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Analysing large pelagic fisheries data from the open waters of the southeastern Mediterranean Sea during 1998 to 2005, we identified no more than 10 species of large sharks, although most updated literature cites more than twice this number in the region. We identified a statistically significant decline in species richness, with the probability of shark occurrence reducing to its lowest level in the most recent years. Blue shark was the predominant species, comprising approximately 70% of all large sharks encountered. A Milk shark was observed for the first time in the region. Based on their capture location, a series of maps depicting the spatial distribution of large sharks is provided. It seems as if currently the continuity of the presence of some species in the region may be questionable or that some species may have become too rare to be detected in the course of a conventional monitoring survey.

Keywords: shark; oceanic; Mediterranean; longline; chondrichthyan

Introduction

The most recent update on Mediterranean sharks gives the number of identified sharks as 47 species, of which 42 reside in the southeastern Mediterranean Sea (Serena 2005). However, some of these sightings date back over half a century. Taking into account the degradation of the marine environment through anthropogenic activities and plausible population depletion as the result of intensive fishing, the continuing presence of some species in the region seems questionable.

In this work we focused on a subset of shark species: large sharks of open waters. These are, more often than not, highly mobile species that are not associated closely with the sea floor and primarily live in the open ocean away from continental landmasses. Their highly migratory nature and their free-ranging behaviour in a relatively inaccessible and concealing environment ignoring national boundaries poses several difficulties for gathering scientific data, as well as future monitoring and fixing a common regimen for assessing their populations. We defined as "large", all shark species surpassing 100 cm in total length. This approach has been adopted by MEDLEM (2012) defining "large cartilaginous fish" as an elasmobranch of more than 100 cm (total length) or a batoid fish with a disc width more than 100 cm or total length more

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than 150 cm. The size of the monitored cartilaginous fishes is established on the basis of the maximum size reached by the different species.

In the southeastern Mediterranean Sea, data on large sharks are rare. Shark-directed fisheries in the southeast Mediterranean are mostly demersal and coastal ("kellabia" nets in Libya – UNEP 2005; "bestinare" gillnets in Italy – Ferretti et al. 2008; "skyloparagado" bottom longline in Greece – Mytilineou and Machias 2007; gillnets for *Mustelus mustelus* in western Turkey – Ceyhan et al. 2010). In open waters, no shark-directed fishery exists at present (because of their relatively low commercial prices); however, other large pelagic fisheries in the region, targeting mainly swordfish or tuna, catch sharks incidentally (Filanti et al. 1986; Pisanty 1986; Pisanty and Sonin 1991, 1992; Pisanty et al. 1996; Di Natale 1998; Fowler et al. 2005; Megalofonou, Damalas et al. 2005; Megalofonou, Yannopoulos et al. 2005; Tserpes et al. 2005). For most of these large shark species, surface drifting longlining can be considered the principal (if not exclusive) source of fishing mortality, serving at the same time as the sole monitoring tool for obtaining valuable scientific information.

We concentrated on certain shark families (Alopiidae, Cetorhinidae, Carcharhinidae, Lamnidae, Hexanchidae, Odontaspidiidae, Sphyrnidae, Triakidae), as definition by habitat is unsatisfactory, with inconsistencies in the meaning of terms such as "coastal" or "pelagic" when applied to the areas where different shark species are found. At least 26 species of large sharks belonging to the aforementioned families have been reported from the region (Serena 2005). This work updates the 1998–2001 data set on southeastern Mediterranean sharks (Megalofonou Damalas et al. 2005), populating it with more recent observations (2003–2005), made both on-board commercial fishing vessels as well as at landing locations. By merging and re-analysing the whole 1998–2005 period data set, our aspiration was to provide new all-inclusive information, such as detailed spatial occurrence and trends of species richness on this group of species inhabiting the open waters of the southeastern Mediterranean Sea.

Materials and methods

The Mediterranean Sea constitutes less than 1% of the total water surface of the planet with 22 different countries bordering its coastline. It extends from the Straits of Gibraltar to the Near East for about 4000 km, reaching its maximum depth (5121 m) in the eastern Ionian Sea. The Mediterranean Sea can be divided into two main basins: western and eastern separated by the Sicily–Tunisia ridge. The eastern basin (Figure 1), is characterized by great oceanographic variability on the surface with temperatures of 16°C in winter and up to 29°C in summer, as opposed to 12° and 23°C in the western basin, and salinities of 39‰ as opposed to 36‰ in the west (Serena 2005). Despite its small size, the fish biodiversity and absolute number of species are relatively high: about 6% of the entire world's fish species occur in its waters (Fredj et al. 1992), and moreover the chondrichthyans present in the area represent about 7% of the total number of species of this group in the world (Compagno 1984a, 1984b; Seret and Serena 2002; Serena 2005).

During the period 1998–2001 and 2003–2005, 62 Greek and two Cypriot commercial longlining fishing boats were followed, operating from 24 fishing ports located in the southeastern Mediterranean Sea (Figure 1; Tables 1, 2). As this was a fishery-dependent survey, no fixed sampling stations were applicable, although occasionally

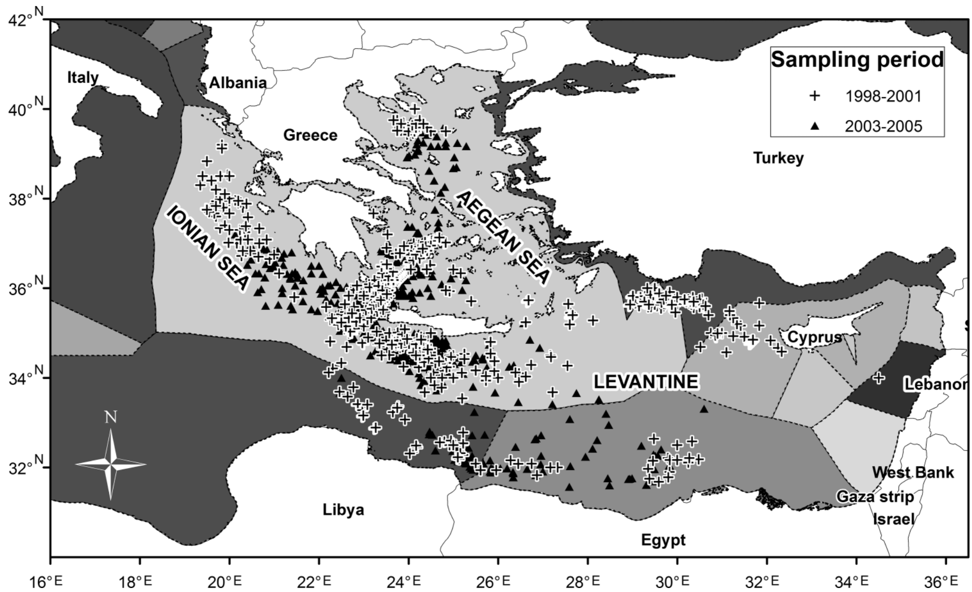

Figure 1. Map of the study area in the southeastern Mediterranean Sea. Fishing locations are indicated by crosses (1998–2001) and solid triangles (2003–2005). Shaded marine regions designate *potential* Exclusive Economic Zones (EEZ) as provided by Flanders Marine Institute (VLIZ), available at: http://www.vliz.be/vmdcdata/marbound/. To date, very few Mediterranean countries have claimed an EEZ.

the boats fished in adjacent locations. The longline gears deployed were surface drifting longlines targeting swordfish or tuna (SWO-LL_T, traditional swordfish longline; SWO-LL_A, American-type swordfish longline; ALB-LL, albacore longline). The fishing period was March to September for swordfish longlines and September to December for albacore longlines. Detailed information regarding gear configuration, as well as hauling and retrieving tactics, can be found in Megalofonou, Damalas et al. (2005);

Table 1. Summary table by fishing gear indicating number of ports, vessels, fishing sets, hooks deployed, sharks caught, nominal catch rates and percentage of total catch in the open waters of southeastern Mediterranean Sea, during the periods 1998–2001 and 2003–2005.

Fishing gear	No. of ports	No. of boats	No. of fishing sets	No. of hooks deployed	No. of sharks caught	Catch rate (sharks/1000 hooks deployed)	% of total catch
SWO-LL_T	12	12	283	289,110	22	0.07	1.44%
SWO-LL_A	16	32	978	494,609	221	0.45	3.12%
ALB-LL	2	32	99	151,100	6	0.04	0.66%
Total	24*	64*	1360	934,819	249	0.27	2.62%

*Ports and vessels may overlap between fishing gears.
SWO-LL_T, traditional swordfish longline; SWO-LL_A, American-type swordfish longline; ALB-LL, albacore longline.

Table 2. Summary table by fishing gear and study period, indicating number of fishing sets observed on board fishing vessels (OB) and at landing locations (AL).

	AL	OB	Total
1998–2001			
ALB-LL	99		99
SWO-LL_T	74	37	111
SWO-LL_A	395	86	481
2003–2005			
ALB-LL			
SWO-LL_T	136	36	172
SWO-LL_A	424	73	497
Total	1128	232	1360

Megalofonou, Yannopoulos et al. (2005) and Damalas and Megalofonou (2009). During each fishing set, observers stationed on board the vessels recorded the following operational data: date, location (determined from GPS), number of hooks, gear configuration and bottom depth. In the absence of on board observers, the aforementioned information was gathered at the landing locations, by interviewing the skippers and consulting the boats' unofficial logbooks. Later on, "distance from coast" was estimated for each fishing point, applying a MATLAB (version R2007b, Mathworks Inc., Natick, Massachusetts, USA) script, which located the nearest land point and calculated the straight line between the two points in nautical miles (after corrections for the Earth's spheroid shape).

For each fishing set, shark specimens were identified to species level and a series of morphometric measurements were kept for each specimen (as defined in "Technical terms and measurements" – Compagno 1984a; Serena 2005). The most common measurements kept included total length, fork length, pre-pectoral length, interdorsal space, dorsal caudal margin and eviscerated weight. Relationships between total length and other length morphometrics were investigated with simple linear regression analysis, provided the sample size was sufficiently large. The relationship between length and weight measurements was calculated using the multiplicative regression model, weight $= a \times \text{length}^b$, fitted on the log scale (Zar 1996). Ratios between total length and most common morphometrics were also computed.

The number of species (i.e. species richness) is the most frequently used measure of biodiversity. In view of the fact that fishing effort was not homogeneously spread across regions, years or seasons, correction for the effort effect was essential to obtain consistent results because estimates might have been heavily influenced by the amount of effort applied. The probability of observing a species is more likely to rise with fishing effort, and the use of an annual mean number of species per unit of effort would underestimate annual species occurrence. We followed the approach used by Daan et al. (2005), and Damalas and Vassilopoulou (2011), who studied chondrichthyan biodiversity in the North Sea and the Aegean Sea, respectively. We initially identified in our data set the year with the least effort exerted (expressed in number of hauls: N_{min}). Afterwards, so as to eliminate the effort effect, we randomly selected a sequence of N_{min} hauls in each year. For these N_{min} random hauls, we calculated the number of species encountered in all of them. This random selection was repeated 1000 times on an annual basis, and these 1000 different values (of number of species encountered), were averaged over each year. Finally, the annual trend was expressed by the slope of a linear regression when number of species was regressed upon year.

Presence/absence data were analysed to assess how the probability of shark occurrences in the catches evolved through time. A standardized index of occurrence probability was acquired by applying a generalized additive model approach (Hastie and Tibshirani 1990) taking into account: the two time periods (1998–2001 and 2003–2005), the gear effect, the seasonal effect and the spatial effects (longitude, latitude, distance from coast, bottom depth). Fishing effort was used as an offset in the predictors. The response variable in the generalized additive model was the binary variable *Presence*, assigned a value of 0 if no sharks were present in the catch, and 1 otherwise (Bernoulli-type 0/1 measurements). The model acquired the following formula:

$$\Pr esence \sim c + Time.Period + Gear + Month + s(Longitude) + s(Latitude) \\ + s(Distance) + s(Depth)$$

where the response variable followed the binomial distribution, *c* was the intercept, and *s( )* represented smooth functions using penalized regression splines. The optimum degree of smoothing was defined by the generalized cross-validation criterion using the MGCV package (Wood 2006) in R v.2.11.0 (R Development Core Team 2011).

Finally, each individual large shark capture location was mapped on a Geographical Information System layer using ESRI's ARCMAP desktop GIS software (version 9.2. SP4; Environmental Systems Research Institute, Inc., Redlands, CA, USA).

Results

Large sharks were present in 207 out of a total of 1360 fishing sets (exerting an effort of almost a million hooks). In these sets, 249 large shark specimens were observed, belonging to at least 10 species and five families (Tables 1, 2 and 3). Observations made at landing locations (Table 2), posed a series of obstacles. All shark specimens landed were gutted and for this reason eviscerated weight was the only weight measurement kept (weighing on board the vessels upon capture was not an option). In several cases, gutting was accompanied with removal of the external genitals, making sex identification impossible. In extreme cases, specimens were gutted, finned and decapitated, restricting identification to the family/genus taxon (e.g. *Carcharhinus* spp. in Table 3). The slope of the linear regression relating number of large shark species encountered with year (Figure 2, top) was negative and statistically significant ($p < 0.001$), suggesting that species richness decreased by an average of 0.125 species per year. In addition, generalized additive models demonstrated that time period was the most influential predictor of shark occurrence. The probability of a shark occurring in the catches differed significantly among the two time periods of the study (1998–2001; 2003–2005); a shark was more likely to be caught in the early years (Figure 2, bottom). Catch rates, expressed as nominal catch per unit of effort (CPUE: numbers captured per 1000 hooks deployed) were 0.27 sharks/1000 hooks in total (0.34 during 1998–2001; 0.18 during 2003–2005) (Table 1).

Table 3. Synoptic table of the shark taxa caught in the 1360 hauls of the surface drifting longlines in the open waters of southeastern Mediterranean Sea during 1998–2005.

Order	Family	Taxa	Common name	No.	Distance from land (n.m.) min/avg/max	Sea bottom depth (m) min/avg/max	Total length (cm) min/avg/max	Eviscerated weight (kg) min/avg/max	Sexed animals	Male : Female ratio
Carcharhiniformes	Carcharhinidae	*Prionace glauca*	Blue shark	170	5/32/110	152/1923/4120	101/225/387	8/38/175	53	1.30
Lamniformes	Lamnidae	*Isurus oxyrinchus*	Shortfin mako	25	7/37/66	524/2227/4110	101/167/270	12/54/205	7	2.50
Carcharhiniformes	Triakidae	*Galeorhinus galeus*	Tope shark	22	10/35/55	620/1066/2830	126/143/190	8/11/23	0	–
Lamniformes	Alopiidae	*Alopias vulpinus*	Common thresher shark	13	12/34/55	352/1660/3128	108/331/514	20/55/197	4	0.33
Carcharhiniformes	Carcharhinidae	*Carcharhinus plumbeus*	Sandbar shark	11	11/38/53	1180/2013/2954	110/123/163	15/17/25	2	1.00
Carcharhiniformes	Carcharhinidae	*Carcharhinus spp.*	–	2	16/61/107	568/1825/3082	113/156/200*	10/27/45†	1	–
Lamniformes	Alopiidae	*Alopias superciliosus*	Bigeye thresher shark	2	20/23/26	544/1514/2484	151/255/360	10/42/75	1	–
Lamniformes	Lamnidae	*Carcharodon carcharias*	Great white shark	1	38	2364	429	500	1	–
Hexanchiformes	Hexanchidae	*Heptranchias perlo*	Sharpnose sevengill shark	1	18	382	104	3	1	–
Hexanchiformes	Hexanchidae	*Hexanchus nakamurai*	Bigeye sixgill shark	1	18	230	106	4	1	–
Carcharhiniformes	Carcharhinidae	*Rhizoprionodon acutus*	Milk shark	1	51	3354	162	22	1	–
		Total		249	5/34/110	152/1946/4120	101/230/514	3/39/500	71	1.37

*Pre-pectoral length.
†Dressed weight (gutted, finned and decapitated).
n.m., nautical miles.

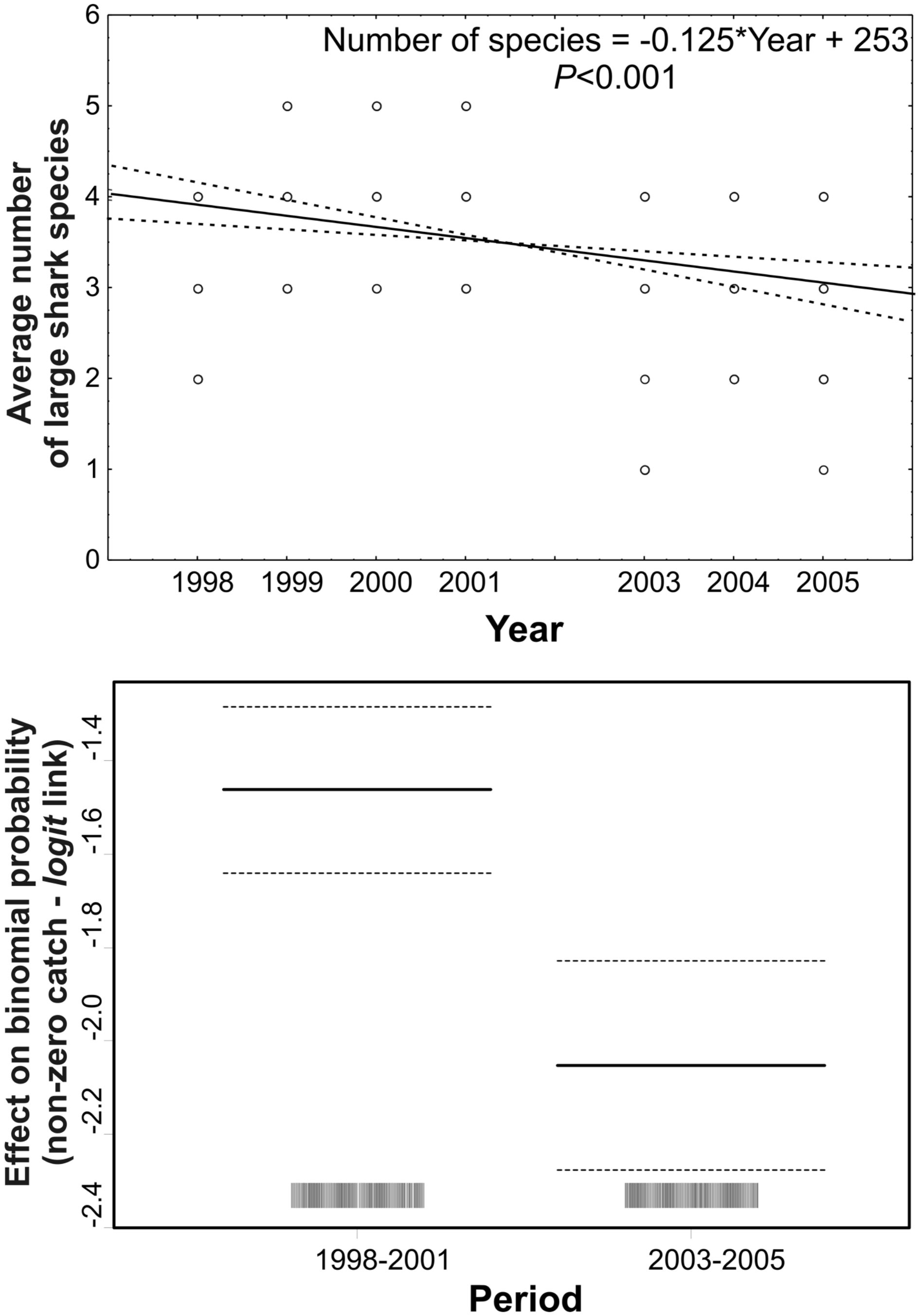

Figure 2. (Top) Annual trend of large shark species richness as inferred from the slope of a linear regression of average number of species upon year on a series of randomly selected hauls in each year. Open circles depict number of species observed during a year. Dashed lines indicate centred 95% confidence intervals. (Bottom) Generalized additive model derived effects of the investigated parameters on the binomial probability of encountering large sharks. Dashed lines indicate two standard errors above and below the estimates.

Large sharks comprised 2.6% (in number) of total catches in the surface drifting longlines targeting swordfish or tuna, with proportions varying between the different fishing gears (Table 1). All sharks arriving on deck showed vigorous vital signs, giving the impression of animals remarkably tolerant to the hardships of being hooked on a longline for several hours; a single female blue shark was recorded dead upon capture. Most sharks were kept for marketing; discarding occurred only in exceptional cases. No more than nine specimens (seven blue sharks, two bigeye thresher sharks) representing a negligible 3%, were thrown back to sea, unfortunately all of them already dead. Most of the sharks were captured in distant deep open waters (average bottom depth 1946 m, average distance from the coastline 34 nautical miles; Table 3).

The blue shark, *Prionace glauca* (Linnaeus, 1758), was the predominant species, comprising around 70% of all large sharks encountered. Sandbar sharks, *Carcharhinus plumbeus* (Nardo, 1827), milk sharks, *Rhizoprionodon acutus* (Rüppell, 1837), and unidentified carcharinids of the genus *Carcharhinus*, provided another 4% bringing the requiem sharks (Carcharhinidae) total to 74% (184 out of 249). Mackerel shark species (Lamniformes), were the second largest group after the requiem sharks (41 out of 249 or 16%). Shortfin makos, *Isurus oxyrinchus* Rafinesque, 1810, thresher sharks, *Alopias vulpinus* (Bonnaterre, 1788) and bigeye thresher, *Alopias superciliosus* Lowe, 1841, made up the mackerel shark species, supplemented by a rare catch of a female great white shark, *Carcharodon carcharias* (Linnaeus, 1758), caught off the Libyan coast in April 2000. Houndsharks (Carcharhiniformes: Triakidae) were represented by 22 specimens (8%) of tope, *Galeorhinus galeus* (Linnaeus, 1758). The remaining two specimens belonged to the cow shark family (Hexanchidae): a sharpnose sevengill shark, *Heptranchias perlo* (Bonnaterre, 1758), and a bigeye sixgill shark, *Hexanchus nakamurai* Teng, 1962. It is noteworthy that, milk shark (male, 16 July 2004, southeast Ionian Sea) and bigeye sixgill shark (male, 18 May 2001, off western Cretan coast) were observed for the first time in the southeastern Mediterranean region during these series of surveys.

Spatial distribution of all shark species observed, based on their capture location, are given in the maps of Figures 3, 4 and 5. From these distribution maps, it becomes obvious that the Levantine basin exhibits an increased diversity of shark species. In contrast, the Aegean Sea hosts, almost exclusively, blue shark populations.

Analyses on morphometric measurements were conducted for the blue shark only, because it was the sole species with an adequate sample size. A histogram of length frequency distribution (Figure 6) and ratios of total length and the most common morphometric measurements (Table 4) are provided. Relationships between total length and the other morphometric variables were significantly correlated. The equations and the correlation coefficients computed, as well as the number of samples used, are given in Table 5.

Discussion

This study focused on a subset of sharks consisting of large species occurring in the open waters of the southeastern Mediterranean region. Figure 1, with potential exclusive economic zones superimposed, depicts clearly how the sharks caught during this study were distributed throughout the region, ignoring administrative boundaries and national sovereignties. However, classification under the category “pelagic”, “oceanic” or “coastal”, proved not to be so straightforward for some species. As an

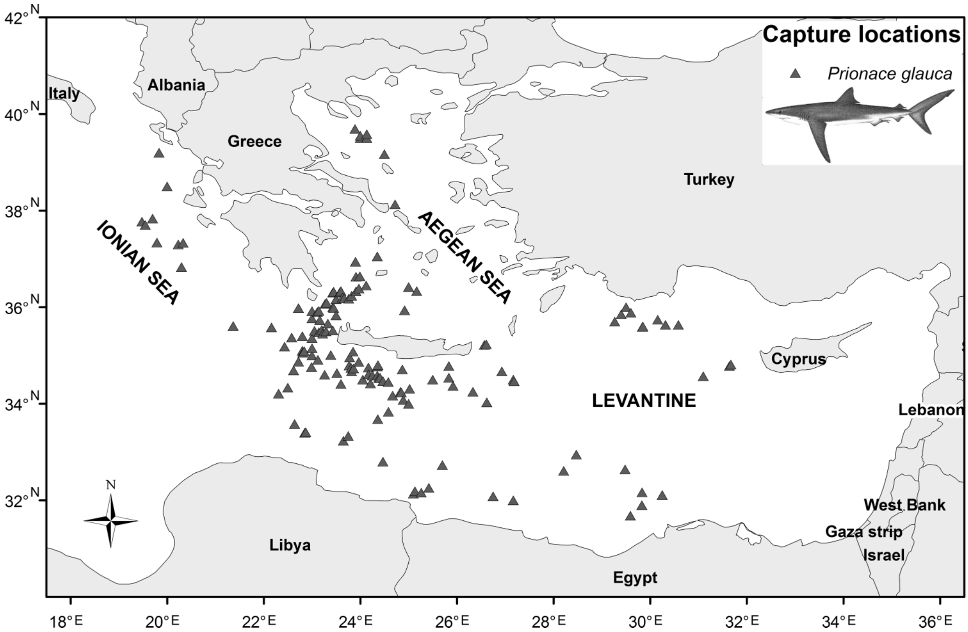

Figure 3. Map depicting capture locations of blue sharks (*Prionace glauca*) in the southeastern Mediterranean large pelagic fisheries during 1998–2005.

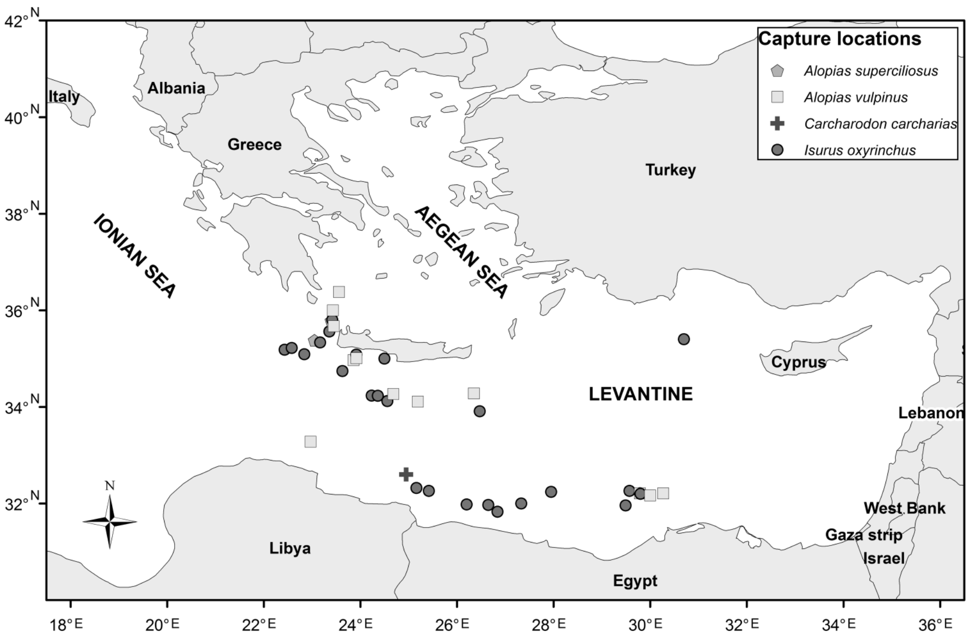

Figure 4. Map depicting capture locations of mackerel shark species (Lamniformes) in the southeastern Mediterranean large pelagic fisheries during 1998–2005.

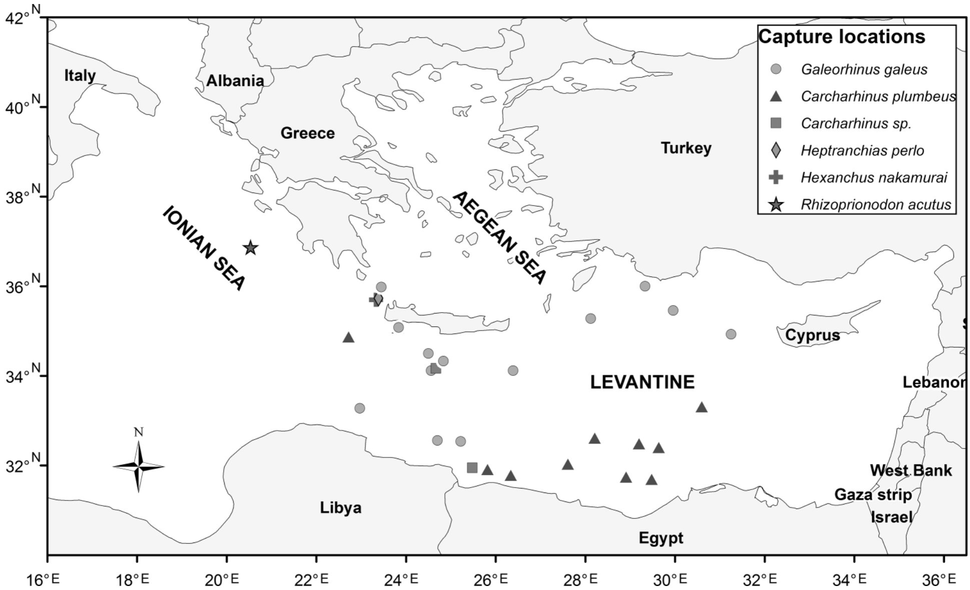

Figure 5. Map depicting capture locations of other large shark species in the southeastern Mediterranean large pelagic fisheries during 1998–2005.

example, *Carcharodon carcharias* is categorized under the classification "coastal-pelagic", and although mostly encountered in coastal regions, it undertakes extensive migrations to the open ocean, swimming thousands of miles off the coast (Domeier and Nasby-Lucas 2008). *Carcharhinus plumbeus* is also categorized as "coastal-pelagic", common on the continental shelf and at depths up to 280 m (Compagno 1984b; Castro et al. 1999; Serena 2005). Bradai et al. (2010), cite certain areas in the region (Gulf of Gabes, Tunisia and Boncuk Bay, Turkey) that serve as nursery grounds for the species; however, during our study they were observed at an average distance of 38 nautical miles ($\sim$ 70 km) off the coast, captured in surface waters at night. In a similar way, although *G. galeus* is classified as "coastal to epipelagic" (Compagno 1984b; Serena 2005), most specimens were detected in the open sea.

Three main outcomes are of note: (i) the small number of species observed, compared with the alleged number of species inhabiting the region, (ii) the moderate, but significant, decline in species richness during the study period, and (iii) the very low levels of catch rates, compared with the catch rates reported in the world's oceans (Strasburg 1958; De Metrio et al. 1984; Filanti et al. 1986; Di Natale 1998; Buencuerpo et al. 1998; Fowler et al. 2005; Ferretti et al. 2008).

Shark species occurrence (this study and other concurrent sources)

Only *P. glauca*, *I. oxyrinchus* and *A. vulpinus* were observed in both sub-periods (Table 6). An analogous declining trend, like the one observed here in large shark species richness, has been recently identified in demersal chondrichthyans of the Aegean Sea (Damalas and Vassilopoulou 2011), and was attributed to the known vulnerability of cartilaginous fish to fishing. The actual number of shark species captured

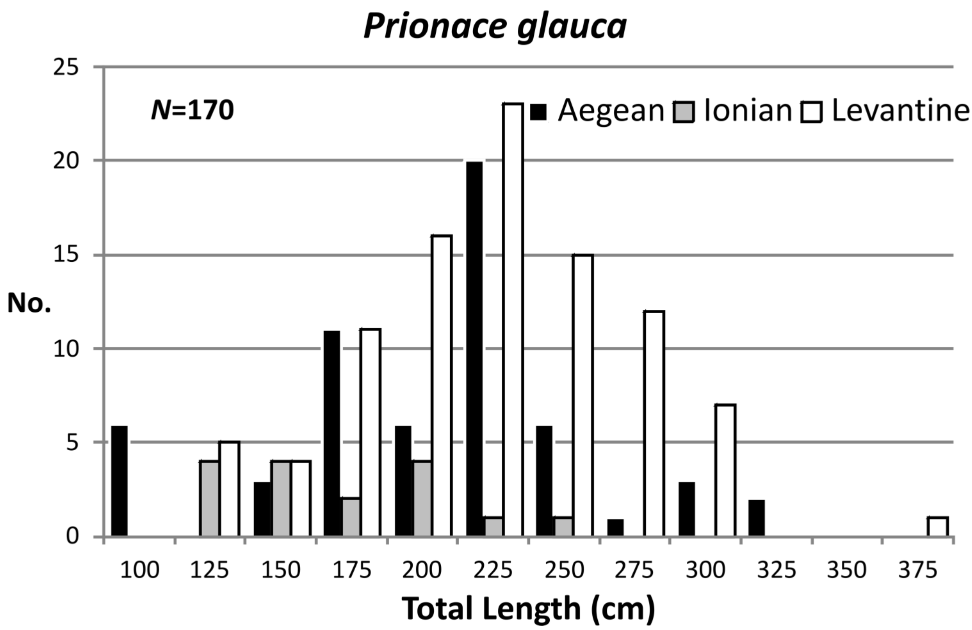

Figure 6. Total length frequency distribution for blue sharks (*Prionace glauca*) captured in the southeastern Mediterranean large pelagic fisheries during 1998–2005.

Table 4. Ratios between total length and morphometric measurements for blue shark, *Prionace glauca*, caught in the open waters of southeastern Mediterranean large pelagic fisheries during 1998–2005. Ratios are expressed as % of total length.

Morphometric measurements	Sample no.	Mean	SD	Min.	Max.
TL (cm)	170	225.1	51.2	101.6	387.9
Expressed as % of TL					
FL	60	81.3	1.5	78.6	85.4
PL	72	60.3	1.7	54.3	64.7
IDS	79	20.7	2.5	16.6	32.4
CDM	57	25.2	2.1	17.8	37.1

TL, total length; FL, fork length; PL, pre-pectoral length; IDS, interdorsal space; CDM, dorsal caudal margin.

may be higher; however, the poor state in which some *Carcharhinus* spp. specimens were landed, hindered us from identifying them to species level (Table 3). As a general rule, Carcharhinidae genera can be difficult to identify because of similar body shape and colour, and overlapping distributions; particularly *Carcharhinus* species and *Rhizoprionodon* species. In response, the US Department of Commerce has published a special field identification guide dedicated to requiem sharks (Grace 2001). The unidentified specimens observed during our survey, could belong to any of the seven *Carcharhinus* species present in the southeastern Mediterranean (Serena 2005). These captures were made in the Levantine basin (Figure 6). In this region during the period 1986–1996, a series of experimental open sea surface longline surveys confirmed

Table 5. Relationships between morphometric variables and total length (TL) for blue shark, *Prionace glauca*, caught in the open waters of southeastern Mediterranean large pelagic fisheries during 1998–2005.

Independent variable	No.	TL range (cm)	a	b	r^2
FL	60	101–387	3.6026	1.2073	0.9943
PL	72	133–387	0.6846	1.6546	0.9858
IDS	79	133–387	73.116	3.3241	0.7611
CDM	57	133–301	25.708	3.5098	0.8406
$RW = a \times TL^b$	167	101–387	1.821E-06	3.0823	0.9218

TL, total length; FL, fork length; PL, pre-pectoral length; IDS, interdorsal space; CDM, dorsal caudal margin; RW, eviscerated weight.
$TL = a + (b \times$ *Independent variable*).

the presence of the dusky shark, *Carcharhinus obscurus* (Lesueur, 1818) (Pisanty 1986; Pisanty and Sonin 1991, 1992; Pisanty et al. 1996).

Additionally, seven other species, also not detected during our study, have been reported from the southeastern Mediterranean area in the recent years (Table 6). The porbeagle *Lamna nasus* (Bonnaterre, 1788) and the smooth hammerhead *Sphyrna zygaena* (Linnaeus, 1758) were caught in the North Ionian surface longline fisheries during 1998 and 1999 (Megalofonou, Yannopoulos et al. 2005). The bluntnose sixgill shark, *Hexanchus griseus* (Bonnaterre, 1788), the smooth-hound, *Mustelus mustelus* (Linnaeus, 1758) and the starry smooth-hound, *Mustelus asterias* Cloquet, 1821, have been repeatedly witnessed in experimental bottom trawl surveys throughout Greek waters (Abello et al. 2002; Peristeraki et al. 2007; Serena 2007), as well as from commercial fisheries (gillnets, longlines, trawlers) in Turkey (Kabasakal and Kabasakal 2004; Kabasakal 2006; Ceyhan et al. 2010). In Italian northern Ionian waters, *H. griseus* has been reported as by-catch in the open water swordfish longline fishery (Filanti et al. 1986). A large basking shark, *Cetorhinus maximus* (Gunnerus, 1765), individual, (approx. 7 metres, 2 tonnes) was entangled in the static nets of a coastal fisher off the Athenian coast on 9 March 2009 (Megalofonou 2009). The day after, the specimen was landed in the Athens auction fish market (Figure 7). As the species is protected (EC 407/2009; European Commission 2009), it triggered a series of reactions from environmental groups and non-government organizations, reaching even a Parliament hearing. A final court decision is still pending, but the incident revealed the unawareness or indifference of the involved stakeholders (fishermen, fisheries inspectors, port police authorities, auction market officials) with respect to the legal framework regulating shark official marketing. Mancusi et al. (2005), reviewing the presence of the species in the Mediterranean, also report observations in the southeastern Mediterranean dating back to the eighteenth century, however they underline the poor information available in the region. A rare specimen of a smalltooth sandtiger shark, *Odontaspis ferox* (Risso, 1810), (approx. 500 kg) was caught at a depth of 600 m in the bottom static net fishery of Andros Island (central Aegean Sea) during December 2007.

Despite the confirmed observation of certain large shark species during the past decade or so, the rarity of their occurrence poses serious concerns about their population status. It is noteworthy that although hammerhead sharks *Sphyrna* spp. have been

Table 6. List of orders, families and species for large sharks present in the open waters of southeastern Mediterranean Sea.

Order	Family	Species	Author	Common name	Present during 1998–2001	Present during 2003–2005	Present (based on other recent sources)	Population Status (IUCN Red List for Mediterranean)
Carcharhiniformes	Carcharhinidae	*Carcharhinus altimus*	Springer, 1950	Bignose shark			–	Data Deficient
Carcharhiniformes	Carcharhinidae	*Carcharhinus brachyurus*	Günther, 1870	Copper shark			–	Data Deficient
Carcharhiniformes	Carcharhinidae	*Carcharhinus brevipinna*	Müller and Henle, 1839	Spinner shark			Capapé et al. (2003)	Data Deficient
Carcharhiniformes	Carcharhinidae	*Carcharhinus falciformis*	Müller and Henle, 1839	Silky shark			Bradai et al. (2004)	Least Concern
Carcharhiniformes	Carcharhinidae	*Carcharhinus limbatus*	Müller and Henle, 1839	Blacktip shark			Capapé et al. (2004)	Data Deficient
Carcharhiniformes	Carcharhinidae	*Carcharhinus obscurus*	Lesueur, 1818	Dusky shark			Pisanty (1986); Pisanty and Sonin (1991, 1992) Pisanty et al. (1996); Saad et al. (2004)	Threatened
Carcharhiniformes	Carcharhinidae	*Carcharhinus plumbeus*	Nardo, 1827	Sandbar shark		+	Bradai et al. (2010)	Endangered
Carcharhiniformes	Carcharhinidae	*Prionace glauca*	Linnaeus, 1758	Blue shark	+	+	Bradai et al. (2010)	Vulnerable
Carcharhiniformes	Carcharhinidae	*Rhizoprionodon acutus*	Rüppell, 1837	Milk shark		+	–	Data Deficient
Carcharhiniformes	Triakidae	*Galeorhinus galeus*	Linnaeus, 1758	Tope shark	+		Peristeraki et al. (2008)	Vulnerable
Carcharhiniformes	Triakidae	*Mustelus mustelus*	Linnaeus, 1758	Smooth-hound			Peristeraki et al. (2007)	Vulnerable
Carcharhiniformes	Triakidae	*Mustelus punctulatus*	Risso, 1827	Black-spotted smooth-hound			Saidi et al. (2009)	Vulnerable
Carcharhiniformes	Triakidae	*Mustelus asterias*	Cloquet, 1821	Starry smooth-hound			Kabasakal and Kabasakal (2004)	Vulnerable
Carcharhiniformes	Sphyrnidae	*Sphyrna mokarran*	Rüppell, 1837	Great hammerhead			–	Endangered
Carcharhiniformes	Sphyrnidae	*Sphyrna zygaena*	Linnaeus, 1758	Smooth hammerhead			Megalofonou, Yannopoulos et al. (2005)	Vulnerable

(*Continued*)

Table 6. (Continued).

Order	Family	Species	Author	Common name	Present during 1998–2001	Present during 2003–2005	Present (based on other recent sources)	Population Status (IUCN Red List for Mediterranean)
Hexanchiformes	Hexanchidae	*Heptranchias perlo*	Bonnaterre, 1788	Sharpnose sevengill shark	+		Serena (2007)	Vulnerable
Hexanchiformes	Hexanchidae	*Hexanchus griseus*	Bonnaterre, 1788	Bluntnose sixgill shark			Kabasakal (2006); Serena (2007)	Near Threatened
Hexanchiformes	Hexanchidae	*Hexanchus nakamurai*	Teng, 1962	Bigeye sixgill shark	+		–	Data Deficient
Lamniformes	Alopiidae	*Alopias superciliosus*	Lowe, 1841	Bigeye thresher shark	+		Kabasakal and Ünsul Karhan (2008)	Data Deficient
Lamniformes	Alopiidae	*Alopias vulpinus*	Bonnaterre, 1788	Common thresher shark	+	+	Hattour and Nakamura (2004)	Vulnerable
Lamniformes	Cetorhinidae	*Cetorhinus maximus*	Gunnerus, 1765	Basking shark			Megalofonou (2009)	Vulnerable
Lamniformes	Lamnidae	*Carcharodon carcharias*	Linnaeus, 1758	Great white shark	+		Galaz and de Maddalena (2004); Kabasakal & Özgür Gedikoğlu (2008)	Endangered
Lamniformes	Lamnidae	*Isurus oxyrinchus*	Rafinesque, 1810	Shortfin mako	+	+	Peristeraki et al. (2008)	Critically Endangered
Lamniformes	Lamnidae	*Lamna nasus*	Bonnaterre, 1788	Porbeagle			Megalofonou, Yannopoulos et al. (2005)	Critically Endangered
Lamniformes	Odontaspididae	*Carcharias taurus*	Rafinesque, 1810	Sandtiger shark			–	Critically Endangered
Lamniformes	Odontaspididae	*Odontaspis ferox*	Risso, 1810	Smalltooth sandtiger			Pollard et al. (2009)	Endangered

Based on Compagno 1984a, 1984b; Serena 2005; only southeastern Mediterranean Sea.

Figure 7. A rare specimen of basking shark (*Cetorhinus maximus*) landed in the Athens auction fish market in March 2009.

recently captured in the North Ionian Italian fisheries (Megalofonou, Damalas and De Metrio 2005), Greek and Cypriot fishermen interviewed during this study unanimously acknowledged that they have never captured a hammerhead shark in their southeastern Mediterranean fishing grounds. In data-poor cases, such as the open water fisheries of the southeastern Mediterranean, seeking advice from fishermen (as observers of the marine system) may be the only way to gather information. Fishers, and especially retired fishermen with professional careers often exceeding 40 years, can provide ecological knowledge on the functioning of marine systems and their resources (Maynou et al. 2011). Out of the 33 interviewed skippers (unpublished data), two old Cretan fishers recalled witnessing hammerhead sharks being landed in Cretan ports during their childhood (post World War II). Moreover, a former sponge diver from Kalymnos Island (south Aegean Sea) claimed frequent sightings of hammerhead shark schools off the Libyan coast, where he and his colleagues were licensed to collect sponges in the mid-1990s. It is striking that the Greek checklist of marine fish species (Papakonstantinou 1988) cites the last observed specimen of hammerhead shark (*Sphyrna zygaena*) half a century ago.

Carcharodon carcharias is also rare in the literature during the past three decades. A large specimen (approx. 5 metres) was landed in the village of Paliouri, Chalkidiki (northern Aegean Sea) in 1985 (Bardanis 2008). Peristeraki et al. (2008) report a single catch during a 2004–2006 survey in the Greek swordfish fishery. More recently (July 2008), two newborn sharks were surprisingly caught in Edremit bay, northeast Aegean Sea (Kabasakal and Özgür Gedikoğlu 2008).

The unique specimens of *R. acutus* and *H. nakamurai* were both caught in the south-western part of the studied area. *Rhizoprionodon acutus* has been added to the marine alien biota of Greek waters entering from the Atlantic through the Gibraltar strait (2010 update – Zenetos et al. 2011). The only specimen described so far in the whole Mediterranean region, came from the adjacent North Ionian Sea (Pastore and Tortonese 1985).

The absence of any other shark species in our central-north Aegean Sea observations (except blue shark), could be attributed to the extreme fishing effort exerted in this area, possibly having a negative effect on the populations. The intensity of pelagic longline fishing effort is four to five times higher in the Aegean compared with the Levantine basin (supplementary material in Ferretti et al. 2008), which is a relatively new fishing ground for fishers targeting large pelagic species (Tserpes et al. 2004).

Shark presence and catch rates

Modelling presence/absence data confirmed that the main driver of occurrence probability was the time period. The standardized probability of encountering large sharks as a function of time, revealed a decreasing trend throughout the study period. However, the short time series of this study does not allow us to speculate whether the trend in the presence of sharks is a negative result of over-fishing or simply part of a regular inter-annual environmental fluctuation affecting large shark distribution and abundance.

Catch rates, expressed as CPUE, were highly influenced by blue shark catch rates, the dominant species in catches. This is the reason we avoided modelling CPUE and concentrated on occurrence data (presence/absence). The very low shark catch rates in the large pelagic fisheries of the eastern Mediterranean Sea have already been documented (Megalofonou, Yannopoulos et al. 2005). For comparable fishing gears (swordfish drifting longlines), nominal shark catch rates in the region were below 0.5 sharks/1000 hooks deployed, compared with the 1.0 and 3.8 sharks/1000 hooks in the Adriatic and Alboran Seas, respectively. It is difficult to detect whether these low catch rates are an anthropogenic result (depletion from historical fishing) or whether they reflect the very low productivity of the region. Specifically, a strong longitudinal constituent in the presence of sharks, the probability increasing from east to west, has been confirmed throughout the Mediterranean (Megalofonou, Yannopoulos et al. 2005). During 1998–1999 a joint project conducted in the Mediterranean Sea with the participation of Greece, Italy and Spain, attempted to estimate the magnitude of shark by-catches in their large pelagic fisheries (Megalofonou et al. 2000). It provided evidence of spatially imbalanced catches, with Spanish fishermen taking larger and more frequent catches of sharks compared with Italian and Greek fishermen. It was clear that these differences were not just a result of dissimilar catchabilities because of the similar configuration and effectiveness of fishing gear used. Additionally, when fishing sets were deployed in the vicinity of the Gibraltar straits (Atlantic and Mediterranean waters) during that project, the Atlantic sets caught more sharks. The findings of Buencuerpo et al. (1998) (studying western Mediterranean and eastern Atlantic waters) were also consistent with these conclusions. Availability of food and increased productivity–abundance of living resources in general, may be a key factor in these differences. The higher trophic potential of the western part of the Mediterranean compared with the eastern part supports this assumption; the eastern Mediterranean is regarded as one of the most oligotrophic regions of the world's oceans (Stergiou et al. 1997; Caddy 1998; Serena 2005). Azov (1991) has explicitly portrayed the eastern Mediterranean as a "marine desert".

A comparison of historical catch rate records in the North Ionian Sea with recent records (De Metrio et al. 1984; Megalofonou, Yannopoulos et al. 2005) revealed that shark catch rates have decreased by an average of 38.5% over the past 20 years. Ferretti et al. (2008) estimated that certain Mediterranean large predatory shark species have declined between 96 and 99% relative to their former abundance in the past century.

Blue shark

The blue shark, *Prionace glauca*, was the only species caught consistently throughout the study area and period. *Prionace glauca* is among the most abundant, widespread, fecund and fast growing of the elasmobranchs, making it less susceptible than any other elasmobranch to exploitation (Castro et al. 1999). Paradoxically, it is also one of the most heavily fished sharks in the world; annual fisheries mortality (mainly as by-catch) is estimated at 10–20 million individuals (Stevens 2000). More recently, Clarke et al. (2006) suggested that *P. glauca* current global trade volumes are close to or possibly exceeding maximum sustainable yield levels.

Prionace glauca was the only large shark observed in the central and north Aegean Sea. As a consequence of the very low sample size for most shark species, detailed analyses modelling catch rates have been conducted so far only for *P. glauca*, revealing interesting patterns in its behaviour (Megalofonou, Damalas et al. 2009; Damalas and Megalofonou 2009). Southeastern Mediterranean *P. glauca* distributions were significantly related to environmental cues (ambient temperature, bottom topography and lunar cycle: Damalas and Megalofonou 2009), demonstrating seasonal periodic movements towards coastal areas during spring; a fact presumably associated with reproduction.

Based on the age–length keys estimated for Mediterranean *P. glauca* (Megalofonou, Yannopoulos et al. 2009), captured specimens ranged from 2 to over

20 years of age (101–387 cm total length), with the average individual being an adult 5+ years of age (225 cm total length). Larger fish were more likely to occur in the Levantine, whereas smaller fish were more likely in the Ionian Sea. No young-of-the-year specimens have been witnessed, bringing into question whether the region can be considered as a *P. glauca* nursery area. However, this finding may be an effect of the fishing gears used, which did not allow for undersized specimens to be hooked on the relatively large baited surface longline hooks.

Conservation

Large sharks, as do all chondrichthyans in general, possess some special biological characteristics (low productivity, close stock–recruitment relationships and slow stock recovery in the event of overfishing), making them extremely vulnerable to non-natural induced mortality. Elasmobranchs, taken as by-catch in fisheries targeting other species could be extirpated long before appropriate management policies could be implemented (Walker 1998; Castro et al. 1999). Recent research suggests that the absence of sharks can indirectly alter predation pressure on different fish species via behavioural responses of meso-consumers released from predator intimidation and shark declines might have stronger ecological consequences than previously recognized (Frid et al. 2008).

In the framework of the Common Fisheries Policy, adopted in 1983 by the European Union member states, a data collection scheme, monitoring harvested marine resources, was established in 2000 (EC 1543/2000; EC 199/2008; EC 93/2010; European Commission 2000, 2008, 2010). It is mandatory that sharks are recorded in all EU fleets targeting large pelagics, however submitted annual reports group all species under the category "pelagic sharks". As a result, species identification is not usually carried out and this monitoring scheme is inadequate to assess the populations at a stock level.

Taking into consideration the fact that the greater part of large shark species in the region are classified as threatened, vulnerable, endangered or critically endangered (Table 6; Cavanagh and Gibson 2007; IUCN 2010), it is surprising that no conservation measures have been actioned to date in the Mediterranean (except for *Carcharodon carcharias*, *Cetorhinus maximus* – EC 407/2009 (European Commission 2009); and the general shark-finning ban regulation – EC 1185/2003; European Commission 2003). Numerous reports on the alarming status of Mediterranean shark species have populated the literature (Seret and Serena 2002; Fowler et al. 2005; Cavanagh and Gibson 2007; Melendez and Macias 2007; Dulvy et al. 2008; Bradai et al. 2010). Each provides sufficient and conclusive scientific advice for managers to take action. Some even put forward guiding rules for effective conservation and management. Large pelagic fish in the Mediterranean are managed by two major organizations: (i) the General Fisheries Commission of the Mediterranean and, (ii) the International Commission for the Conservation of Atlantic Tunas (ICCAT). They both collaborate on management recommendations and promote data exchange between nations. Both Commissions have management power and their rules are mandatory for members. However, implementation is at a national level and management approaches among nations may be diverse with many regulations, legally effective only within narrow territorial waters. A multi-lateral agreement on prohibition of landing the endangered species, as well as the establishment of a series of minimum landing sizes for those that are vulnerable/threatened, would be the most straightforward approach to promote the sustainable management of their populations.

In conclusion, this study's intention was to make available new knowledge on the populations of large sharks inhabiting the open waters of the southeastern Mediterranean Sea. Although 26 large shark species are currently considered as resident in the area (Serena 2005), our study did not succeed in identifying more than 10. Only five of these species were observed more than 10 times. The remaining five species were encountered only once or twice, suggesting that they are either ephemeral visitors in the region or their population levels are very low and close to detection thresholds. Moreover, a significant decrease in large shark species richness was evident, the probability of shark occurrence declining to its lowest level the most recent years. The fishery-dependent nature of the surveys did not allow the region to be sampled homogeneously in time and space and the limited range of fishing gears operating in the open waters must have affected the data set and may have added to the low species diversity. However, this multi-annual data set is a valuable source of information on the large sharks encountered in the open waters of the southeastern Mediterranean Sea.

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