conservation.

Material and Methods

Study area (Figure 1). Iskenderun Bay is located in the northern end of the Levant part of the Mediterranean Sea with an area of approximately 2275 km^2 and a width of 35 km. The bay has a very wide continental shelf, and the depth within this region does not exceed 90 m (Erguden & Turan, 2013). The bottom structure of the western parts of the Iskenderun Bay is primarily sandy and muddy, while the eastern parts have a more rocky habitat. The topography of the coastline is rich of several streams and rivers, where Asi and Ceyhan rivers are the major sources of freshwater supplies into Iskenderun Bay. This area is rich in biodiversity and fisheries resources.

Mersin Bay is situated between Taşucu (36°18′N, 34°02′E) in the west and Karataş (36°32′N, 35°22′E) in the east. The total water surface is about 2300 km^2. The deepest point is 365 m. The western region of the bay is slightly deeper than the eastern region. The bay is the spawning and breeding area for many fish species due to the wide continental shelf. The biodiversity of the Taşucu and Yeşilovacık coast is affected by the migration of the fish species. Both areas are surrounded by littoral shores, while sandy beach is located inside. These areas are covered with the sandy, muddy sediment on the seafloor of the bay. At the same time, these areas have an anticyclonic gyre opposite the cyclonic gyre, which is the main gyre of the Mediterranean Sea.

Figure 2. Examples of young shark specimen, *Alopias supercilious*; which was incidentally captured off Turkish coast of eastern Mediterranean.

Sampling of shark individuals. Samples were collected through fishery-dependent surveys conducted between 2010 and 2021. The regional commercial fisheries is characterised by the use of different type of nets (trawling nets, trammel nets, bottom longlines and fishing lines). Trawl fishery surveys were carried out on a commercial trawler (18–24 m and 420–480 hp main engines) during daytime in stable weather and sea conditions. Catches of commercial trammel-netters, bottom longliners and hand-liners, landed at regional fishing ports were also examined on an opportunistic basis to collect data on by-caught neonate and young sharks. This commercial fishery-dependent study is a kind of opportunistic research, which is based on dead animal sampling, for methodological details was given by Jessup (2003). The sampling process was not carried out in a regular time interval. Juvenile sharks were collected by boat personnel or by an observer on the fishing vessel and sent to the first author.

Definition of neonates, juveniles and nurseries. Following Castro (1993), neonates are post-hatching or post-birth, free-swimming young bearing fresh, unhealed, or healing umblical scars in the case of placental species, or those at or near birth size in the case of a placental or ovoviviparous species. Juveniles are all the post-neonatal individuals prior to sexual maturation (Castro, 1993) and nursery areas (nurseries) are geographically discrete parts of the species range where the gravid females deliver their young or deposit their eggs, and where the young spend their first weeks, months, or years. Size at birth and maturity of examined shark species are presented in Supplementary Table S1, based on Compagno (1984).

The identification and taxonomic nomenclature of juvenile sharks were carried out following Serena (2005, 2020), Bariche (2012) and Kabasakal (2020). These records constitute the young records of these shark species in the eastern Mediterranean coast of Turkey (Iskenderun and Mersin Bays) (Figure 2).

Results

A total of 269 young shark specimens, representing 15 species in 11 families (Hexanchidae, Lamnidae, Cetorhinidae, Alopiidae, Penthanchidae, Scyliorhinidae, Carcharhinidae, Dalatiidae, Etmopteridae, Oxynotidae, and Squalidae) were obtained from fishing nets in Iskenderun and Mersin Bays (Figure 2, Table 2). The most abundant species reported was the Lesser Spotted Dogfish, *Scyliorhinus canicula* (n=134), comprising 49.8% of all specimens, followed by the Velvet Belly, *Etmopterus spinax* (27.1%), the Blackmouth Catshark, *Galeus melastomus* (11.9%), the Angular Rough Shark, *Oxynotus centrina* (2.2%), Longnose Spurdog, *Squalus blainvillei* (1.8%), the Shortfin Mako, *Isurus oxyrinchus* (1.8%), the Bluntnose Sixgill Shark *Hexanchus griseus* (1.8%), and the Sandbar Shark,

Table 1. Young sharks caught in Iskenderun and Mersin Bays in 2010 and 2021. Gear: FL = fishing line; T = trawl; L = longline; TN = trammel net. MB = Mersin Bay, IB = Iskenderun Bay. TL: Total length (in cm), Av: Average.

Family	Species	Nos.	Date	Gear	Depth (m)	TL	Locations
Hexanchidae	*Heptranchias perlo*	1	27.06.2014	T	601	105.0	MB: off Erdemli
Hexanchidae	*Hexanchus griseus*	1 2	27.06.2014 20.03.2018 25.02.2019	T	300 200	90.0 350.0 N/A	MB: Taşucu coast-Dana Island
		1	12.01.2021	T	200	210.0	MB: Taşucu coast
Lamnidae	*Isurus oxyrinchus*	2	25.03.2010-30.03.2016	L	55-65	59.0-69.8	IB: Samandağ coast
		1	12.04.2018	L	73	75.0	MB: Taşucu coast-Dana Island
		1	05.02.2020	L	67	70.0	MB: Taşucu coast
		1	10.02.2021	L	70	73.0	MB: Taşucu coast-Dana Island
Cetorhinidae	*Cetorhinus maximus*	1	20.03.2014	TN	25	245.0	MB: off Yeşilovacık
Alopiidae	*Alopias vulpinus*	1	09.03.2019	TN	38	250.0	MB: Erdemli coast
	Alopias superciliosus	1	02.01.2020	TN	25	240.0	MB: Taşucu coast
Penthanchidae	*Galeus melastomus*	14	17.05.2014	T	500	32.5-67.0	MB: off Erdemli
		1	May 2018	T	641	19.0	MB: off Erdemli
		17	13-15.05.2020	T	450	18.5-24.5	MB: off Erdemli
Scyliorhinidae	*Scyliorhinus canicula*	49	17.05.2014	T	500	28.0-42.5	MB: off Erdemli
		85	May 2018	T	641	30.0-33.5	MB: off Erdemli
Carcharhinidae	*Carcharhinus altimus*	1	20.07.2019	L	25	65.2	MB: Göksu
	C. brevipinna	1	Feb. 2019	L	20	115.0	MB: Göksu
	C. plumbeus	2 1	25.10.2014 26.12.2019	L	42 40	62.0-65.0	IB: Arsuz coast
Dalatiidae	*Dalatias licha*	1	11.06.2016	L	40	118.0	IB: Çevlik coast
Etmopteridae	*Etmopterus spinax*	60 2	17.05.2014 25.06.2014 09.07.2019	T	601 595	15.0-30.5	MB: off Erdemli
		11	14-17.05.2018	T	641	Av. 17.25 cm	MB: off Erdemli
Oxynotidae	*Oxynotus centrina*	4	17.05.2014 25.06.2014	T	600	40.3-46.0	MB: off Erdemli
		1	05.10.2018	FL	25	39.0	MB: Göksu River estuarine
		1	13.05.2020	T	450	50	MB: off Erdemli
Squalidae	*Squalus blainvillei*	5	17.05.2014 25.06.2014	T	301	27.5-65.0	MB: off Erdemli

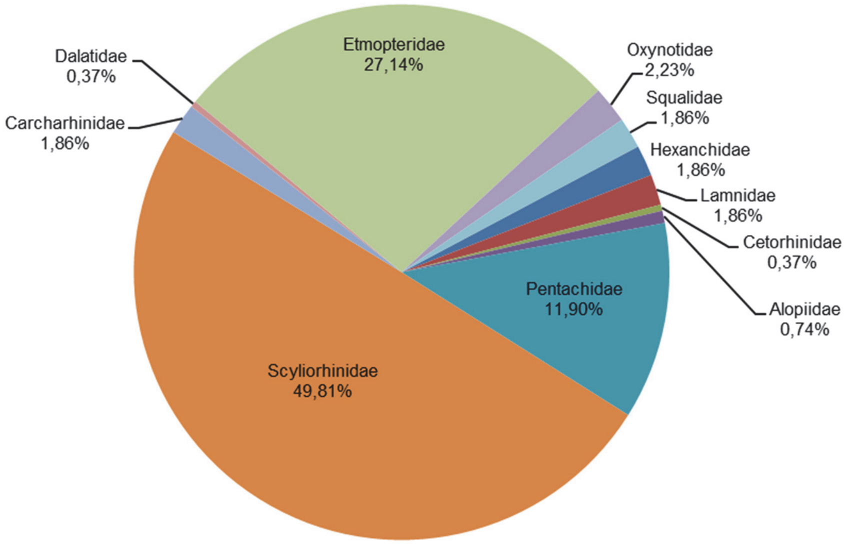

Figure 3. Occurrence of incidentally captured young sharks by families, examined in the present study.

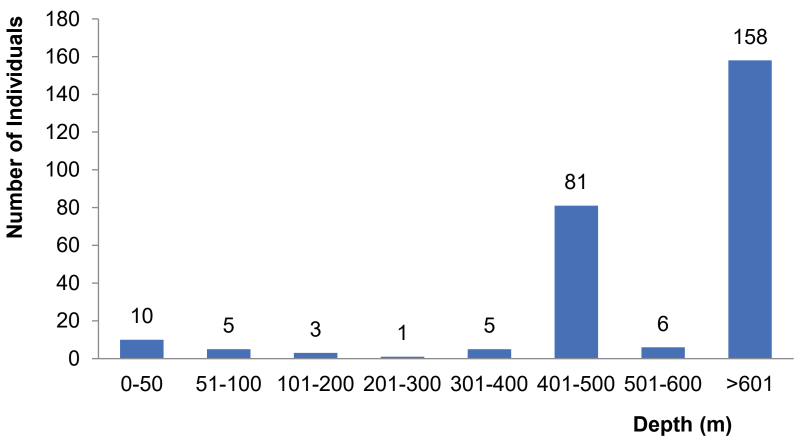

Figure 4. Bathymetric distribution of incidentally captured young sharks, with respect to numbers of specimens.

Carcharhinus plumbeus (1.2%). Other sharks (Table 1) were represented at the rate of as 0.4%. According to these bycatch data, the family with the highest number of young individuals is Scyliorhinidae (n=134, 49.8%) (Figure 3).

In bottom trawl fishery, 254 individuals of 7 species were accidentally caught with trawl nets. *Hexanchus griseus* was caught at 200–300 m depth contour range (N=4), *Squalus blainvillei* at a depth of 301 m (N=5), *Oxynotus centrina* at depths of 450 m (N=1) and 601 m (N=4), the latter together with one individual of *Heptranchias perlo*; two individuals of *Etmopterus spinax* were caught at 595 m, 60 at 601 m and 11 at 641 m

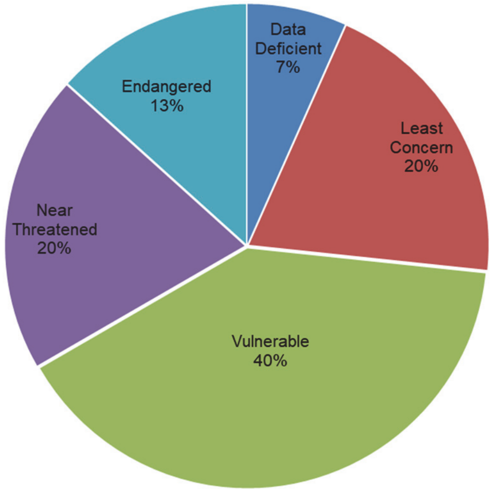

Figure 5. Global Red List status of the shark species found in the Eastern Mediterranean coast. Categories are abbreviated as: EN- Endangered; NT- Near Threatened; VU-Vulnerable; LC-Least Concern; DD-Data Deficient.

depth contour; 17 individuals of *Galeus melastomus* were caught at 450 m, 14 at 500 m depth and one at 641 m depth. Forty-nine individuals of *Scyliorhinus canicula* were caught at 500 m depth and 85 at 641 m depth contour (Figure 4).

Eleven sharks belonging to five species were obtained in the long-line fishery: *Isurus oxyrinchus* (N=2 at 55-65 m), *Carcharhinus plumbeus* (N=3 at 40-42 m), *Dalatias licha* (N=1 at 40 m); *I. oxyrinchus* (N=3 at 67-73 m), *C. altimus* (N=1 at 25 m) and *C. brevipinna* (N=1 at 20 m) (cf. Figure 4).

In the gill-net fishery, one individual of *Cetorhinus maximus* was accidentally caught at 25 m depth, one individual of *Alopias superciliosus* at a depth of 25 m, and one individual of *A. vulpinus* at 38 m depth. Regarding *Oxynotus centrina*, one individual was hooked at the Göksu River mouth (Mersin Bay) (Figure 4).

Based on Global Red List status of the examined species (IUCN, 2021), 40 percent of the incidentally captured young sharks are considered as "Vulnerable" species (n=6), followed by "Near Threatened (20%; n=2)", "Least Concern (20%; n=2)", "Endangered (13%; n=2)" and "Data Deficient (7%; n=1)" species (Figure 5).

Discussion

There is no targeted fishery for shark species in Iskenderun and Mersin bays and all sharks examined were incidentally caught by trawlers or bottom long-liners.

Yaglioglu et al. (2015) reported seven shark species (*Carcharhinus plumbeus, C. altimus*, *Isurus oxyrinchus*, *Mustelus mustelus*, *Scyliorhinus canicula*, *S. stellaris*, *Squatina squatina*) in bottom trawl fishery in the Iskenderun Bay at depths between 50 and 100 m for. However, they sampled *S. canicula and S. stellaris* from greater depths than in the present study and they also reported that *Oxynotus centrina* and *Galeus melastomus* were recorded in trawl catches, hauled at depths >100 m.

Elasmobranch bycatch in fisheries has become one of the main sources of population declines. Juvenile sharks are caught in large numbers in longline, purse seine and trawl fisheries, contributing to long-term declines in populations that may not be immediately apparent (Campbell & Corwell 2008; Damalas & Vassilopoulou, 2011; Favaro & Coté, 2015). The actual amount of shark bycatch in fisheries is difficult to determine due to a lack of reporting or underreporting at both the fishermen and national levels, even in regulated fisheries. According to Dulvy et al. (2021), overfishing is the sole threat for 67.3% of elasmobranch species, and science-based limits on fishing, effective marine protected areas, and approaches that reduce or eliminate fishing mortality are urgently needed to minimize mortality of threatened species.

From a biological perspective, large sharks are characterised by K-selected life history traits, including slow growth, late onset of sexual maturity, low fecundity and remarkable longevity, all of which leading to low rates of population increase (Fowler et al., 2005). Such fragile life histories make large sharks highly vulnerable to overexploitation, which was recently demonstrated in a large-scale Mediterranean case study (Ferretti et al., 2008). Thus, once their populations depleted, recovery may take several decades or longer. Besides, these species are extremely vulnerable to habitat degradation and together with overexploitation, this may result in dramatic declines in their populations (Frisk et al., 2002; Ferretti et al., 2008; Bradley & Gaines, 2014; Peristeraki et al., 2020). Myers and Worm (2005) estimated that sharks had twice the risk of extinction in fishing operations compared to bony fish. Many sharks and rays are being considered vulnerable, threatened, endangered, or critically endangered in the Mediterranean waters (Otero et al., 2019). Among the 85 species known in the Mediterranean, only 73 were assessed within the framework of the International Union for Conservation of Nature (IUCN) Red List. Despite this high biodiversity, the Mediterranean Sea shows more significant conservation concern for chondrichthyans than the rest of the world, as reported by the last IUCN Regional Red List assessment, which listed more than half of the 73 evaluated species as threatened (Dulvy et al., 2016). In addition, 16 species (13 shark and three ray species) are still considered data deficient "DD" (Otero et al., 2019).

Historically, many sharks have low commercial value and are not regularly recorded in fishing statistics. For this reason, detailed capture or survey data are often lacking (Dulvy & Reynolds, 2002; Clarke et al., 2006), and also population changes are not well documented for many shark species in Mediterranean waters.

Traditional commercial fisheries have exploited many small bottom-living coastal sharks and skates, and have recently increased their exploitation efforts of deep-water sharks, both as target and utilised bycatch in multi-species fisheries. This situation is especially serious for shark species that are regarded as vulnerable to exploitation.

Iskenderun Bay and the neighboring Mersin Bay are important fishing grounds with regards to pelagic swordfish drift lines and drift nets, and demersal trawl fisheries. At least for the last decade, the importance of the region with regards to marine aquaculture has been significantly rising. Recently, newborn and young-of-the-year (YOY) specimens of several elasmobranch species were recorded in previous studies (Basusta et al., 2021; Erguden et al., 2020).

Bycatch is one of the most significant issues in the management and conservation of global fisheries and has been known as one of the leading causes of shark population declines (Hall et al., 2000; Lewison et al., 2004; Peristeraki et al., 2020). Up to date, the Eastern Mediterranean is not in a good state of conservation due to the high effects of fishing (target and bycatch), which causes a significant decline in the number of sharks day by day. Therefore, the present study contains important data in terms of focusing on the incidental captures of young sharks in the region by fishing activities and reconsidering fishing regulations in the region.

Based on the data on the incidental captures of young-of-the-year and juvenile specimens (n=269; 15 species), between 2010 and 2021, it was suggested that İskenderun and Mersin bays may serve as a nursery ground for several shark species. Since nursery grounds are essential habitats, and may serve as a growing and feeding ground for juveniles until maturity, a long-term monitoring program is required to provide the necessary conservation for sharks in this valuable nursery area and to detect spatio-temporal changes. Cooperation between policymakers, fishers, conservationists, and researchers are necessary to significantly reduce the threat of bycatch and help sharks gain a chance at recovery.

Supplementary Material

Supplementary Material is given as a Supplementary Annex, which is available via the "Supplementary" tab on the article's online page.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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