CONSUMPTION OF MARINE MAMMALS BY BROADNOSE SEVENGILL SHARK *NOTORYNCHUS CEPEDIANUS* IN THE NORTHERN AND CENTRAL PATAGONIAN SHELF

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Abstract – The study of food habits of the broadnose sevengill shark (*Notorynchus cepedianus*) based on the observation of the stomach contents of 22 individuals, revealed the importance of marine mammals as part of the shark's diet. The analysis showed that marine mammals represent at least 30% of the total consumed biomass by broadnose sevengill sharks. The frequency of occurrence was estimated to be 35%. The three pinnipeds with local distribution and at least two species of cetaceans were consumed. Although consumption of marine mammal was high, there was no evidence of direct attack on living preys by *N. cepedianus*, in Argentine waters.

Resumen – El estudio de la dieta del tiburón gatopardo (*Notorynchus cepedianus*) se basó en el análisis del contenido estomacal de 22 individuos y reveló la importancia de los mamíferos marinos como parte del consumo de los tiburones. Los análisis mostraron que los mamíferos marinos representan al menos el 30% de la biomasa total consumida por el gatopardo. La frecuencia de ocurrencia porcentual se estimó en 35%. Entre las especies consumidas se hallaron los tres pinnipedos con distribución local en la región y al menos dos cetáceos no identificados. A pesar que el consumo de mamíferos marinos fue importante, no existen referencias para el litoral argentino que indiquen que *N. cepedianus* ataque directamente a las presas vivas.

Key words: *Notorynchus cepedianus*, broadnose sevengill shark, feeding, stomach contents, marine mammals, Southwestern Atlantic Ocean.

Introduction

Shark predation on marine mammals has been reported worldwide. For example, Leatherwood *et al.* (1972) and Ainley *et al.* (1981) described attacks by sharks on many species of seals and dolphins off California. Cockcroft *et al.* (1989) mentioned predation by sharks on bottlenose dolphins (*Tursiops truncatus)* off Natal, South Africa. Brodie and Beck (1982) reported shark attacks on gray seals (*Halichoerus grypus)* in eastern Canada. Some authors suggested that shark predation may influence the marine mammal population dynamics. Such may be the case for the Hawaiian monk seal (*Monachus schauinslandi)*, where shark predation is considered to be an important mortality factor (Kenyon, 1981). Ainley *et al.* (1985) speculated how this interaction could have influenced the population dynamics of the northern elephant seal (*Mirounga angustirostris)*, by delaying the weaning of pups until the sharks are no longer concentrated around the breeding site. Würsig and Würsig (1980) also suggested that dusky dolphins (*Lagenorhynchus obscurus)* in Patagonia rest close to the shore, in order to avoid shark predation.

The broadnose sevengill shark (*Notorynchus cepedianus)* is one of the five shark species that frequently attack cetaceans (Heithaus, 2001). Praderi (1985) reported broadnose sevengill attacks on the franciscana dolphin (*Pontoporia blainvillei)* in Uruguayan waters, describing the species as a very voracious one. Ebert (1991a) also observed that this species heavily predates on marine mammals in South African waters.

N. cepedianus is a benthic and neritic species inhabiting the continental shelf in temperate seas in both hemispheres. It is common in shallow waters and sometimes it can be seen or caught close to the shore, but larger individuals are found in deeper waters (Compagno, 1984). According to this author, the maximum length recorded for the broadnose sevengill shark was 290cm. However, as he recognized, when he states that the species may reach up to 400cm he may have confused with an old record of a bluntonse sixgill shark *Hexanchus griseus.*

Fragments of a southern elephant seal (*Mirounga leonina*) in the stomach of a broadnose sevengill shark in Patagonian waters is the only record suggesting that sharks may feed upon marine mammals in Argentina (Falabella *et al.,* 1996[2]). Over the past few years, several sharks of this species were collected by sport fishing, the longline fishery for tope shark (*Galeorhynus galeus*) and as by-catch in the Argentine hake (*Merluccius hubbsi*) and Argentine red shrimp (*Pleoticus muelleri*) fisheries. The aim of this paper is to report new information regarding the consumption of marine mammals by broadnose sevengill sharks in Patagonia.

Material and Methods

The stomach contents of 22 broadnose sevengill sharks was analyzed. These individuals were captured as by-catch in the Argentine hake bottom trawl fishery (n=10), Argentine red shrimp twin-beam trawl fishery (n=4), tope shark longline fishery (n=6) and fishing cane sport fishery (n=1) (Table 1). In addition to our sample, we analyzed the contents of the individual studied by Falabella *et al.* (1996). The sharks were identified based on Compagno (1984) and Menni *et al.* (1984). They were sexed, weighed and measured in the Marine Mammals Laboratory (LAMAMA[3]). Finally, the sharks were dissected and the digestive tracts preserved frozen for further analysis.

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[2] Falabella, V., Lewis, M. and Elías, I. (1996) *Registro de predación sobre una cría de elefante marino en Patagonia*. Page 102 *in* Abstract, 7ª Reunión de trabajo de especialistas en mamíferos acuáticos de América del Sur, 22-25 October, Viña del Mar, Chile.
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Table 1. Records of *Notorynchus cepedianus* specimens caught in Patagonian waters.

SPECIMEN NUMBER	SEX	LENGTH (cm)	WEIGHT (kg)	CAPTURE DATE	LATITUDE	LONGITUDE	FISHING GEAR	AREA
1	♀	224	57.95	08-Jan-96	43º 40′ S	63º 30′ W	Bottom trawls	Continental shelf
2	♀	201	35.00	28-Feb-96	43º 00′ S	63º 30′ W	Bottom trawls	Continental shelf
3	♀	197	39.10	09-Feb-96	43º 59′ S	63º 37′ W	Bottom trawls	Continental shelf
4	♀	181	26.50	13-Jun-97	46º 10′ S	66º 00′ W	Twin-beam bottom trawls	Golfo San Jorge
5	♀	210	36.50	03-Feb-98	45º 30′ S	62º 50′ W	Bottom trawls	Continental shelf
6	♀	158	13.25	16-Feb-98	44º 05′ S	62º 15′ W	Bottom trawls	Continental shelf
7	♀	159	16.00	13-Mar-98	46º 10′ S	66º 10′ W	Twin-beam bottom trawls	Golfo San Jorge
8	♀	210	35.00	20-Dec-98	45º 05′ S	65º 48′ W	Twin-beam bottom trawls	Golfo San Jorge
9	♂	128	6.88	09-Dec-98	-	-	Bottom trawls	Continental shelf
10	♂	167	18.57	28-Nov-99	42º 49′ S	64º 52′ W	Sport fishing	Golfo Nuevo
11	♀	210	-	25-Jan-00	45º 14′ S	66º 42′ W	Twin-beam bottom trawls	Golfo San Jorge
12	♂	175	35.00	02-Dec-00	42º 43′ S	64º 56′ W	Longline	Golfo Nuevo
13	♀	126	7.99	19-Mar-02	42º 11′ S	61º 50′ W	Bottom trawls	Continental shelf
14	♀	215	47.00	11-Mar-01	42º 43′ S	64º 56′ W	Longline	Golfo Nuevo
15	♀	136	10.00	12-Mar-02	42º 43′ S	64º 56′ W	Longline	Golfo Nuevo
16	♂	167	18.00	12-Mar-02	42º 43′ S	64º 56′ W	Longline	Golfo Nuevo
17	♀	147	11.25	12-Mar-02	42º 43′ S	64º 56′ W	Longline	Golfo Nuevo
18	♀	143	10.75	12-Mar-02	42º 43′ S	64º 56′ W	Longline	Golfo Nuevo
19	♀	162	17.15	23-Jan-03	45º 20′ S	62º 58′ W	Bottom trawls	Continental shelf
20	♀	244	90.00	16-Nov-02	42º 58′ S	62º 14′ W	Bottom trawls	Continental shelf
21	♂	162	25.00	19-Mar-03	-	-	Bottom trawls	Continental shelf
22*	♀	244	97.00	14-Nov-95	43º 22′ S	64º 22′ W	Bottom trawls	Continental shelf

(*) specimen obtained by Falabella *et al*. (1996); (-) no data available.

Food items were determined according to the methodology described by Koen Alonso *et al.* (1998). Prey species were identified and quantified from fish otoliths or bones, squid beaks, and crustacean exoskeletons by means of the LAMAMA reference collection and published catalogues (Clarke, 1986; Boschi *et al.,* 1992; Volpedo and Echeverría, 2000). In order to estimate the total length and weight of preys (other than marine mammals), published regressions calculated by Koen Alonso *et al.* (1998) were applied. The biomass for a 51cm chunk of tail of a scombrid (Scombridae) was estimated by comparison with reference material of the LAMAMA collection. Marine mammal remains in the stomach contents were weight as they were found, and identified by direct observation (bones and coloration of the skin for cetaceans and fur characteristics for pinnipeds). Samples of marine mammal tissue were collected and frozen (-20ºC) in order to identify the species through DNA analysis. For each prey item the percentage frequency of occurrence (%FO) was estimated following Cortés (1997). Homogeneity of the sample in terms of sexual maturity and sex composition was examined by means of a Fisher Exact Test. The lengths at sexual maturity used were 165 cm for males and 200cm for female (Compagno, 1984).

Results and Discussion

Our sample consisted of 17 females with lengths ranging from 107 to 244cm; and of five males ranging from 128 to 175cm (Table 1). This sample could be biased as a consequence of size or sex segregation, which is very common in many shark species (Compagno, 1984). However, no bias was found regarding sex nor sexual maturity (Fisher Exact Test $p>0.5$).

Out of 22 stomachs examined, two were empty, seven contained marine mammals (35 %FO) and 17 contained fishes and squids (85 %FO). Five stomachs presented marine mammal remains exclusively. Pinnipeds were found in five stomachs: South American sea lion (*Otaria flavescens)* (n=3), South American fur seal (*Arctocephalus australis)* (n=1) and southern elephant seal (n=1) (Table 2). Cetaceans were found in three stomachs; however there is some degree of uncertainty in the species identification. Two of the samples containing cetaceans were taken at Golfo Nuevo (42º43´S, 64º56'W) and one was collected at Golfo San Jorge (45º14'S, 66º42'W). One of the sharks from Golfo Nuevo presented a small piece of cetacean remains (four pieces between 0.021 and 0.048kg of muscle with bubbler) with black skin. Most species of cetaceans suffer

a post-mortem darkening which makes difficult the identification of the species. This piece is likely to be from a dusky dolphin, due to the higher frequency of this species at Golfo Nuevo (LAMAMA, unpublished data). The other shark captured at Golfo Nuevo presented a thick piece of blubber (the measures were 10.5cm x 5cm x 4.8cm and weight 0.15kg); probably belonging to a large cetacean. The most common large cetacean in the area is the southern right whale (*Eubalaena australis*) but there is no certainty about the identification of this species. The third sample with cetacean remains was collected from a shark caught at Golfo San Jorge. It was a tail 17.3cm long, fluke width (tip to tip) 20.5cm and weight 0.254kg (Fig.1). This sample could belong either to a dusky dolphin, a Commerson´s dolphin (*Cephalorhynchus commersonii)* or a Peale´s dolphin (*Lagenorhynchus australis)*, all of which are frequently seen in the area. Burmeister´s porpoise was discarded due to the shape of the caudal vertebrae found in the stomach. Common and bottlenosed dolphins were also discarded as potential preys because they are not present in the area.

The total biomass of marine mammals found in the set of stomachs analyzed was 8.68kg, representing almost 30% of the total estimated consumed biomass. The South American sea lion accounted for 10.24% of the consumed biomass, the South American fur seal 6.7%, the southern elephant seal 10.6%, and all cetaceans combined only 1.82%. The remaining percentage was fish and squid. However, this estimation could be negatively biased, because the biomass of marine mammals found in the stomachs was weighed directly, without regard for the biomass already digested. In three individuals, at least, the degree of digestion was very advanced, hence the weight of the pieces originally consumed was underrepresented (Table 2). On the other hand, the biomass of fish and squid consumed was estimated by means of regressions based on hard structures found in the stomachs. However, the frequency of occurrence of marine mammals could be overestimated because digestion time for these items is expected to be longer than for fishes, increasing the probability of the capture of a shark with marine mammal remains.

Table 2. Estimated consumed biomass for fishes and squids and weighed biomass for marine mammals found in stomach contents of *Notorynchus cepedianus*.

SPECIMEN NUMBER	BIOMASS IN GRAMS (FISHES AND CEPHALOPODS)	BIOMASS IN GRAMS (MARINE MAMMALS)	CETACEANS	PINNIPEDS
1	1141	-		
2	1769	-		
3	3448	-		
4	3641	-		
5	-	1983		*Arctocephalus australis*
6	99	-		
7	600	-		
8	872	-		
9	-	-		
10	+	-		
11	-	648	Small cetacean	*Otaria flavescens*
12	-	139*	Small cetacean	
13	647	-		
14	-	2430		*Otaria flavescens*
15	4502	-		
16	-	223*		*Otaria flavescens*
17	168	150*	Cetacea (blubber)	
18	124	-		
19	629	-		
20	1125	-		
21	-	-		
22	2255	3150		*Mirounga leonina*
Total	21023	8683		

(*) highly digested marine mammals' remains; (+) no biomass back-calculation available.

Figure 1. Rest of pinniped and cetacean found in stomach of de *Notorhynchus cepedianus* captured in San Jorge Gulf, Chubut, Argentina. The reference is a 15cm rule.

Besides this paper and Falabella *et al.* (1996), there is only one previous record of broadnose sevengill shark predation on marine mammals in the southwestern Atlantic. Praderi (1985) reported for the Uruguayan coast that 17% of the stomach contents of *N. cepedianus* contained franciscanas and that 1% contained South American sea lions, pointing out that this shark usually predates on marine mammals. In the present study, 15% of the sampled stomachs contained cetaceans, while 25% contained pinnipeds. The overall frequency of occurrence of marine mammals in the stomachs was 35%. This confirms Praderi's (1985) statement that marine mammals are a frequent item in the diet of *N. cepedianus*. Similarly, Ebert (2002) observed that marine mammals composed almost one third of the diet of *N. cepedianus* in *cepedianus* in California, USA, and in Southern Africa.

Despite our small sample size, pinnipeds were more abundant than cetaceans in the stomach contents. In addition to the limited swimming skills of pinnipeds with respect to cetaceans, this could be also related to the higher relative abundance of pinnipeds in the area. South American sea lions are estimated to number over 70,000 individuals in northern and central Patagonia (Dans *et al.*, 1996, accepted manuscript[4]; Reyes *et al.*, 1999) and the population of southern elephant seals in Península Valdés area was estimated to be around 51,000 individuals (Lewis and Campagna, 2002). In contrast, population size estimates for dusky and Commerson´s dolphins (the most abundant small cetaceans in the area), are around 11,000 (Schiavini *et al.*, 1999) and 2,600 respectively (Pedraza *et al.*, submitted[5]) considering for both dolphins the upper confidence limit of the estimation. It seems to be a real fact of the higher abundance of pinnipeds in the area with respect to small cetaceans.

In addition to marine mammals, a total of seventeen prey species of fish and squid were identified (Table 3). The percentage frequency of occurrence was 60% for bony fishes, 35% for chondrichthyans, 25% for cephalopods and 5% for hagfish. The total estimated biomass of fish and squid was 21.2kg. One Argentine seabass (*Acanthistius brasilianus*) was recognized by bones without available regression, and thus excluded from this estimation. Even though, this bias can be ignored due to the insignificant amount of remains found.

[4] Dans, S.L., Crespo, E.A., Pedraza, S.N. and Koen Alonso, M. (accepted manuscript) Recovery of the South American sea lion population in northern Patagonia. *Canadian Journal of Fishery and Aquatic Science*.

[5] Pedraza, S.N., Schiavini, A.C.M., Crespo, E.A., Dans, S.L. and Coscarella, M.A. (Submitted). Abundance of commerson´s dolphin (*Cephalorhynchus commesonii*) in the coasts of Patagonia (Argentina). *J. Cetacean Research and Management*.

Table 3. Percentage frequency of occurrence (%FO) of the consumed fishes and squids by *Notorynchus cepedianus*.

FISH AND SQUID SPECIES		
COMMON NAME	SCIENTIFIC NAME	%FO
Argentine Shortfin squid	*Illex argentinus*	20
Argentine sea bass	*Acanthistius brasilianus*	15
South Atlantic bream	*Seriolella porosa*	15
Spiny dogfish	*Squalus acanthias*	15
Patagonian smoothhound	*Mustelus schmitti*	10
Elephant fish	*Callorhynchus callorhynchus*	5
Skate	*Dipturus flavirostris*	5
Argentine hake	*Merluccius hubbsi*	5
Hagfish	*Mixine* sp.	5
Silverside	*Odonthestes smitti*	5
Wreckfish	*Poliprion americanus*	5
Brazilian sandperch	*Pseudopercis semifasciata*	5
Raneya	*Raneya brasiliensis*	5
Tuna fish	Scombridae	5
Butterfish	*Stromateus brasiliensis*	5
Horse mackerel	*Trachurus picturatus*	5
Flounder	*Xystreuris rasile*	5

In spite of the small size of the sample, it seems that sharks that consumed marine mammals were larger than those that did not (Fig.2). This shark is known to present ontogenetic driven diet change, shifting from bony fishes to chondrichthyans with growth and sexual maturity. Marine mammals then, become increasingly important for larger size classes of *N. cepedianus* (Ebert, 2002).

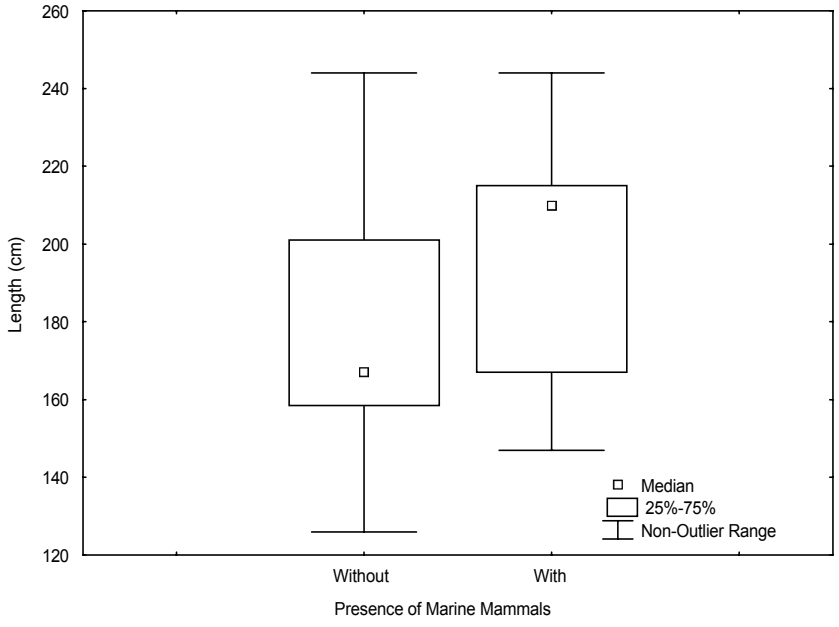

Figure 2. Box-plots showing length of *Notorynchus cepedianus* with and without presence of marine mammals in stomach contents.

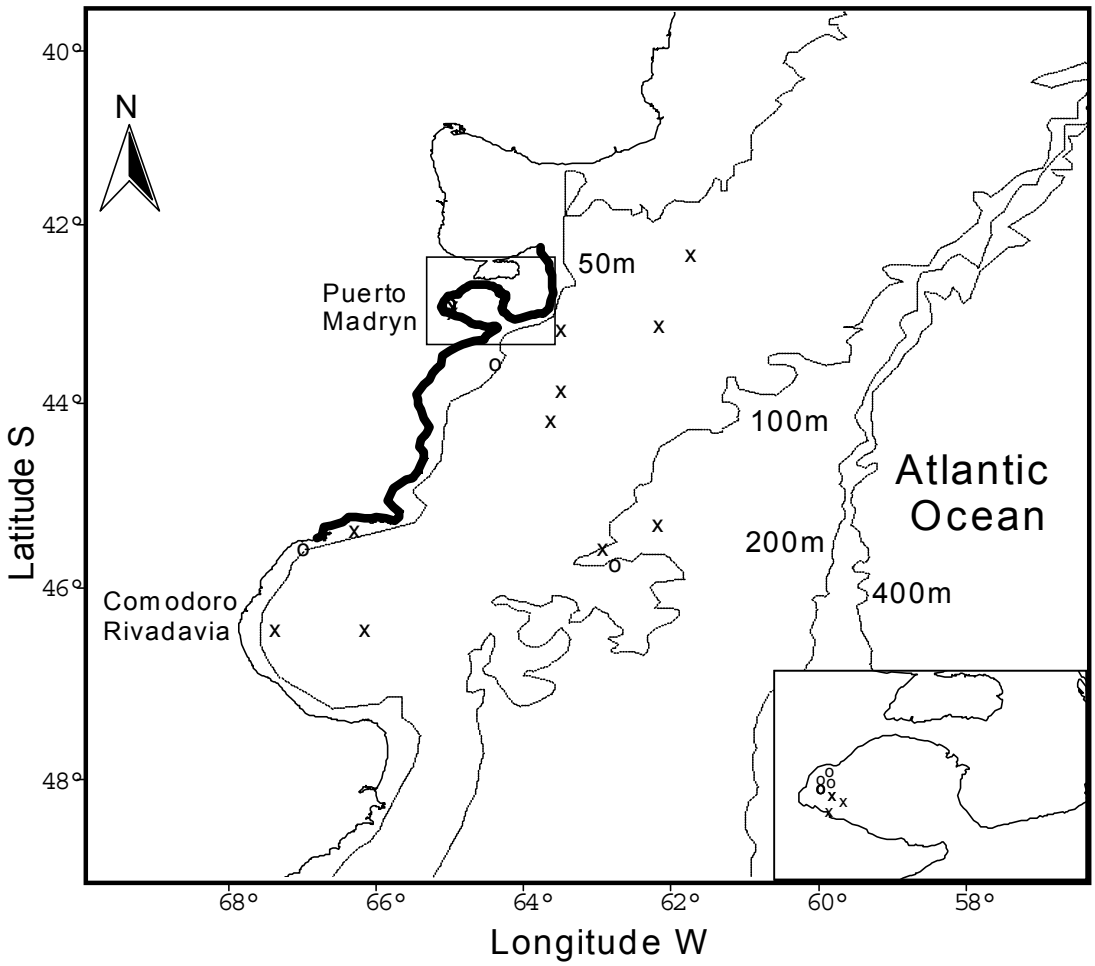

Figure 3. Location of *Notorynchus cepedianus* caught along the Patagonian shelf, indicating with circles those that consumed marine mammals and with crosses those that did not. Rookeries zones are shown with a thick line on the coast. At the bottom, a detail of Golfo Nuevo is shown.

Although the consumption of marine mammals can be considered important for *N. cepedianus*, there is no direct evidence that predation exist in the study area. Nevertheless, Ebert (1991b) described the predatory behavior of broadnose sevengill shark on marine mammals and other preys in South Africa, confirming that the species actively pursuits or ambushes its preys. The frequency of occurrence of marine mammal items found in shark stomachs appears to be too high to be solely related to scavenging (Ebert, 1991a). Leatherwood *et al.* (1972) observed shark attacks on dolphins only when they were dead or entangled in fishing nets. Ross and Bass (1971) found that the aggressive behavior of some shark species is more frequent on sick or heavily parasitized dolphins.

Attacks on marine mammals have not been recorded during this investigation; however scars on Commerson's dolphins in Bahía Engaño (43º20´S, 65º00´W) could be attributed to shark bites (LAMAMA, unpublished data). South American sea lions and elephant seals have also been recorded with scars. Whether these wounds were inflicted by *N. cepedianus*, or resulted from intraspecific aggressive behavior, could not be determined, but considering the high proportion of marine mammals in shark stomach contents, its aggressive behavior, and its relative high abundance in the area, some shark-caused lesions are expected. Obviously it is not discarded that broadnose sevengill shark feed of carrion, since it is a very versatile predator which is known to exploit a broad variety of food resources.

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