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Feeding habits of the sandbar shark *Carcharhinus plumbeus* (Chondrichthyes: Carcharhinidae) from the Gulf of Gabès, Tunisia

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Abstract: Feeding habits of the sandbar shark *Carcharhinus plumbeus* caught in the Gulf of Gabès were studied from examination of 130 stomach contents. *C. plumbeus* mainly fed on fishes (osteichthyans and chondrichthyans). Cephalopods and crustaceans are respectively secondary and occasional preys. *C. plumbeus* is an opportunistic species and diet is depending on available preys in the environment. Changes in diet were observed and related to size of specimens.

Résumé : *Régime alimentaire du requin gris* Carcharhinus plumbeus *dans le golfe de Gabès, Tunisie.* La nourriture et le comportement alimentaire du requin gris *Carcharhinus plumbeus* capturé dans le golfe de Gabès sont étudiés à partir de l'examen de 130 contenus stomacaux. *C. plumbeus* se nourrit surtout de poissons (ostéichtyens et chondrichtyens). Les céphalopodes et les crustacés constituent respectivement des proies secondaires et accessoires. *C. plumbeus* est une espèce opportuniste et son régime alimentaire dépend des proies disponibles dans l'environnement. Des changements dans le régime alimentaire ont été observés et ils sont liés à la taille des spécimens.

Keywords: Chondrichthyes • Carcharhinidae • *Carcharhinus plumbeus* • Diet • Gulf of Gabès • Tunisia • Mediterranean Sea

Introduction

The sandbar shark *Carcharhinus plumbeus* (Nardo, 1827) is widely distributed in tropical and subtropical region of the Pacific Ocean, the Indian Ocean, the Atlantic Ocean and the Mediterranean (Compagno, 1984). In the Mediterranean Sea, few studies have dealt with this species and data on its morphology and reproductive biology are mostly restricted to Tunisian coast specimens (Capapé, 1984; Saïdi et al., 2005). Information on its diet is scarce, Capapé (1975) gave only preliminary data. *C. plumbeus* is landed throughout the year in the fishing sites located in southern Tunisia (Bradaï et al., 2002). Sandbar sharks occur in a variety of coastal habitats in the Gulf of Gabès, some of which are proposed nursery areas (Bradaï et al., 2005). *C. plumbeus* is a placental viviparous shark with a gestation period of 12 months and female reproduces in alternate years. Sandbar shark pupping

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season occurs in summer. Females reach larger length (2185 mm total length, TL) than males (1905 mm TL) and were mature at 1720 and 1600 mm respectively. Size at birth ranged between 450 and 650 mm TL and litter size varied from 4 to 10, increasing with maternal size (Saïdi et al., 2005).

Information on feeding ecology is necessary to understand the role that the predator plays in the trophic structure of coastal marine community. As part of sampling of all aspect of the biology of the sandbar shark (Bradaï et al., 2005; Saïdi et al., 2005), stomachs were collected from specimens not eviscerated to provide a quantitative description of the diet of the species in the area and strengthen our knowledge on the biology and ecology of this species in the Mediterranean. Our observations are compared and contrasted with those previously reported from other marine areas.

Material and Methods

In the Gulf of Gabès (Fig. 1) the sandbar shark is landed as by-catch by bottom trawlers and targeted from March to July by gill-netters and from June to August by pelagic longlines.

The stomach contents of a total of 130 individuals, ranging from 450 to 2100 mm in total length, were examined between January 2001 and May 2005.

Samples were collected by commercial trawlers, gill-netters and bottom and pelagic longlines vessels. The bottom trawl had a cod end of 20 mm stretched mesh targeting both shrimps and demersal fishes at depths between 30 and 100 m. Sharks were by-catch species. Sandbar sharks were targeted by gill-nets from March to July in the southern Gulf of Gabès between Jerba Island and Zarzis. Gill-nets were constructed of polyamide

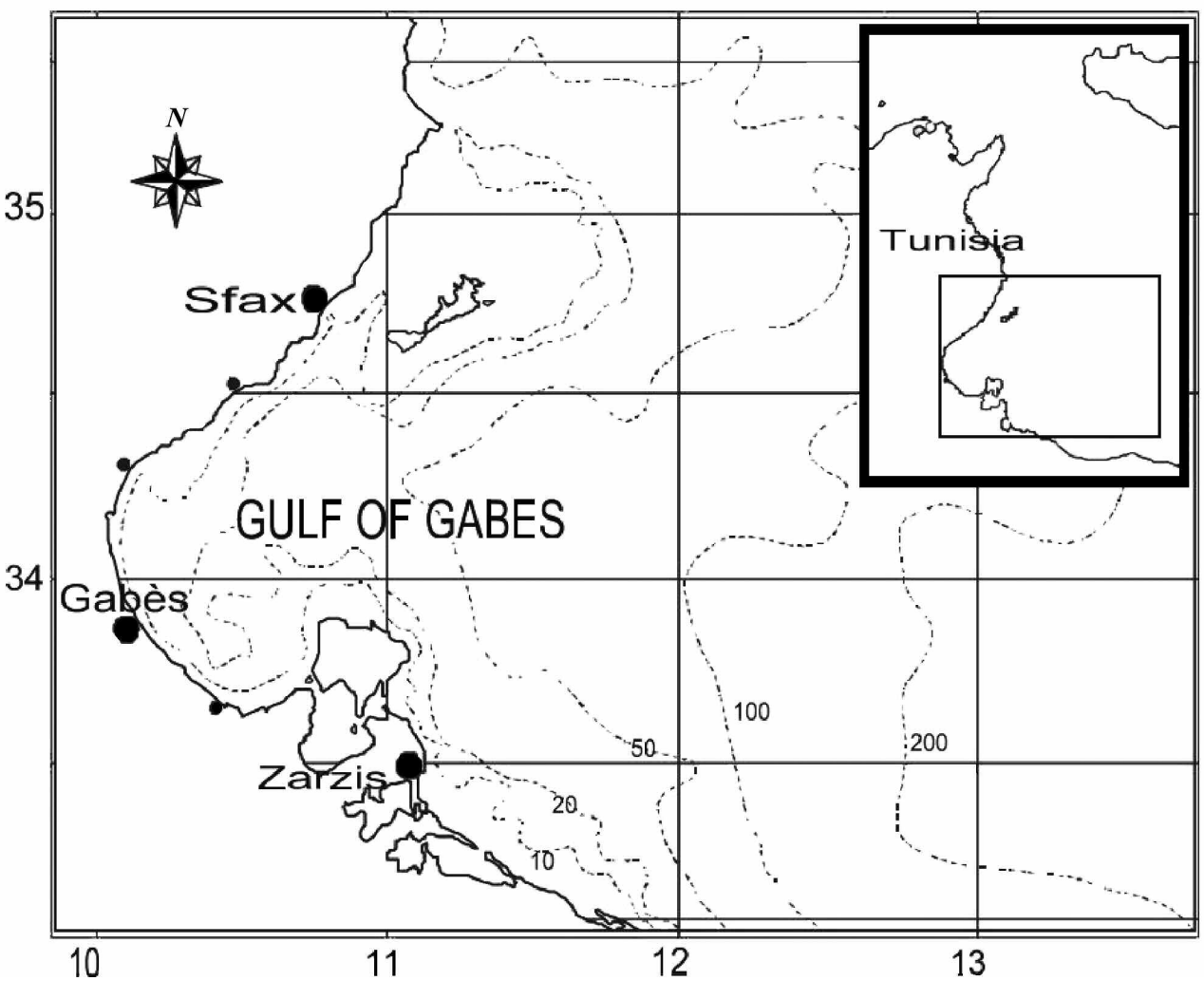

Figure 1. *Carcharhinus plumbeus*. Map of the study area (Gulf of Gabès).
Figure 1. *Carcharhinus plumbeus*. Carte de la zone d'étude (golfe de Gabès).

monofilament netting with a stretched mesh size of 300-400 mm. Nets were between 1000 and 3000 metres long and were set on the sea floor at depths between 10 and 25 m. Gill-nets were checked and cleared of catch, or pulled and reset daily. These special gill-nets, used only to capture sharks are locally known under the vernacular name of 'kallabia', from kalb' bhar (literally sea dog) which means shark in Arabic. *C. plumbeus* was also captured by pelagic and bottom longlines. Pelagic lines, used in June, July and August consist of a heavy nylon monofilament mainline, 7-28 km long, connected to buoys by a 10 m buoy line. Twenty-five large hooks (hook size: 00-01) are suspended every, approximately, kilometer, at depths of 30-100 m. Bottom longlines, used in August-October, consist of a heavy nylon monofilament, 1.5-3 km long, carrying small hooks, generally 200 (hook size: 04-05) suspended every kilometer and a single hook per light-stick. For both types of longlines, the hooks are baited with pieces of teleosts such as pilchard and mackerel or cephalopods such as cuttlefish.

The specimens were measured to the nearest millimetre for total length following Bass et al. (1973) and Castro (1996). The observed sandbar sharks were between 450 and 2100 mm including 50 males (450-1660 mm TL) and 80 females (475-2100 mm TL).

The stomach contents were removed, sorted and identified to the lowest possible taxon using keys and fields guides (Fischer et al., 1987). They were counted and weighed to the nearest decigram. The percentage of empty stomachs was also recorded.

To analyse the food and the feeding habits of *C. plumbeus*, we used the following indices according to Berg (1979), Hyslop (1980) and Tirasin & Jörgensen (1999):

- Percentage frequency of occurrence (%F): number of stomachs in which a food item was found, expressed as a percentage of the total number of full stomachs

- Percentage numerical abundance (%Cn): number of each prey type, expressed as a percentage of the total number of all food types in all stomachs

- Percentage ponderal composition (%Cw): wet weight of each prey type, expressed as a percentage of the total weights of stomach contents in a sample

We carried out all the calculations using number of non-empty stomachs. We also used the index of relative abundance, IRI (Pinkas et al., 1971; Cortés, 1997):

$$IRI = \%F \times (\%Cn + \%Cw) \quad (1)$$

expressed as a percentage to quantify the diet as:

$$\%IRI = (IRI / \sum IRI) \times 100 \quad (2)$$

To assess for possible change in diet with respect to length, fish were divided in three size-classes: ≤ 899 mm (n = 75), 900-1399 mm (n = 30) and ≥ 1400 mm (n = 25). %Cw and %Cn were examined for the three groups.

Statistical differences ($P < 0.05$) in basic diet composition as a function of size were established by applying a Chi-square test (Sokhal & Rohlf, 1981). This was applied over the direct variables, grouping types of prey into large categories and using contingency tables. These categories are teleosts and cephalopods. Chondrichthyes, crustaceans, and unidentified preys were not considered to avoid having more than 20% of cells with values < 5.

Results

Of all sandbar sharks examined, 35.4% were empty and 64.6% contained food item (Fig. 2), but there were not significant differences between sexes (38% in male and 33.75% in females) ($\chi^2 = 0.24$, df = 1). The preys of the sandbar shark consisted of at least 15 families and 17 species (Table 1), with a low average number (mean 2.03%) and weight (mean 49.68 g) per stomach. Teleosts were the dominant food category by number (74.27%), wet weight (52.93%) and frequency of occurrence (80.95%). The %IRI indicated that teleosts comprised 83.5% of the diet, followed by cephalopods, chondrichthyes (Batoids) and crustaceans (Table 1). Clupeids constituted the bulk of the observed prey items (%IRI = 41.4). Among cephalopods, the common Octopus *Octopus vulgaris* (Cuvier, 1797) was the major food group eaten by weight (%Cw = 19.59), followed by the European squid *Loligo vulgaris* (Lamarck, 1798) which was also the most important cepholopod species eaten numerically (16.7%). Among teleost species, specimens belonging to species of small size such as the bogue *Boops boops* (Linnaeus, 1758), were the most observed in number, while those of larger size such as the common dentex *Dentex dentex* (Linnaeus, 1758), and the grey triggerfish *Balistes carolinensis* (Gmelin, 1789) were the most important in weight.

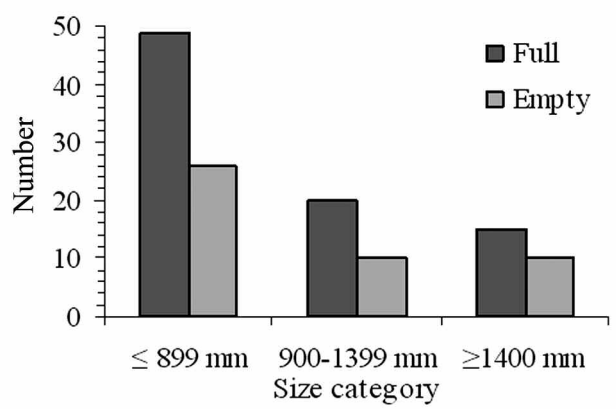

Figure 2. *Carcharhinus plumbeus*. Number of full and empty sandbar shark stomachs by size category.

Figure 2. *Carcharhinus plumbeus*. Nombre d'estomacs pleins et vides pour chaque classe de taille.

Table 1. *Carcharhinus plumbeus*. Diet composition of 130 *C. plumbeus* off Gulf of Gabès (%F frequency of occurrence, %Cn percentage in number, %Cw percentage in weight; %IRI Index of relative importance of preys item).
Tableau 1. *Carcharhinus plumbeus*. Composition du régime alimentaire de 130 *C. plumbeus* du golfe de Gabès. (%F Indice de fréquence ; %Cn pourcentage en nombre ; %Cw pourcentage en masse ; %IRI indice de l'importance relative des items).

Food items	%F	%Cn	%Cw	%IRI
Osteichthyes	**80.95**	**74.27**	**52.93**	**83.50**
Sparidae				
Diplodus annularis (Linneaus, 1758)	2.38	1.17	0.36	0.16
Boops boops (Linneaus, 1758)	2.38	9.94	3.52	1.37
Pagellus erythrinus (Linneaus, 1758)	1.19	0.58	0.27	0.04
Pagrus caeruleostictus (Valenciennes, 1830)	1.19	0.58	0.97	0.08
Dentex dentex (Linneaus, 1758)	1.19	0.58	9.35	0.51
Unidentified Sparids	2.38	2.34	1.17	0.36
Clupeidae				
Sardinella aurita (Valenciennes, 1847)	7.14	3.51	3.29	2.08
Sardina pilchardus (Walbaum, 1792)	3.57	5.26	1.91	1.10
Unidentified clupeids	20.24	18.13	10.84	25.10
Carangidae				
Trachurus ssp	2.38	1.75	1.13	0.29
Scombridae				
Scomber scombrus (Linneaus, 1758)	2.38	1.17	0.49	0.17
Mullidae				
Mullus surmuletus (Linneaus, 1758)	1.19	0.58	0.36	0.05
M. barbatus (Linneaus, 1758)	3.57	2.34	1.42	0.58
Mugilidae				
sp.	3.57	1.75	2.44	0.64
Soleidae				
sp.	1.19	0.58	0.91	0.08
Balistidae				
Balistes carolinensis (Gmelin, 1788)	1.19	0.58	5.03	0.29
Belonidae				
Belone belone	2.38	1.17	2.46	0.37
Unidentified teleosts	29.76	22.22	7.02	37.26
Chondrichthyes	**4.76**	**2.34**	**11.60**	**0.54**
Rajidae	2.38	1.17	5.75	0.71
Unidentified batoids	2.38	1.17	5.85	0.72
Cephalopoda	**36.90**	**20.47**	**32.35**	**15.81**
Octopus vulgaris (Cuvier, 1797)	9.52	5.85	19.59	10.37
Loligo vulgaris (Lamarck, 1798)	16.67	9.94	7.94	12.76
Sepia sp.	10.71	4.68	4.82	4.36
Crustaceans	**3.57**	**1.75**	**2.05**	**0.11**
Penaeus kerathurus (Forsskål, 1775)	1.19	0.58	0.03	0.03
Squilla mantis (Linnaeus, 1758)	1.19	0.58	2	0.13
Unidentified crustaceans	1.19	0.58	0.01	0.03
Unidentified items	**2.38**	**1.17**	**1.08**	**0.04**

Chondrichthyes prey items were represented by batoids. Crustaceans were accidental preys.

The mean number of prey per stomach was 1.45, 3 and 2.6 for the classes ≤ 899 mm, 900-1399 mm and ≥ 1400 mm, respectively. These means were relatively low in all classes. Nevertheless, the average stomach content weight which was 19.77, 30.43 and 173 g for classes ≤ 899 mm, 900-1399 mm and ≥ 1400 mm respectively, increased with predator size.

In the Gulf of Gabès, %Cw and %Cn of higher prey categories varied with the size of *C. plumbeus* (Fig. 3). Teleosts and cephalopods were the predominant prey found in all shark size groups (Fig. 3). The χ^2-test showed that the %N of teleosts and cephalopods did not vary among size categories (χ^2 = 5.96, df = 2). However differences in weight consumption on teleosts and cephalopods were significant between small, medium and large sharks (χ^2 = 192.80, df = 2). There is a tendency for consumption of big prey with increasing shark size. Chondrichthyes did not

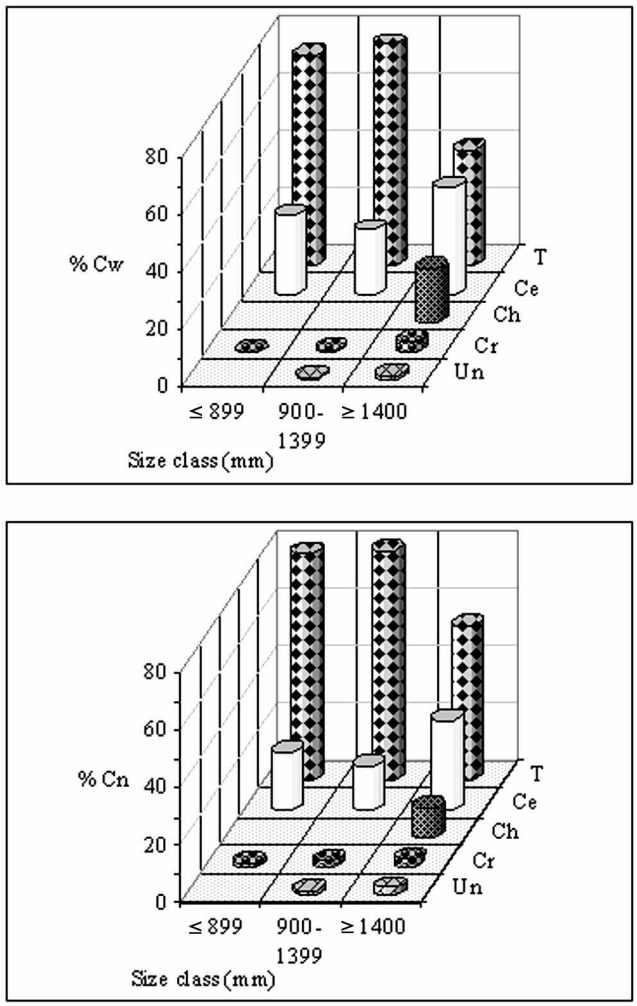

Figure 3. *Carcharhinus plumbeus*. Percentage in weight (%Cw) and number (%Cn) of prey categories for each size class of *C. plumbeus* from Gulf of Gabès. (T, Teleosts; Ce, Cephalopoda; Ch, Chondrichthyes; Cr, Crustacea; Un, unidentified item).

Figure 3. *Carcharhinus plumbeus*. Pourcentage en masse (%Cw) et en nombre (%Cn) des items pour chacune des classes de taille de *C. plumbeus* dans le golfe de Gabès. (T, Téléostéens ; Ce, Céphalopodes ; Ch, Chondrichtyens ; Cr, Crustacés ; Un, item indéterminés).

occur in the small and medium size classes, but constituted a substantial portion of the diet of the large shark (%Cn = 10 and %Cw = 18%). Crustaceans were of minor importance in all size categories.

Discussion

Our study shows that osteichthyans were the most abundant preys of *C. plumbeus* from the Gulf of Gabès. This prey group represented more than 50% of the total %IRI and can be classified as main food following Rosecchi & Nouazé (1987). Cephalopods were secondary preys while chondrichthyans and crustaceans were of minor importance in stomachs contents and accidentally consumed. Our observations are in agreement with preliminary data provided by Capapé (1975) for specimens from off the Tunisian coast. Similar patterns were reported for *C. plumbeus* from other Mediterranean areas such as the Italian Seas (Tortonese, 1956; Bini, 1967), from the western north Atlantic (Bigelow & Schroeder, 1948; Medved et al., 1985; Stillwell & Kohler, 1993; Ellis, 2003). *C. plumbeus* is rather an opportunist feeder and its diet is depending on what may be locally available (Bigelow & Schroeder, 1948).

Sandbar sharks clearly undergo ontogenic changes in diet, cephalopods and chondrichthyans were observed in stomach contents while sharks increased in size. Larger sandbar sharks spend more time in deeper coastal waters and thus are likely to encounter more cephalopods and elasmobranchs (Ellis, 2003). Osteichthyans remained the most important prey food throughout lifespan, although size of preys increased concomitantly with shark size, in agreement with Ellis (2003). Juveniles tend to consume mostly smaller preys than adults did. Large sharks appear to become more capable of capturing large teleosts and even small elasmobranchs. Similar patterns were reported in other shark species, such as the bluntnose sixgill shark, *Hexanchus griseus* (Bonnaterre, 1788) by Ebert (1994), the tiger shark, *Galeocerdo cuvier* (Person & Lesueur, 1822) by Lowe et al. (1996) and the Galapagos shark, *Carcharhinus galapagensis* (Snodgrass & Heller, 1905) by Wetherbee et al. (1996). According to Labropoulou et al. (1999) consumption of large and heavy prey items provides to predator energetic investment used for migrations and reproductive processes. Changes in diet may be also due to increasing of jaws related to size (Heupel & Bennet, 1998; Ellis, 2003). Moreover, Medved et al. (1985) and Ellis (2003) noted that both neonate and juvenile *C. plumbeus* from Chincoteague Bay and Chesapeake Bay preferentially fed on crustaceans, although teleosts were also abundantly consumed. This is probably due to food preys available in biological environment, or to sampling.

Salini et al. (1992) noted that both *Carcharhinus amblyrhinchos* (Whitley, 1934) and *C. sorrah* (Valenciennes, 1839) from Australia fed more on cephalopods at offshore sites than at the estuarine ones. In the Gulf of Gabès, sandbar sharks spent a long time in deeper coastal waters where they were able to find more cephalopod species. Large shark species such as *C. plumbeus* are active feeders that visit a great number of habitat types during their migrations and they can find a large spectrum of prey species (Lowe et al., 1996). Nevertheless, sandbar sharks from the Gulf of Gabès as those of other marine areas are opportunistic feeders (*sensu*

Wetherbee et al., 1990), and their diet is depending on what is available in its environment.

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