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Elasmobranchs longline fisheries in the Gulf of Gabès (southern Tunisia)

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In Tunisia, elasmobranch landings have decreased substantially in recent years. Generally, species-specific information is largely unavailable for artisanal fisheries, but it is essential to increase knowledge and to ensure proper management of these species. This study analysed elasmobranch catches with longline fishery in the Gulf of Gabès. In total, 21 and 20 pelagic and bottom longline fishing trips were conducted, respectively, from July to September in 2007 and 2008. A total of eight elasmobranch species were caught: four batoids and four sharks. Pelagic longline captures were hooked externally while a high number of individuals captured with bottom longline were hooked internally. Discards due essentially to low commercial value and size represented 7.6% of total number of elasmobranch specimens caught. Longline landings in the Gulf of Gabès were principally composed of sandbar shark, Carcharhinus plumbeus*, representing, respectively, 94.14% and 21.17% in number of pelagic and bottom longline captures. The importance of rhinobatids and* Mustelus *capture with bottom longline reflect their abundance in this area compared to other Mediterranean zones. Juveniles, including neonates with umbilical scars, dominated carcharhnids specimens, while smoothhound and guitarfish captures were dominated by mature individuals. Mitigation measures based on gear modifications, size limits and delineated nursery areas in the Gulf of Gabès should be developed to protect these vulnerable species.*

Keywords: elasmobranch, longline, capture, Gulf of Gabès, fishery

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INTRODUCTION

Elasmobranch fish are generally top-level predators in most marine ecosystems (Wetherbee & Cortés, 2004). Their abundance is relatively small compared to groups situated in lower trophic levels. However, their life history parameters such as being long-lived, with delayed maturity and low reproductive rates, make them particularly sensitive to increased mortality above natural levels (Musick, 1999).

The historically low economic value of elasmobranchs products compared to teleost fish has resulted in generally a lower priority for research and conservation of these species (Barker & Schluessel, 2005). However, in more recent years there has been an increased demand for elasmobranchs and their derivative, which has significantly increased their economic value and simultaneously driven a growing global concern about shark conservation and management (Musick *et al.*, 2000).

In the Mediterranean, elasmobranchs are generally declining in abundance, diversity and range, and are possibly facing a worse scenario than chondrichthyans populations elsewhere in the world (Walker *et al.*, 2005). This decline can be attributed to a number of factors, mainly the intense fishing activity throughout the coastal and pelagic waters of the basin, such as the Gulf of Lions (Aldebert, 1997), the Tyrrhenian Sea (Ferretti *et al.*, 2005) and the Adriatic Sea (Jukic-Peladic *et al.*, 2001). In addition, an overall dramatic decline in the abundance of large predatory sharks over the last two centuries in the Mediterranean has been recently demonstrated (Ferretti *et al.*, 2008). Moreover, the lack of biological information and appropriate fisheries databases limit the assessment and management plan of elasmobranchs in this area (Cavanagh & Gibson, 2007).

In Tunisia, the capture of elasmobranchs began in the mid-1980s using artisanal bottom-set gill-nets targeting smoothhound, *Mustelus mustelus*. In recent years, elasmobranch species, which were considered by-catch, have become the object of directed artisanal longline fisheries, based on their seasonal abundance (Bradai *et al.*, 2006). In the Gulf of Gabès (central Mediterranean, southern Tunisia), two types of longline gear are used to capture elasmobranch species: pelagic and bottom longlines. These fishing gears were initially used to target swordfish and groupers, respectively, but the decline in catches has resulted in a shift in target to some elasmobranch species. Although elasmobranchs are a significant component of the Gulf of Gabès longline fisheries, there is no quantification of the discard portion, which is never accounted for in the official fisheries statistics.

Because of the unregulated nature of most longline fisheries, the information describing their operational characteristics and associated by-catch is limited in the Mediterranean Sea. This study is the first assessment of the impact of the longline fleet operating in the Gulf of Gabès on elasmobranch species. To improve the understanding, conservation and management of exploited elasmobranch populations in the Gulf of Gabès, a two-year study was undertaken during

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2007–2008 to describe the extent and activities of the longline elasmobranch fishery. Specific objectives of this project were: (1) to determine the catch composition, catch per unit effort (CPUE) and discards of elasmobranch species; (2) to provide biological information (size composition and sex-ratios) for the species captured; and (3) to recommend measures to increase management-relevant information on species characteristics, abundance and distribution.

MATERIALS AND METHODS

During June–September in 2007 and 2008, a total of 41 randomly-chosen fishing trips, 21 (48 sets) with pelagic longline and 20 (38 sets) with bottom longline, were investigated on-board two commercial traditional longline boats. The two boats were selected randomly from among the 72 vessels between 10 and 14 m in length which belonged to the ports of Zarzis and Djerba (south of the Gulf of Gabès), where 80% of the longline Tunisian fleet fishing is based. The two boats were 12 m in length and had a gross tonnage (GT) of 11.45, and a gross register tonnage (GRT) of 10.80.

The length of a monofilament polyamide mainline of pelagic longline varied from 20 to 50 km and comprising 500–2500 hooks (size 12/0 'J' hook: 111 mm long and 57 mm wide; and 11/0 'J' hook: 98 mm length and 51 mm width) attached to the branchlines separated by an average distance of 40 m. The pelagic longline was set close to the water surface using a buoy after every two hooks. The baits used were mackerel (*Scomber scombrus*) and pieces of rays (*Dasyatis* sp.). Setting began around 18:00 h and hauling occurred around 07:00 h on the following day. Bottom longline consists of a 10–12 km mainline anchored to the bottom, suspended by a series of monofilament polyamide branchlines separated by a distance of about 7 m, each branchline is 1 m long and 2 mm in diameter, terminating with a single baited 'J' hook. The number of hooks ranges from 1200 to 1800 and the hook sizes are 78 mm long and 41 mm wide. Frozen round sardinella (*Sardinella aurita*) or common cuttlefish (*Sepia officinalis*) are the baits mainly used. The geographical bottom longline was deployed at any time in daylight, and retrieval could start immediately or after a few hours.

During the fishing operations, on-board observers recorded the date, geographical coordinates at both the beginning and the end of the hauling of the gear, fishing depth, information concerning the fishing operation (number of hooks, gear setting and hauling times, time of every catch), hooking location (internal hooking = oesophagus or deeper; external hooking = mouth) and physical condition of specimens. All individuals were identified and their total length (TL) and disc width of batoids (DW) (to the nearest millimetre) were recorded. The discarded individuals were processed on-board and returned to the sea. The maturity status and stage (juveniles and mature) of specimens was determined based on studies conducted in the study area (Capapé, 1974; Capapé *et al.*, 2003; Hemida *et al.*, 2003; Saidi *et al.*, 2005, 2008, 2009; Enajjar *et al.*, 2008, 2012).

For longline, the standard unit considered was 1000 hooks and the resulting standard catch rate was CPUE 1: number of specimens per 1000 hooks. To estimate total elasmobranchs catch from the total fishing effort, another catch rate, CPUE 2 (number of specimens per fishing trip), was calculated. Total catch was estimated by applying CPUE 2 to the total fishing effort, H (number of trips during the two study years: Source DGPA: General Directorate of Fishing and Aquaculture). The difference in size between males and females was evaluated using two-tailed non-parametric Mann–Whitney *U*-tests (Zar, 1998). Additionally, the assumption of equal sex-ratios (1:1) was tested using χ^2 analysis with Yates correction for continuity (Zar, 1998).

RESULTS

Species composition and catch rates

A total of 48 pelagic longline sets were carried out, corresponding to 35,950 hooks deployed. A total of 581 elasmobranchs and four swordfish specimens were caught. The sandbar shark, *Carcharhinus plumbeus*, was the primary species, accounting for 94.14% of the elasmobranch catch number. The spinner shark, *Carcharhinus brevipinna* (3.78%) and the pelagic ray *Pteroplatytrygon violacea* (2.06%) were minor components of the capture.

A total of 402 grouper individuals belonging to two species and 392 elasmobranch specimens corresponding to four sharks, one skate and two guitarfish species were recorded in the 38 bottom longline sets (48,020 hooks). Among elasmobranch species, the blackchin guitarfish, *Rhinobatos cemiculus*, was the most abundant (31.7%) followed by *C. plumbeus*, (21.17%), the smoothhound, *Mustelus mustelus*, (15.81%) and the blackspotted smoothhound, *M. punctulatus* (13.52%).

The numbers of individuals per species captured and corresponding CPUE values are summarized in Table 1. The CPUE values reached a maximum level for *C. plumbeus* captured with pelagic longline, while for the bottom longline, catch rates of different elasmobranch species were nearly similar.

Taking into account the mean annual total fishing effort with pelagic (316.5 trips) and bottom longlines (177.5 trips) and catch rates (CPUE2), the mean total annual captures were estimated in the two study years (Table 1).

Hooking locations and survival

For pelagic longline captures, hooking locations did not vary among species: all specimens were hooked externally, hooks tended to lodge in the jaw. Elasmobranch mortality rate at haulback varied considerably among species. In contrast to the spinner shark, which had 0% mortality, *C. plumbeus* and *P. violacea* had 41% and 66.66% mortality at retrieval, respectively.

The proportion of internal hooking was high with the bottom longline: 56% for *R. cemiculus*, 51.6% for *M. mustelus*, 47.7% for *R. rhinobatos*, 41.5% for *M. punctulatus* and 38.5% for *C. plumbeus*. However *C. brevipinna* and *Raja radula*, specimens were hooked externally. All specimens captured were alive (Table 2).

Retained and discarded species

The main fraction of individuals caught was retained (92.4% by number). Elasmobranchs discarded represented 2% and 15.81% of the total number of individuals caught with pelagic and bottom longlines, respectively (Table 3). The main reasons for discard were the lack of commercial value (37.38%) and size (62.16%). Species with a high commercial

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Table 1. Catch rates and total captures estimated with longline fishery in the Gulf of Gabès during 2007–2008.

Gear	Species	Number	CPUE1 (indiv/1000 hooks)	CPUE2 (indiv/trip)	Mean total number of capture (2007–2008)
Pelagic longline	*Xiphias gladius* (Linnaeus, 1758)	4	0.11 ± 0.098	0.19 ± 0.23	60.29 ± 72.79
	Carcharhinus plumbeus (Nardo, 1827)	547	15.22 ± 3.587	26.05 ± 11.93	8244.07 ± 3775.84
	Carcharhinus brevipinna (Müller & Henle, 1839)	22	0.61 ± 0.340	1.05 ± 0.95	331.57 ± 300.67
	Pteroplatytrygon violacea (Bonaparte, 1832)	12	0.33 ± 0.159	0.57 ± 0.33	180.86 ± 104.44
Bottom longline	*Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817)	221	4.60 ± 1.24	11.05 ± 2.28	1961.38 ± 404.70
	Epinephelus marginatus (Linnaeus, 1758)	181	3.77 ± 1.41	9.05 ± 2.25	1606.38 ± 399.37
	Rhinobatos cemiculus (Geoffroy Saint-Hilaire, 1817)	123	2.56 ± 0.95	6.15 ± 2.01	1091.63 ± 356.77
	Rhinobatos rhinobatos (Linnaeus, 1758)	44	0.92 ± 0.60	2.20 ± 1.45	390.50 ± 257.37
	Mustelus mustelus (Linnaeus, 1758)	62	1.29 ± 0.74	3.10 ± 1.40	550.25 ± 248.50
	Mustelus punctulatus (Risso, 1827)	53	1.10 ± 0.70	2.65 ± 1.53	470.38 ± 271.57
	Carcharhinus plumbeus (Nardo, 1827)	83	1.72 ± 0.69	4.15 ± 1.26	736.63 ± 223.65
	Carcharhinus brevipinna (Müller & Henle, 1839)	11	0.23 ± 0.14	0.55 ± 0.54	97.63 ± 95.85
	Raja radula Delaroche, 1809	16	0.33 ± 0.23	0.80 ± 0.30	142 ± 53.25

Table 2. Hooking location and mortality of captured species.

Gear	Species	Number	External hooking (%)	Internal hooking (%)	Mortality (%)
Pelagic longline	*C. plumbeus*	547	547	0	224(41%)
	C. brevipinna	22	22	0	0
	P. violacea	12	12	0	8 (66%)
Bottom longline	*R. cemiculus*	123	54(43.90%)	69(56.09%)	0 (0%)
	R. rhinobatos	44	23(52.72%)	21(47.72%)	0 (0%)
	M. mustelus	62	30(48.38%)	32(51.61%)	0 (0%)
	M. punctulatus	53	31(58.49%)	22(41.50%)	0 (0%)
	C. plumbeus	83	51(61.44%)	32(38.55%)	0 (0%)
	C. brevipinna	11	11(100%)	0(0%)	0 (0%)
	R. radula	16	16(100%)	0(0%)	0 (0%)

Table 3. Discards and retained portion of catches.

Gear	Species	No.	Retained (%)	Discarded (%)
Pelagic longline	*C. plumbeus*	547	547 (100)	0(0)
	C. brevipinna	22	22 (100)	0(0)
	P. violacea	12	0 (0)	12 (100)
Bottom longline	*R. cemiculus*	123	109 (88.6)	14 (11.4)
	R. rhinobatos	44	28(63.6)	16 (36.4)
	M. mustelus	62	52 (83.9)	10 (16.1)
	M. punctulatus	53	47 (88.7)	6 (11.3)
	C. plumbeus	83	83 (100)	0 (0)
	C. brevipinna	11	11 (100)	0 (0)
	R. radula	16	0 (0)	11(100)

value, such as *Rhinobatos cemiculus*, *R. rhinobatos*, *M. mustelus*, *M. punctulatus*, *C. brevipinna* and *C. plumbeus*, were usually retained, while species with low or no commercial value, such as *Raja radula* and *P. violacea* were always discarded.

Biological information

Specimens were often examined at retrieval. Size–frequency distribution and sex composition were available for each species (Table 4; Figures 1 & 2).

In pelagic longline captures, females were more common than males (Table 4). However, size composition of females and males did not differ significantly (Table 4). Juveniles, including specimens with umbilical scars, dominated capture (Figure 1).

In bottom longline captures, about half of *Rhinobatos cemiculus* males were mature and 69% of females were pregnant carrying near term embryos or post-partum. More than 96% of *C. plumbeus* and all *C. brevipinna* individuals caught were juveniles. The majority of *Mustelus* species were mature: 69% of males and 61% of females for *M. mustelus* and 87% of males for *M. punctulatus* (Table 4; Figure 2).

DISCUSSION

In the Gulf of Gabès, during 2007–2008, longline fishing effort was considerable, and eight elasmobranch species were recorded among 43 species reported in this area (Bradai *et al.*, 2006). However, several other species such as *Isurus oxyrinchus* and *Carcharodon carhcarias*, *Prionace glauca, Squalus blainvillei* and *Pteromylaeus bovinus* observed in longline landings were not encountered in our study. Species captured in this study were the most abundant in the area and were landed throughout the year as by-catch and target species (Bradai *et al.*, 2006). The variation in species composition between the two types of fishing activities can be attributed to species behaviour and fishing area. Generally, bottom longline fishing sites were closer to the coast compared to pelagic longline ones (Figure 3).

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Table 4. Size composition of elasmobranch species sampled from longline fishery in the Gulf of Gabès during 2007–2008: (a) Saidi *et al.*, 2005; (b) Capapé *et al.*, 2003; (c) Hemida *et al.*, 2003; (d) Enajjar *et al.*, 2012; (e) Enajjar *et al.*, 2008; (f) Saidi *et al.*, 2008; (g) Saidi *et al.*, 2009; (h) Capapé, 1974.

Gear	Species	Sex	Number	Sex-ratio χ^2 test	Size range (mm)		Mann–Whitney *U*-tests	Size at maturity (References)	Percentage in catch	
					Min	Max			Juveniles	Mature
Pelagic longline	*C. plumbeus*	F	361	$\chi^2 = 23.969$, $P < 0.01$	590	1720	($U = 18{,}500$, $P = 0{,}148$)	1720 (a)	95.6	04.4
		M	186		550	1720		1600 (a)	91.9	08.1
	C. brevipinna	F	16	($\chi^2 = 4.545$, $P = 0.033$)	620	1320	($U = 18825.50$, $P = 0.0725$)	1960 (b)	100	00
		M	6		750	1220		1720 (b)	100	00
	P. violacea	F	7	$\chi^2 = 0.333$, $P = 0.563$	560	640	($U = 15.500$, $P = 0.744$)	375 (c)	00	100
		M	5		490	650		375 (c)	00	100
Bottom longline	*R. cemiculus*	F	72	($\chi^2 = 3.598$, $P = 0.583$)	520	1730	($U = 849.023.0$, $P < 0.0001$)	1381 (d)	30.6	69.4
		M	51		430	1570		1118 (d)	49.00	51.00
	R. rhinobatos	F	23	($\chi^2 = 0.090$, $P = 0.763$)	490	1230	($U = 39{,}000$, $P = 0.891$)	790 (e)	39.1	60.9
		M	21		480	1070		700 (e)	47.6	52.4
	C. plumbeus	F	55	($\chi^2 = 8.783$, $P = 0.003$)	480	1790	($U = 495.000$, $P = 0.008$)	1720 (a)	96.4	03.6
		M	28		580	1590		1600 (a)	96.5	03.5
	C. brevipinna	F	8	($\chi^2 = 2.272$, $P = 0.131$)	480	1790	($U = 23.500$, $P = 0.094$)	1960 (b)	100	00
		M	3		720	1470		1720 (b)	100	00
	M. mustelus	F	26	($\chi^2 = 1.612$, $P = 0.204$)	1120	1260	($U = 797.500$, $P = 0.795$)	1172 (f)	38.5	61.5
		M	36		730	1470		971 (f)	30.6	69.4
	M. punctulatus	F	29	($\chi^2 = 0.692$, $P = 0.405$)	520	1170	($U = 709.500$, $P = 0.065$)	956 (g)	68.1	31.9
		M	24		630	1160		814 (g)	12.50	87.5
	R. radula	F	11	($\chi^2 = 2.252$, $P = 0.133$)	220	420	($U = 15.000$, $P = 0.156$)	340 (h)	68.1	31.9
		M	5		220	370		320 (h)	100	00

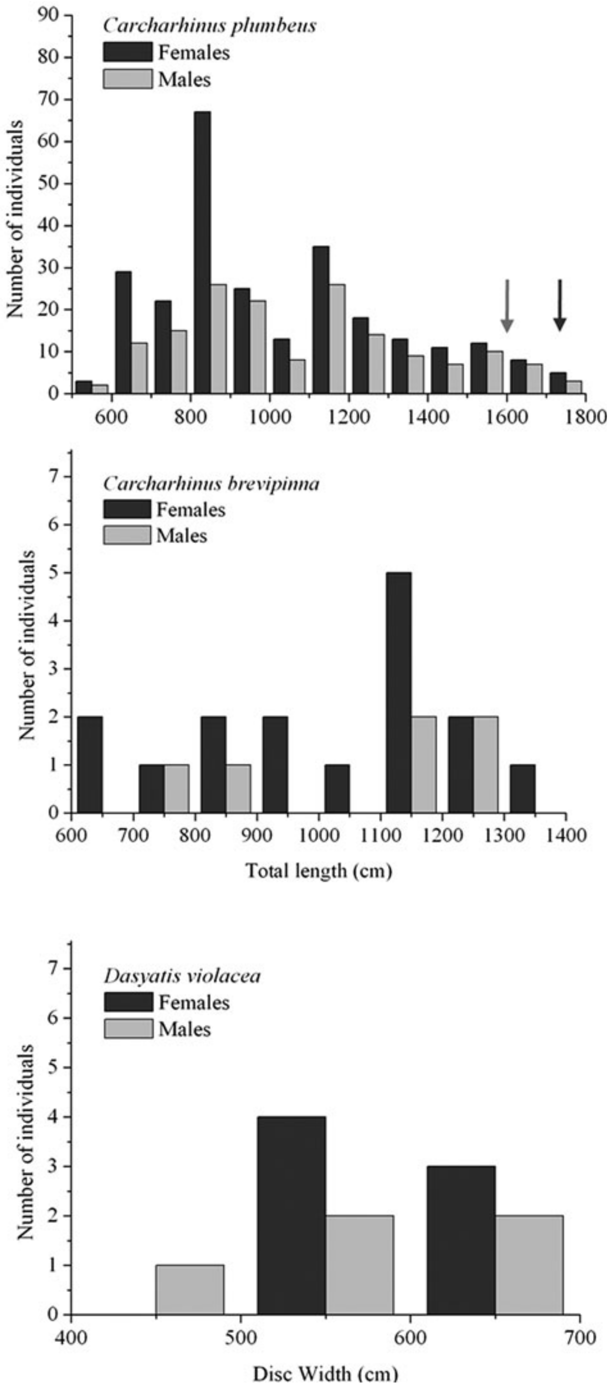

Fig. 1. Length–frequencies distribution of elasmobranch species caught with pelagic longline in the Gulf of Gabès during 2007–2008 (size at maturity of males (grey arrow) and females (black arrow)).

The sandbar shark, *Carcharhinus plumbeus*, is the primary component of pelagic longline elasmobranch fisheries in the Gulf of Gabès. This species was the most abundant species landed in this area, where it was caught mainly between April and September (Bradai *et al.*, 2006). The spinner shark, *C. brevipinna* is rarely reported. This may be due to the competition pressure from its sympatric species *C. plumbeus* (Capapé, 1989). This interspecific competition pressure, corroborated by recent investigation (Saidi *et al.*, 2005), suggests that *C. plumbeus* is able to establish definitively in the area, whereas *C. brevipinna* migrates northward (Capapé *et al.*, 2003). According to catch statistics from Zarzis fish market, which is the main landing port for shark fishery in Tunisia, annual landings by artisanal fisheries of *C. plumbeus* is about 350 t (European Commission, 2009). In the Mediterranean, *C. plumbeus* was described as an endangered species (Cavanagh & Gibson, 2007). This species was previously regularly seen on fish markets of southern Sicily during the summer months but has not been observed recently (Cigala-Fulgosi and Vacchi, personal observations 2003). A similar situation is apparent in the eastern Adriatic Sea (Lipej *et al.*, 2000). Given the high biological vulnerability of this species to exploitation, the declines observed in other Mediterranean areas and continuing unregulated fishing pressure in the Gulf of Gabès, it is strongly suspected that this stock is declining. Investigation on stocks assessments and elasmobranch fisheries surveys in the area are urgently needed.

The importance in numbers and catch rates of smooth-hound and guitarfish species compared to the grouper ones show that these species, which were classified as by-catch in the past, were actually targeted. Rhinobatids were not recognized as common in longline capture. The importance of guitarfish species in our study is that longliners target these species during their reproductive aggregation season, mainly when the primary targeted species (groupers) are caught in small quantities. The abundance of smooth-hound and guitarfish species in the Gulf of Gabès compared to the northern coasts of the Mediterranean, where they are considered to be locally extirpated (Aldebert, 1997; Jukic-Peladic *et al.*, 2001; Ferretti *et al.*, 2005), reflects their abundance in the fishing area. Indeed, specific elasmobranch fisheries already subsist, showing an important exploitation potential. In addition, their abundance suggest that these species find favourable conditions to reproduce in the Gulf of Gabès (Bradai *et al.*, 2005).

The main reasons for discarding commercialized species are: (a) undersized fish that usually have low or negligible market value; (b) regulation demands on minimum landing sizes; and (c) the market value of species caught. It should be mentioned that in the Mediterranean it is difficult to distinguish between the different types of discarded products, and especially between unmarketable and low quality/price species. In the Gulf of Gabès, discards of target species in this fishery are very scarce. But species discarded could be a good indicator of the impact of the fishery on threatened species and the ecosystem. Nevertheless, choice of fishing ground and reduction of the soak time may reduce discards (Gonçalves *et al.*, 2007). Despite its importance, long-term monitoring of the discarded yield is difficult, because of the need for special effort and financing. Consequently, it is important to investigate methods that correlate discarding practices with the landings, thus minimizing the necessary sampling (Hall, 1999).

The size distribution shows that, for carcharinids species, juveniles dominate captures while mature specimens dominate in smoothhound and guitarfish. The capture of neonate and young elasmobranch species in the Gulf of Gabès indicates that juveniles of these species utilize nearshore waters during their first few years of life. The presence of neonate, post-partum and ovulating females indicates that fishing efforts occur in pupping or primary nursery areas (Heupel *et al.*, 2007). In the Gulf of Gabès, artisanal fisheries are related to the seasonal occurrence of these species, which is an annual event linked to the reproductive cycle (Bradai

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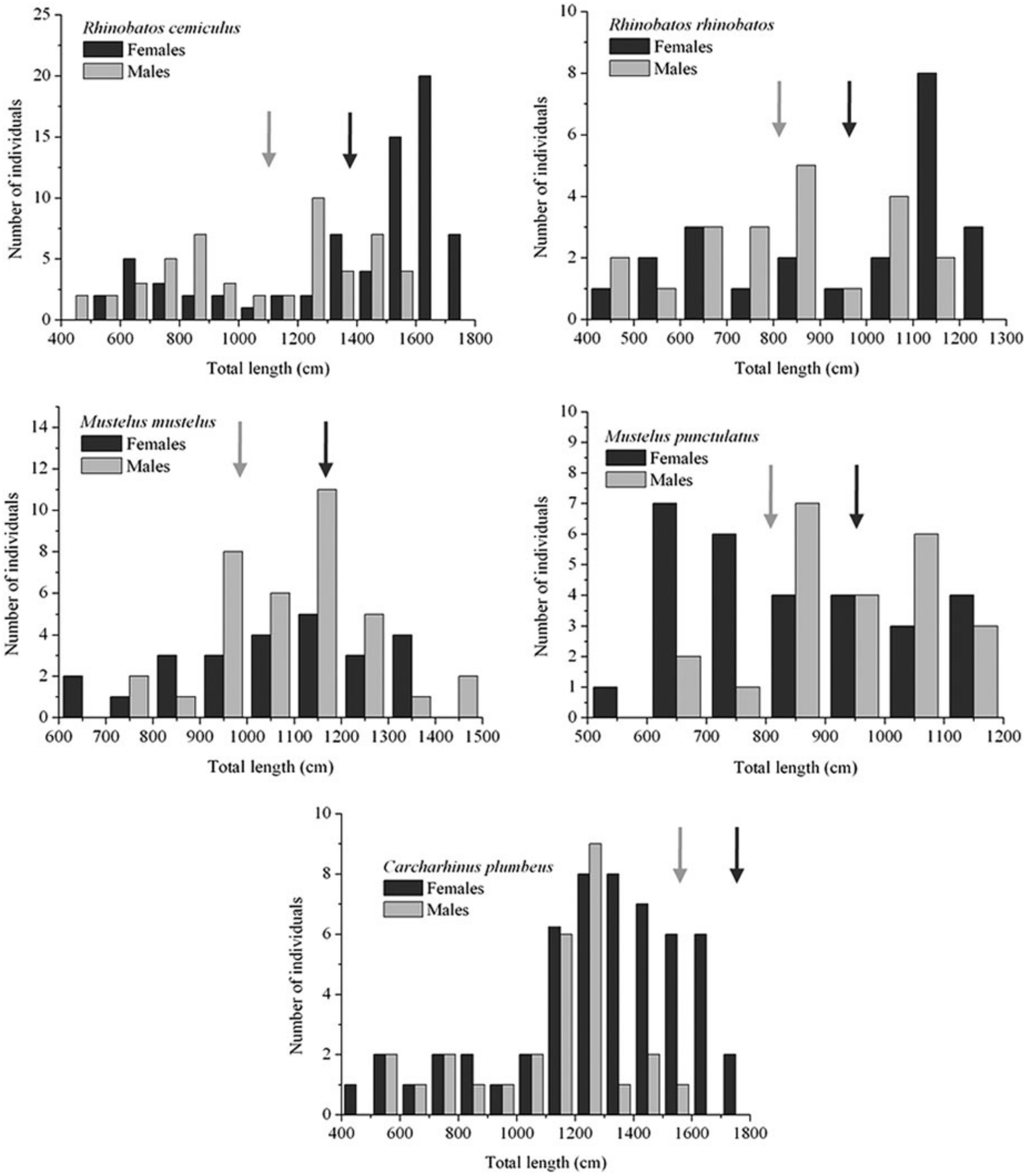

Fig. 2. Length–frequencies distribution of elasmobranch species caught with bottom longline in the Gulf of Gabès during 2007–2008 (size at maturity of males (grey arrow) and females (black arrow)).

et al., 2006). Mature females of some species, such as *C. plumbeus*, *M. punctulatus*, *M. muselus*, *R. cemiculus* and *R. Rhinobatos*, move to nearshore water to give birth in a nursery area with advantageous environmental conditions (Bradai *et al.*, 2005; Saidi *et al.*, 2005). The capture of mature individuals of exploited species reduces their productivity and resilience and the sustainability of populations (Kokko *et al.*, 2001; Smith *et al.*, 2008). Simpfendorfer (1999) suggested that, for some shark species, sustainable exploitation may be possible if the youngest age-classes are targeted and older ages are left unfished.

This study represents the first detailed, quantitative information on the longline elasmobranch fisheries in the Gulf of Gabès. Captures of elasmobranchs were substantial during the survey years and probably represent a considerable source of mortality for exploited populations. The increasing domestic demand for elasmobranch fishing permits, coupled with the lack of regulatory actions, poses a threat to the elasmobranch stocks harvested in Tunisian waters.

Successful management and conservation measures need to be accompanied by complementary tools that promote the meeting of their assumptions. In that respect, gear

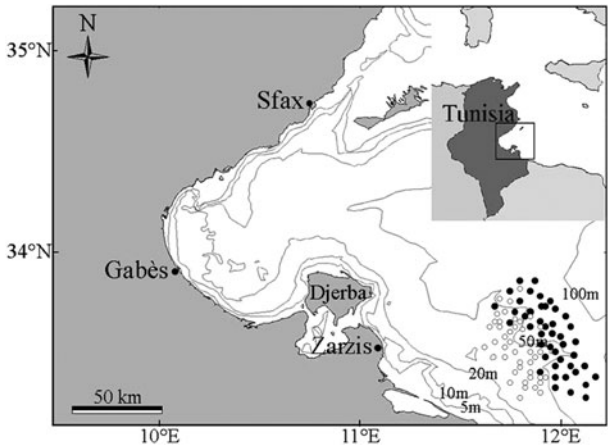

Fig. 3. The Gulf of Gabès. Pelagic longline sets (●), bottom longline sets (○).

modifications are expected to be one of the most effective and inexpensive tools (Madsen *et al.*, 2006; Fonteyne & M'rabet, 1992; Brewer *et al.*, 1996;).

Implementing Marine Protected Areas (MPAs) for species that show some site fidelity may be a useful approach in certain cases (Bonfil, 1999; Garla *et al.*, 2006a, b). However, for species thought to be fished at unsustainable rates, MPAs must be coupled with reductions in fishing capacity to avoid simply displacing effort to other sites (Fogarty & Murawski, 1998). In addition, size limits may be beneficial as a way of protecting neonates and actively breeding individuals (i.e. maximum size limits that are less than the size at maturity) (Simpfendorfer, 1999). Nurseries designated for protection should be refined in accordance with more substantial criteria (Heupel *et al.*, 2007), allowing managers to prioritize nurseries that contain higher neonate and young juvenile populations, have longer residency periods and are repeatedly used across years.

The successful conservation and sustainable use of this fishery resource requires the following actions: (1) continue the collection and survey of species-specific information on catches and landings, by number and weight; (2) improve statistical data collection at the species-specific level; (3) delineate nurseries areas in the Gulf of Gabès; (4) assess the impact of fishing mortality on juveniles and gravid females in elasmobranchs/nursery areas; and (5) conduct socio-economic studies of the coastal artisanal fisheries.

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