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COMPARED DIET OF TWO PELAGIC SHARK SPECIES IN THE NORTHEASTERN ATLANTIC OCEAN

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DIET
SHORTFIN MAKO
BLUE SHARK
STOMACH CONTENTS
TELEOSTS
CEPHALOPODS
NORTHEASTERN ATLANTIC OCEAN

ABSTRACT. – The diet of shortfin makos (*Isurus oxyrinchus)* and blue sharks (*Prionace glauca)* were studied by analyzing stomach contents of specimens captured by longliners near the Azores Archipelago and between the Azores and the Iberian Peninsula. The diet of the shortfin mako is strongly dominated by teleosts (mainly *Scomberesox saurus*), while that of the blue shark is strongly dominated by cephalopods (mainly *Histioteuthis* sp.). In mass of non-reconstituted prey, sea mammals play an important role, especially for the blue shark.

INTRODUCTION

The shortfin mako *Isurus oxyrinchus* Rafinesque, 1809 and the blue shark *Prionace glauca* (Linnaeus, 1758) are the elasmobranch species most impacted by the longliner fishing in the Northeastern Atlantic Ocean (Vandeperre *et al*. 2014). These pelagic species have a slow growth rate and low fecundity (Moreno 2004) and are located at the highest level of the marine food web.

These two shark species may compete for the same food resources with the main target species of commercial fisheries, the swordfish *Xiphias gladius* and the tuna *Thunnus* spp. Between 2001 and 2012, data on the landings of Spanish and Portuguese longliners in the port of Vigo (Spain) show that the blue shark represents more than 60 % of the species caught by longliners, while the swordfish represents 21 % and the shortfin mako 17 % (Xunta da Galicia, pers comm).

The diet of the shortfin mako has been investigated by Stillwell & Kohler (1982) in the Northwestern Atlantic, Maia *et al*. (2007) in the Northeastern Atlantic, Vaske-Júnior & Rincon-Filho (1998) in the Southeastern Atlantic, Cliff *et al*. (1990) and Gorni *et al*. (2012) in the Southwestern Atlantic. In the Pacific Ocean, the shortfin mako diet has been studied by Velasco Tarelo (2005), Mucientes-Sandoval & Saborido-Rey (2008) and Lopez *et al*. (2009). In the case of the blue shark, the most relevant investigations have been carried out by Mendonça (2009) in the Northwestern Atlantic, Vaske Júnior *et al*. (2009) in the Southeastern Atlantic and Clarke *et al*. (1996) in the Azores Archipelago, where the present study was conducted.

The aim of the present study was to investigate and compare the diet of these two shark species through the analysis of the stomach contents from specimens captured by the sea surface longliners based in the port of Vigo (Spain).

MATERIAL AND METHODS

The three study areas were located in the North Atlantic Ocean, between the Azores Archipelago and the Iberian Pen-

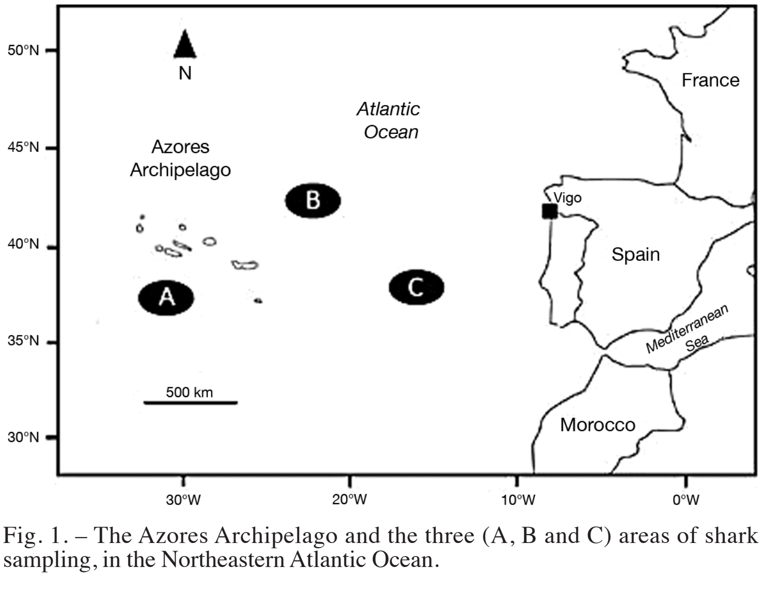

Fig. 1. – The Azores Archipelago and the three (A, B and C) areas of shark sampling, in the Northeastern Atlantic Ocean.

insula (15°-35° W and 30°-45° N; Fig. 1). The studied sharks were caught by Spanish and Portuguese longliners and they landed their catches in the port of Vigo (Galicia, Spain). The longlines measure about 50 km and 90 km with 500 and 1300 hooks, respectively, about 40 m apart. Hooks were located at about 20 m depth. The hooks measure 8.0 cm in total height and 2.5 cm in width. A total of 82 shortfin makos and 54 blue sharks were sampled in March and October 2012. They were measured (total length), weighed and the sex of individuals was noted. Most individuals (95 % and 82 %, respectively) were juveniles, since the size at sexual maturity recorded in the literature was 195 cm in males and 280 cm in females for the shortfin mako, and 180 cm in males and 200 cm in females for the blue shark (Moreno 2004; Hazin & Lessa 2005; Varghese *et al*. 2017).

The specimens, once on board the longliners, were stored in the cold-storage chamber of the ships. The stomachs and other organs of the specimens were extracted after the landing of the sharks in the fish market of the port of Vigo. The samples were immediately frozen and sent by refrigerated trucks to the Mediterranean Institute of Oceanography (MIO) in Marseille (France), where the stomachs were dissected and analyzed. Prey were identified, counted and weighed. On the basis of the number of empty stomachs, the percentage of vacuity index was estimated.

Table I. – Prey found in stomachs of the analyzed shark species. For the meaning of %O, %N, %M, IRI and %IRI, see text. – = absent, 0 = negligible.

	Shortfin mako *Isurus oxyrinchus*					Blue shark *Prionace glauca*				
	%O	**%N**	**%M**	**IRI**	**%IRI**	**%O**	**%N**	**%M**	**IRI**	**%IRI**
Crustaceans	**3.9**	**1.0**	**–**	**3.9**	**0.0**	**8.7**	**2.6**	**–**	**22.6**	**0.2**
Galathea sp. (Decapoda)	1.0	0.5	–	0.5	0.0	–	–	–	–	–
Unidentified Decapoda	2.0	0.5	–	0.5	0.0	4.3	1.3	–	5.6	0.1
Isopoda	–	–	–	–	–	4.3	1.3	–	5.6	0.1
Cephalopods	**23.6**	**10.8**	**0.6**	**269.0**	**2.7**	**95.7**	**86.8**	**3.8**	**8670.4**	**89.9**
Alloposus mollis	–	–	–	–	–	4.3	1.3	–	5.6	0.1
Ancistroteuthis lichtensteinii	2.0	0.5	–	1.0	0.0	4.3	1.3	–	5.6	0.1
Argonauta sp.	–	–	–	–	–	4.3	3.9	–	16.8	0.2
Brachioteuthis riisei	–	–	–	–	–	13.0	3.9	–	50.7	0.5
Gonatus steenstrupi	2.0	0.9	0.4	2.6	0.0	4.3	1.3	–	5.6	0.1
Heteroteuthis sp.	–	–	–	–	–	13.0	3.9	–	50.7	0.5
Histioteuthis elongata	3.9	0.9	–	3.5	0.0	–	–	–	–	–
Histioteuthis sp.	13.7	3.3	–	45.2	0.4	34.8	30.3	0.1	1057.9	11.0
Illex coindetii	2.0	0.5	–	1.0	0.0	–	–	–	–	–
Lepidoteuthis grimaldii	–	–	–	–	–	13.0	2.6	–	29.9	0.3
Octopus sp.	–	–	–	–	–	4.3	1.3	–	5.6	0.1
Pteroctopus tetracirrhus	–	–	–	–	–	4.3	1.3	–	5.6	0.1
Sepiola atlantica	2.0	0.5	–	1.0	0.0	–	–	–	–	–
Taningia danae	–	–	–	–	–	4.3	1.3	–	5.6	0.1
Unidentified Sepiolidae	–	–	–	–	–	26.1	11.8	–	308.0	3.2
Unidentified cephalopods	7.8	4.2	0.2	34.3	0.3	43.5	22.4	3.7	1135.4	11.8
Tunicates	**–**	**–**	**–**	**–**	**–**	**4.3**	**1.3**	**0.9**	**9.5**	**0.1**
Unidentified Salpidae	–	–	–	–	–	4.3	1.3	0.9	9.5	0.1
Teleosts	**80.4**	**85.0**	**30.9**	**9318.4**	**92.3**	**13.0**	**6.6**	**2.1**	**113.1**	**1.2**
Balistes capriscus (Balistidae)	3.9	1.4	0.8	8.6	0.1	–	–	–	–	–
Scomber scombrus (Scombridae)	11.8	3.3	3.9	85.0	0.8	8.7	2.6	1.9	39.2	0.4
Scomberesox saurus (Scomberesocidae)	51.0	76.1	8.4	4309.5	42.7	–	–	–	–	–
Thunnus alalunga (Scombridae)	2.0	0.5	17.1	35.2	0.3	–	–	–	–	–
Unidentified Bramidae	2.0	0.5	0.2	1.4	0.0	–	–	–	–	–
Unidentified teleosts	13.7	3.3	0.4	50.7	0.5	4.3	3.9	0.2	17.6	0.2
Sea turtles	**2.0**	**0.5**	**34.6**	**70.2**	**0.7**	**–**	**–**	**–**	**–**	**–**
Caretta caretta (Cheloniidae)	2.0	0.5	34.6	70.2	0.7	–	–	–	–	–
Cetaceans	**11.8**	**2.8**	**34.0**	**434.2**	**4.3**	**8.7**	**2.6**	**93.1**	**832.6**	**8.6**
Unidentified Odontoceti	11.8	2.8	34.0	434.2	0.1	8.7	2.6	93.1	832.6	8.6

The identification (to the lowest taxon possible) of the prey was carried out through the analysis of the vertebrae (teleosts and cetaceans) or the beak characteristics of cephalopods (Grassé 1958, Clarke 1986). In order to assess the reliability of the results, according to the number of analyzed stomachs, cumulative prey curves were generated for each species. The order in which stomachs were analyzed was randomized ten times and the cumulative number of new prey items was counted for each randomization. When the curves reach an asymptote, the number of stomachs analyzed may be considered as sufficient (Ferry & Cailliet 1996).

Dietary indices of occurrence, number and mass were calculated. Frequency of occurrence (%O) is the percentage of non-empty stomachs containing a type of prey (Cortés 1997). Percent number (%N) and percent mass (%M) are the percentage of individuals and mass, respectively, of a given prey species (or taxon) versus the overall number of prey within non-empty stomachs. The mass is that actually observed in the stomach, not that of reconstituted prey. The index of relative importance (IRI) was calculated as follows: IRI = (%N + %M) × %O (Pinkas *et al*. 1971, Cortés 1997). Dietary indices were compared between species and between sexes for each species.

The Schoener overlap index (α) was used to quantify the dietary overlap between the two studied shark species (Schoener 1970):

$$\alpha = 1 - 0.5\left(\sum_{i=1}^{n} |p_{ij} - p_{ik}|\right)$$

(where p_{ij} = frequency of the prey item i that is consumed by the species j (shortfin mako), p_{ik} = frequency of the prey item i that is consumed by the species k (blue shark); frequencies (0 through 1) are computed based on the %IRI (see Table I).

The mean trophic level TL of the two studied shark species was estimated by using the %IRIi of each prey item in their stomach contents and the trophic level TL_i of each prey item, according to Cortés (1999):

$$TL = \sum_{i=1}^{n} \left[(\%IRI_i/100) \times TL_i \right] + 1$$

In the formula, '+ 1' represents the difference between the trophic level of the prey and that of the predator (shark). The trophic level of the prey items was drawn from Stergiou & Karpouzi (2002), Bănaru *et al*. (2013) and Roscian (2015).

RESULTS AND DISCUSSION

The number of stomachs containing prey was 52 (out of 82) and 23 (out of 54) for shortfin mako and blue shark, respectively. The vacuity index was 36.6 % for shortfin mako and 57.4 % for blue shark. Cumulative prey curves are presented (Fig. 3); it can be observed that the asymptote is not reached, suggesting that the number of stomachs studied is not optimal. This is probably related with the high vacuity index. However, the diet of the two species is so contrasted in the study area (see below) that the number of stomachs hardly biases the conclusions. The diet of shortfin mako is dominated by teleosts (%IRI =92 %, Table I). More than 76 % (%N) of individuals of teleost prey belonged to one species, *Scomberesox saurus*. In addition, remains of a loggerhead turtle *Caretta caretta* (Fig. 2) and several cetaceans were recovered from the diet. Our results are in agreement with the literature, but report a conspicuously higher diversity of teleost prey (*e.g*. Maia *et al*. 2006). As far as the blue

Fig. 2. – Reconstitution of an individual of loggerhead sea turtle (*Caretta caretta*) (total length 60 cm) found in the stomach of a shortfin mako (total length 340 cm) captured in the sampling area A. Photo S Biton-Porsmoguer

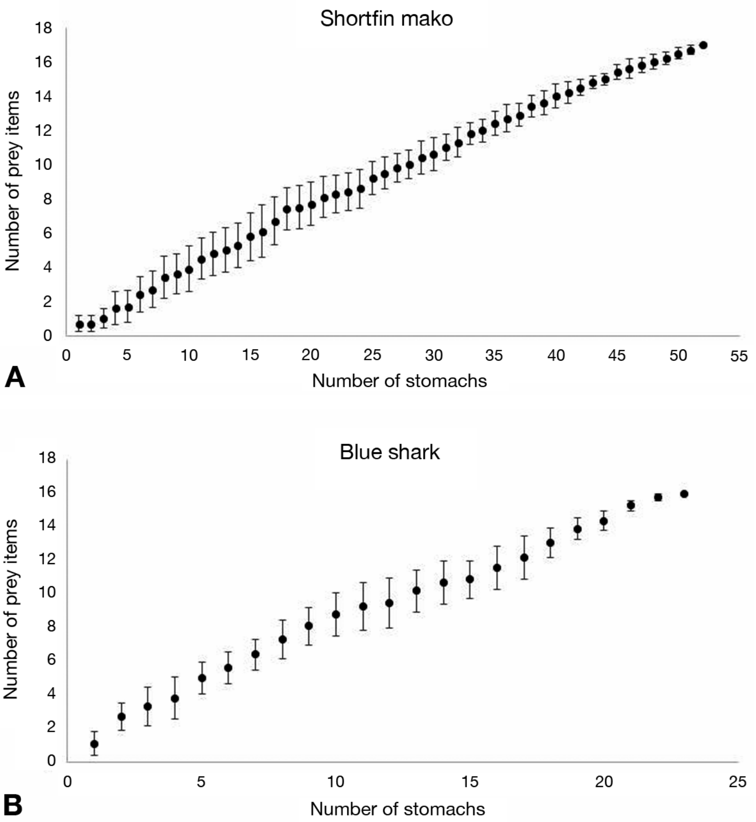

Fig. 3. – Cumulative prey curves for the shortfin mako shark (**A**) and the blue shark (**B**) stomachs analyzed. Bars represent standard deviation.

shark is concerned, cephalopods represent the main prey (%IRI = ~90 %), mostly consisting of *Histioteuthis* sp., but teleosts (mainly *Scomber scombrus*) and cetaceans were also consumed. Our results confirm some literature data (Mendonça 2009), but strongly contrast with other data which report a mainly teleost diet (*e.g.* Clarke *et al.* 1996). In the diets of both shark species, teleosts recovered from the diet were always unexpectedly deprived of head and tail (Biton-Porsmoguer *et al.* 2014). No differences in diet were observed between sexes (Mann-Whitney test) for the shortfin mako ($p = 0.78$; n = 18 males and 34 females) and the blue shark ($p = 0.56$; n = 7 males and 16 females). The possible role of ontogeny was not tested, as most individuals are juveniles.

The comparison of the diet of the two species, using the Schoener overlap index, shows a very low overlap ($\alpha = 0.065$). Feeding niche partitioning by the large oceanic predators is not uncommon, in order to avoid competition for prey, as observed in large predatory fishes, *e.g.* in the eastern Arabian Sea (Varghese *et al.* 2014) and off eastern Australia (Young *et al.* 2010). The mean trophic level of the shortfin mako and the blue shark was quite similar (4.96 and 4.78, respectively). These values were higher than trophic levels of these species reported in the literature and based on stomach content (4.3 for shortfin mako and for 4.1 blue shark) (Cortés 1999). Estrada *et al.* (2003) estimated their trophic levels based on their $\delta^{15}N$ stable isotope ratios and found lower values compared to our study (4.0 for shortfin mako and for 3.8 blue shark). Hussey *et al.* (2014) found similar values for the trophic level of shortfin mako. It is worth noting that discrepancies can exist between the trophic levels calculated from stomach contents versus stable isotopes (Estrada *et al.* 2003) and between trophic levels estimated with $\delta^{15}N$ stable isotope ratios considering fixed or variable fractioning (Hussey *et al.* 2014). This study may be completed with stable isotope analyses to estimate trophic levels using $\delta^{15}N$ and to test whether stable isotope ratios of $\delta^{15}N$ and $\delta^{13}C$ reflect the differences in diet observed with stomach content analyses for these two species.

CONCLUSION

In the study area, with regard to the number of prey, the shortfin mako is mainly a fish consumer, while the blue shark is a predator of cephalopods. The overlap index was very low, indicating that they are probably not competitors. However, if the non-reconstituted mass of prey is considered, sea mammals have a significant place in the diet of the shortfin mako, and are even dominant in the blue shark diet.

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