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FEEDING HABITS OF THE ATLANTIC SPOTTED DOLPHIN, *Stenella frontalis*, IN SOUTHEASTERN BRAZIL

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ABSTRACT

This study presents new information on the feeding habits of the Atlantic spotted dolphins, *Stenella frontalis*, in the Western South Atlantic. Nine stomach contents of *S. frontalis* incidentally caught in fishing operations conducted by the gillnet fleet based on main harbour of Cananéia (25°00'S; 47°55'W), southeastern Brazil, were analyzed. These specimens were captured between 2005 and 2007. A total of 1 422 cephalopod beaks, 147 otoliths and three crustaceans were recovered from the stomach contents. The dolphins assessed preyed on at least eight different fish species of the families Trichiuridae, Carangidae, Sparidae, Merluccidae, Engraulidae, Sciaenidae, Congridae and Scombridae, five cephalopod species of the families Loliginidae, Sepiolidae, Tremoctopodidae and Thysanoteuthidae, and one shrimp species of the Penaeidae family. Based on the analysis of the Index of Relative Importance (IRI), the Atlantic cutlassfish, *Trichiurus lepturus*, was the most important fish species represented. Of the cephalopods, the squid *Doryteuthis plei* was by far the most representative species. Several items were reported for the first time as prey of the *S. frontalis*: *Xiphopenaeus kroyeri*, *Tremoctopus violaceus*, *Semirossia tenera*, *Merluccius hubbsi*, *Pagrus pagrus* and *Paralonchurus brasiliensis*. *S. frontalis* presented teuthophagous and ichthyofagous feeding habits, with apparent predominance of the first, and preyed mainly on pelagic and demersal items.

RESUMO

O presente estudo apresenta novas informações sobre os hábitos alimentares de golfinhos-pintados-do-Atlântico, *Stenella frontalis*, no Atlântico Sudoeste. Foram analisados nove conteúdos estomacais de *S. frontalis* acidentalmente capturados em operações de pesca entre 2005 e 2007 pela frota pesqueira do município de Cananéia (25°00'S; 47°55'W), sudeste do Brasil. Foram recuperados dos conteúdos estomacais 1 422 bicos de cefalópodes, 147 otólitos e três camarões. Dos itens analisados, foram reportados um mínimo de oito espécies de peixes pertencentes às famílias Trichiuridae, Carangidae, Sparidae, Merluccidae, Engraulidae, Sciaenidae, Congridae e Scombridae, cinco espécies de cefalópodes pertencentes às famílias Loliginidae, Sepiolidae, Tremoctopodidae e Thysanoteuthidae, e uma espécie de camarão da família Penaeidae. Com base no Índice de Importância Relativa (IRI), o peixe-espada, *Trichiurus lepturus*, correspondeu à espécie de peixe com maior importância. Entre os cefalópodes, a espécie que apresentou o maior valor de IRI foi *Doryteuthis plei*. Algumas espécies foram reportadas pela primeira vez como presa de *S. frontalis* em águas brasileiras: *Xiphopenaeus kroyeri*, *Tremoctopus violaceus*, *Semirossia tenera*, *Merluccius hubbsi*, *Pagrus pagrus* e *Paralonchurus brasiliensis*. *S. frontalis* apresentou hábitos alimentares teutófagos e ictiófagos, com aparente predomínio do primeiro, e predou principalmente sobre itens pelágicos e demersais.

Descriptors: Cetacea, *Stenella frontalis*, Atlantic spotted dolphin, Feeding habits.
Descritores: Cetacea, *Stenella frontalis*, Golfinho-pintado-do-Atlântico, Hábitos alimentares.

INTRODUCTION

The most traditional method of studying the feeding habits of marine mammals is the analysis of food remains in scats, stomach contents and vomit. However, there are several other available methods, such as direct observations (e.g. FERTL; WURSIG, 1995; HERZING, 1996), the use of stable isotopes (e.g. NEWSOME et al., 2010), the use of fatty acids (e.g. IVERSON et al., 2004; BUDGE et al., 2006), molecular identification (e.g. SYMONDSON, 2002; DEAGLE et al., 2005), the use of crittercams (e.g. IVERSON et al., 2004), and bioacoustics (e.g. MADSEN et al., 2005; BENOIT-BIRD et al., 2008). Although the analysis of food remains may present several disadvantages, it still cannot be replaced effectively by any other method and also provides more information at lower cost (BARROS; CLARKE, 2009). This methodology consists of the identification of prey by means of structures which are more resistant to digestion and present considerable variation among species. Fish otoliths and cephalopod beaks are the most common structures used in the analysis of small cetacean feeding habits. Both structures permit investigators to estimate the size and weight of the prey items consumed (see FITCH; BROWNELL, 1968; JOBLING; BREIBY, 1986; CLARKE, 1962; CLARKE, 1986). The information gathered through species identification, size and biomass enables investigators to verify the characteristics of the spatial distribution of predators, and permits monitoring of the changes in predators' feeding habits as well as, in longer-term studies, the investigation of the dynamics of the relationship between prey and predator.

In the Western South Atlantic, knowledge of the feeding habits of small cetaceans comes mainly from studies based on the analysis of stomach contents. Although the number of published articles on this subject has been increasing over the last decade (e.g. DI BENEDITTO et al., 2001; SANTOS et al., 2002; PINEDO et al., 2002; GURJÃO et al., 2003; MORENO et al., 2003; SECCHI et al., 2003; DI BENEDITTO; RAMOS, 2004; DI BENEDITTO; SICILIANO, 2007; DANILEWICZ et al., 2009; BITTAR; DI BENEDITTO, 2009; MELO et al. 2010), few studies have been undertaken on the feeding habits of the Atlantic spotted dolphin, *Stenella frontalis*. In Brazil, only three such studies are known, including published papers and a thesis, which evaluated a total of 17 stomach contents (see MORENO, 1999; DI BENEDITTO et al., 2001; MELO et al., 2010). These studies listed a total of six cephalopod species and 18 fish species as prey items of *S. frontalis*. MORENO (1999) evaluated just one stomach content, in which three otoliths of the following species were found: the Atlantic cutlassfish, *Trichiurus lepturus*, the rake stardrum, *Stellifer stellifer*, and mullets, *Mugil* spp. In both the studies in which more than one stomach content was considered (see DI BENEDITTO et al., 2001; MELO et al., 2010), the squid *Doryteuthis plei* was the most important cephalopod prey. On the other hand, different fish species were found as the main prey item. Melo et al. (2010) reported *Porichthys porosissimus* as the main fish species found in 10 stomachs of stranded *S. frontalis* investigated in Rio de Janeiro State, between 22 ^{o} 14'S and 23^{o} 06'S, while Di Beneditto et al. (2001) reported *Orthopristis ruber* in six incidentally captured dolphins along the northern coast of Rio de Janeiro State, between 21^{o}35'S and 23^{o}10'S. It is important to quote the study of Santos and Haimovici (2001), which gave the consumption of cephalopods by marine mammals in Brazilian waters, and presented the same information found in Di Beneditto et al. (2001).

Studies conducted in other areas of the distribution of the Atlantic spotted dolphin reported the following prey: cephalopods; fishes, including flatfishes, carangids, clupeids and hemiramphids, and also benthic invertebrates (e.g. holothurians) (PERRIN et al., 1994; PERRIN, 2002). Fernández et al. (2009) analyzed 23 stomachs of 12 different stranded cetaceans, two of which were *S. frontalis*, on the Canary Islands. Offshore and inshore cephalopods of the genera *Hisitiotheuthis* and *Enoploteuthis*, as well as crustaceans of the infraclass Cirripedia were reported. In the Bahamas, Herzing (1996) observed *S. frontalis* preying on bottom fishes such as the flounder (Bothidae), the lizardfish (Synodontidae), the wrass (Labridae), the blenny (Tripterygiidae), the clinid (Clinidae) and the conger (Congridae). Fertl; Wursig (1995) reported a group of Atlantic spotted dolphins feeding in a coordinated manner on clupeid fishes.

Atlantic spotted dolphins are endemic to the tropical and warm-temperate waters of the Atlantic Ocean, where they have been reported from 45°N to 35°S (PERRIN, 2002). They present discontinuous distribution in the Western South Atlantic: north of 6°S and between 21°S and 33°S (MORENO et al., 2005). These authors suggested the existence of an isolated population found on the southeastern and southern Brazilian coast, which would make it more vulnerable to human impacts in view of its small range of distribution. The main threat to the conservation of this population are likely to be the incidental captures made during fishing operations (MORENO et al., 2005). *S. frontalis* is inserted in the category "data deficient" by the IUCN red list (HAMMOND et al., 2008), which means that information on its ecology and natural history is scarce. Based on the scenario described and for the purpose of understanding the ecology of *S. frontalis* better, the aim of the present

study was to evaluate the stomach contents of nine individuals incidentally caught in southeastern Brazil.

Material and Methods

Cananéia (25°00'S; 47°55'W) is a small town located on the southern coast of São Paulo state, southeastern Brazil. The Cananéia gillnet fleet was monitored from November 2004 to August 2007 to evaluate incidental small cetacean captures. Each boat's operation was recorded by the captain, who was engaged to fill out charts with the following data each time the nets were soaked: GPS position, net dimensions, water depth, soaking time, list of fish species caught, and number of events of incidental cetacean captures. When one of the latter was detected, the individual caught was identified in a log-book and, whenever possible, brought to the research team for investigation. Nine Atlantic spotted dolphins were caught incidentally over a period of 35 months, during which up to 17 fishing boats were monitored monthly. Data on the characteristics of each incidental capture event are shown in Table 1.

The stomach contents of the above incidental captures were screened using 200 µm mesh sieves. Fishes, cephalopods and crustaceans, whole or fragmented, fish otoliths and cephalopod beaks were selected and stored. Otoliths were dry stored, cephalopod beaks were stored in a 1:1 solution of glycerin and 70% ethanol, and the fragments and whole animals were kept in 70% ethanol, after 24 hours in a 10% formalin solution.

The otoliths were used to identify the teleostean fish consumed. The fish concerned were identified by consulting catalogs (e.g. ABILHÔA; CORRÊA, 1992/93; CORRÊA; VIANNA, 1992/93; LÊMOS et al., 1992/93; LÊMOS et al., 1995a; LÊMOS et al., 1995b). To estimate the standard length (SL in cm) or total length (TL in mm) and weight (TW in g) of the fish, the total length of each otolith was measured using a stereomicroscope with metric precision of 0.1 mm. Only the otoliths that had not been eroded by digestion were used to estimate the length of the fish to avoid underestimating their sizes. The length of the fish eaten can be reliably estimated when undigested otoliths are found in the stomach content of the predator (FITCH; BROWNELL, 1968). The total length of each otolith was the greatest longitudinal distance toward the groove. *Sagitta* was the only otolith used to estimate the number of fishes consumed by each individual. The number of fish consumed was estimated from the highest number of either right or left *sagitta* otoliths.

Cephalopod beaks were identified using the collection of the "*Centro de Pesquisa e Gestão de Recursos Pesqueiros do Litoral Sudeste e Sul do Instituto Chico Mendes de Conservação da Biodiversidade* (CEPSUL/ICMBio)". To estimate the mantle length (ML in mm) and weight (TW in g) of squids, the measurements of lower rostral length (LRL) and upper rostral length (URL) were taken. To estimate the mantle length and weight of octopus, the measurements of lower hood length (LHL) and upper hood length (UHL) were taken. Measurements were gathered using a stereomicroscope with ocular micrometer and precision of 0.1 mm. When beaks were found, the number of cephalopods consumed was estimated from the highest number of either upper or lower beaks. Crustaceans were identified using the identification key available in the literature (see COSTA et al., 2003).

The regression equations used to estimate the length and weight of fishes and cephalopods were available in the literature (see SANTOS; HAIMOVICI, 1998) or compiled from CEPSUL/ICMBio, "*Laboratório de Biologia da Conservação de Mamíferos Aquáticos da Universidade de São Paulo*" and "*Laboratório de Recursos Pesqueiros Demersais e Cefalópodes da Universidade Federal do Rio Grande*".

Table 1. List of individual Atlantic spotted dolphins, *Stenella frontalis*, incidentally caught from 2005 to 2007 by the gillnet fleet based in Cananéia, Brazil. Field number, date, water depth in meters and GPS position of captures are shown when available. PA means "Projeto Atlantis".

Field Number	Date	Water depth (m)	Coordinates
PA-164	12-Apr-05	65	25°59'S/48°16'W
PA-165	12-Apr-05	65	25°59'S/48°16'W
PA-198	18-Dec-05	20	24°56'S/47°36'W
PA-199	18-Dec-05	20	24°56'S/47°36'W
PA-205	16-Feb-06	20	25°56'S/47°32'W
PA-209	03-Apr-06	60	26°06'S/47°39'W
PA-249	16-Mar-07	21	25°16'S/47°46'W
PA-254	Mar-07	-	-
PA-264	26-Mar-07	17	25°08'S/47°47'W

The Index of Relative Importance (IRI) was calculated based on the following formula:

IRI = (N + W) x F,

where N is the numerical percentage, W is the estimated weight percentage and F is the frequency of occurrence percentage. The percentage of IRI (%IRI) was calculated to permit further comparisons of different studies. The numerical, weight and frequency of occurrence percentages and the %IRI were analyzed separately for fish and cephalopods, as cephalopod beaks remain in cetacean stomachs for longer time than otoliths (CLARKE, 1986). The diagram of %IRI was constructed as proposed by HENRIQUE-GARCIA (2010).

RESULTS

Of the nine stomachs analyzed, ca. 56% contained remains of cephalopods and fishes, 11% cephalopods, fishes and shrimps, and about 33% only cephalopods. A total of 1,422 cephalopod beaks and 147 otoliths were recovered, which rendered an estimated number of 775 cephalopods and 83 fishes. Only three crustaceans were recovered. Data on each individual dolphin evaluated (total length and gender), as well as the number of items found in each stomach, are presented in Table 2. The identified prey species are shown in Table 3. The Atlantic spotted dolphins analyzed preyed on at least eight fish species of the families Trichiuridae, Carangidae, Sparidae, Merluccidae, Engraulidae, Sciaenidae, Congridae and Scombridae, five cephalopod species of the families Loliginidae, Sepiolidae, Tremoctopodidae and Thysanoteuthidae, and one shrimp species of the family Penaeidae.

The minimum length of the fishes was 6.88cm and the maximum 101.01 cm (mean=24.92 cm, SD=27.17) (Fig. 1). The minimum length of the cephalopods was 4.26 cm and the maximum 35.89 cm (mean=14.58 cm, SD=5.20 cm) (Fig. 2).

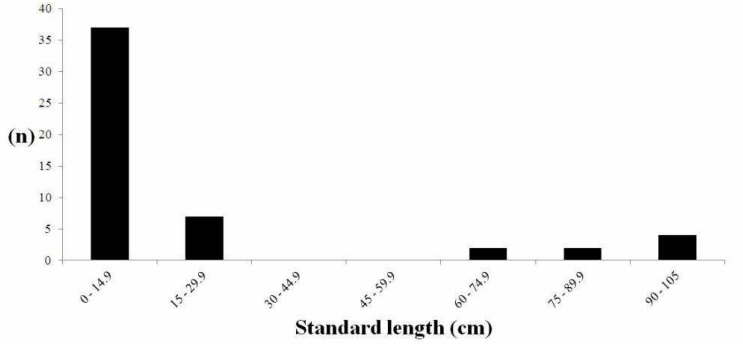

Fig. 2. Distribution of standard length classes of fishes found in the stomachs of nine Atlantic spotted dolphins (*Stenella frontalis*) in southeastern Brazil from 2005 to 2007. The horizontal axis represents the classes of standard length, and the vertical axis represents the number of fishes in each class (n).

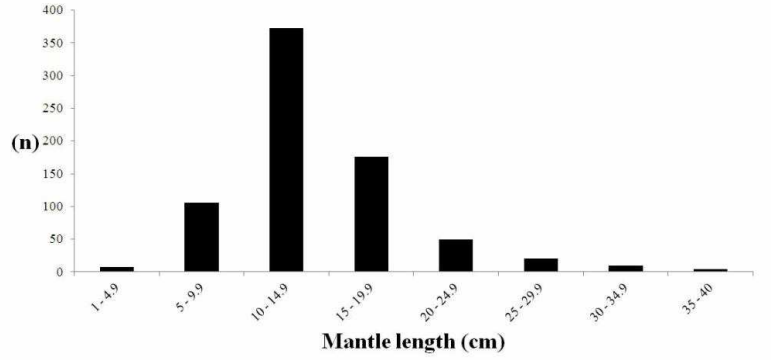

Fig. 3. Distribution of mantle length classes of cephalopods found in the stomach of nine Atlantic spotted dolphins (*Stenella frontalis*) in southeastern Brazil from 2005 to 2007. The horizontal axis represents the classes of mantle length, and the vertical axis represents the number of cephalopods in each class (n).

Table 2. List of prey items of Atlantic spotted dolphins, *Stenella frontalis*, incidentally caught from 2005 to 2007 by the gillnet fleet based in Cananéia, Brazil. The field number, sex, and total length (TL in cm) of each dolphin, and the number of otoliths, beaks and crustaceans found in each stomach are presented.

Field Number	Sex	TL (cm)	Otoliths	Beaks	Crustaceans
PA-164	F	197	102	199	-
PA-165	F	184	8	283	-
PA-198	F	147	-	223	-
PA-199	M	150	-	320	-
PA-205	M	158	-	31	-
PA-209	F	147	17	136	3
PA-249	F	153	-	15	-
PA-254	M	192	11	66	-
PA-264	M	175.5	9	149	-

Table 3. List of prey items found in nine stomach contents of Atlantic spotted dolphins, *Stenella frontalis*, incidentally captured in southeastern Brazil from 2005 to 2007. The number of stomachs in which prey items were found (o), the frequency of occurrence (F), the number of each prey found (n), the numerical percentage (N), the weight percentage (W), the Index of Relative Importance (IRI), and the percentage of IRI (%IRI) are presented.

Prey species	o	F	n	N	W	IRI	IRI%
Fishes							
Trichiuridae							
Trichiurus lepturus	2	22	8	12.12	72.94	1 871.43	58.06
Carangidae							
Trachurus lathami	1	11	46	69.7	14.7	928.43	28.8
Sparidae							
Pagrus pagrus	2	22	4	6.06	1.89	174.95	5.43
Merluccidae							
Merluccius hubbsi	1	11	4	6.06	9.33	169.27	5.25
Engraulidae							
Engraulis anchoita	1	11	4	6.06	1.13	79.11	2.45
Sciaenidae							
Paralonchurus brasiliensis	1	-	1	-	-	-	-
Congridae							
Ariosoma opisthophthalma	1	-	2	-	-	-	-
Scombridae	1	-	1	-	-	-	-
Cephalopods							
Loliginidae							
Doryteuthis plei	9	100	742	95.23	97.79	19 303.9	98.98
Doryteuthis sanpaulensis	3	33	30	3.87	1.6	181.73	0.93
Sepiolidae							
Semirossia tenera	1	11	4	0.51	0.28	8.79	0.05
Tremoctopodidae							
Tremoctopus violaceus	1	11	2	0.26	0.28	5.92	0.03
Thysanoteuthidae							
Thysanoteuthis rhombus	1	11	1	0.13	0.06	2.05	0.01
Crustaceans							
Penaeidae							
Xiphopenaeus kroyeri	1	-	3	-	-	-	-

Six prey items of the Atlantic spotted dolphin were reported for the first time: Seabob shrimp, *Xiphopenaeus kroyeri* (Crustacea); common blanket octopus, *Tremoctopus violaceus* and bobtail squid, *Semirossia tenera* (Cephalopoda); Argentine hake, *Merluccius hubbsi*, common seabream, *Pagrus pagrus*, and banded croaker, *Paralonchurus brasiliensis* (Actinopterygii).

Based on the analysis of the Index of Relative Importance (IRI), the Atlantic cutlassfish was the main fish species found in the stomach contents. Of the cephalopods, the squid *D. plei* was the most representative species, based on the IRI analysis. Diagrams of the IRI of fishes and cephalopods are presented in Figures 3 and 4, respectively.

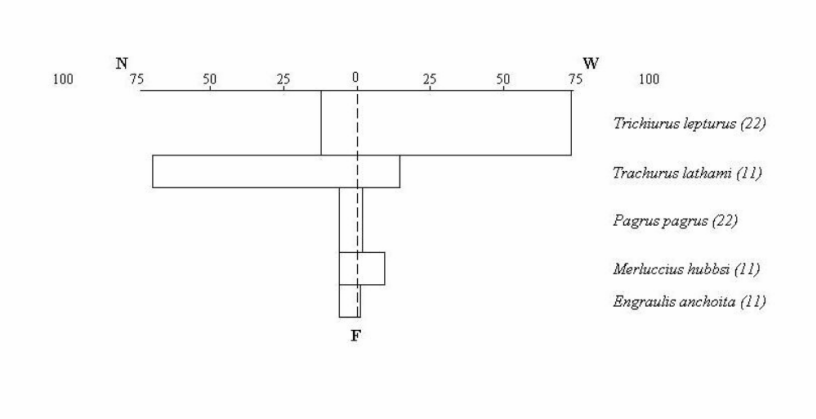

Fig. 3. Diagram of %IRI regarding fish species found in the stomachs of nine Atlantic spotted dolphins (*Stenella frontalis*) incidentally captured in gillnets in southeastern Brazil from 2005 to 2007. The horizontal axis represented the numerical (N) and weight (W) percentages, and the vertical axis represented the frequency of occurrence percentage (F), also indicated in parenthesis.

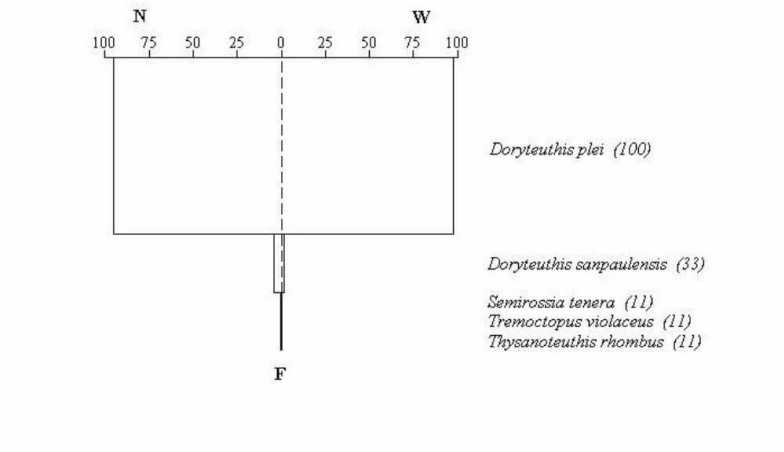

Fig. 4. Diagram of %IRI regarding cephalopod species found in the stomachs of nine Atlantic spotted dolphins (*Stenella frontalis*) incidentally captured in gillnets in southeastern Brazil from 2005 to 2007. The horizontal axis represented the numerical (N) and weight (W) percentages, and the vertical axis represented the frequency of occurrence percentage (F), also indicated in parenthesis.

DISCUSSION

Although Atlantic spotted dolphins seem to be abundant off southern and southeastern Brazil (MORENO et al., 2005), only three studies have been conducted to investigate their feeding habits in Brazilian waters. The relatively small sample number in the present study could be considered unrepresentative. However, it represents 34.6% of the total sample number evaluated for *S. frontalis* in Brazilian waters. It was possible to identify 1 422 cephalopod beaks and 147 otoliths, and the remains of at least 860 prey items retrieved from nine stomachs (775 cephalopods, 82 fishes, 3 shrimps). MELO et al. (2010) recovered a total of 356 otoliths and 153 beaks in ten stomach contents. DI BENEDITTO et al. (2001) did not present the number of otoliths and beaks found in the six stomach contents analyzed, though that study presented the remains of at least 139 prey items.

MORENO (1999) found three otoliths of three different fish in the contents of one stomach.

In the present study, teuthophagous and ichthyofagous feeding habits are shown for *S. frontalis*, with apparent predominance of the former. This predominance had already been observed by DI BENEDITTO et al. (2001). In the study of MELO et al. (2010), the consumption of cephalopods and fishes was considered equivalent. In other locations of the Atlantic spotted dolphin's distribution range, fishes and cephalopods have also been reported as important prey, with some variation in accordance with the area of the study (see PERRIN et al., 1994; FERTL; WURSIG, 1995; HERZING, 1996; PERRIN, 2002; FERNÁNDEZ et al., 2009). It is important to be aware of potential bias when considering cetacean feeding habits as predominantly teuthophagous or ichthyofagous, since cephalopod beaks remain in the stomach for longer than fish otoliths (CLARKE, 1986). Additional, previously quoted, tools may provide clues as to such preferences.

Atlantic spotted dolphins may be found feeding in the water column and close to the sea bottom. *D. plei* and *T. lepturus* migrate vertically (see ROPER et al., 1984; FIGUEIREDO; MENEZES, 2000) and could, therefore, have been captured anywhere in the water column. In Bahamas, HERZING (1996) observed Atlantic spotted dolphins emitting echolocation clicks directly to the sandy bottom and feeding on buried fishes. On the other hand, FERTL; WURSIG (1995) observed *S. frontalis* feeding near the water surface. Their flexibility in searching out their prey at different depths may be an important characteristic of coastal dolphins adapted to depending on patchy food resources. Of the cephalopods identified, the squid *D. plei* accounted for ca. 95%. This squid usually occurs at depths down to 370m in coastal waters (see ROPER et al., 1984). *D. plei* and *D. sanpaulensis* are abundant along the southeastern Brazilian coast (HAIMOVICI; PEREZ, 1991). On the other hand, *Thysanoteuthis rhombus*, a cephalopod reported in this study but of less importance in the feeding habits of *S. frontalis*, occurs in oceanic waters. The presence of shallow and deeper water prey in the stomachs of Atlantic spotted dolphins was also observed by MELO et al. (2010). In Brazil, previous studies on the distribution of *S. frontalis* have shown the species' greatest preference for near shore habitats, but with recordings as far out as the 1 000 m isobath (ZERBINI et al., 2004; MORENO et al., 2005; RAMOS et al., 2010). These records and the results shown in the available studies on southeastern Brazil provide evidence of the flexibility of the Atlantic spotted dolphin when exploiting different niches. The study of FERNÁNDEZ et al. (2009), conducted with animals stranded on the Canary Islands, also reported inshore and offshore species of cephalopods listed as Atlantic spotted dolphins' prey items. The presence of *M. hubbsi*, a species which is more commonly found in colder waters, in just one stomach, could be related to the site where the dolphin was incidentally captured. The individual that fed on four *M. hubbsi* represented the southernmost and the easternmost spot of capture of the nine Atlantic spotted dolphins analyzed. *M. hubbsi* occurs between the 20m and 700m isobaths but is most commonly found at depths greater than 300m (VÁZ-DOS-SANTOS; ROSSI-WONGTSCHOWSKI, 2005).

It is important to evaluate the individual contributions of all the percentages (occurrence, numerical and volumetric frequency) when comparing the %IRI values. The highest value of %IRI observed for *T. lepturus*, for example, was induced by the higher F value. The second fish species in importance, *Trachurus lathami*, presented a higher value of N, but the estimated consumed biomass of *T. lepturus* was much higher than that of *T. lathami* (see Fig. 2). As regards the cephalopods, the species with the highest value of %IRI (98.9%), *D. plei*, was also the one with the highest N, F and W (see Fig. 3). In the study of Melo et al. (2010), this cephalopod species was also the one that presented the highest value of %IRI: 77.3%. The fish species that presented the highest value of %IRI in the present study was the Atlantic cutlass fish with 58.1%, which was also reported by Melo et al. (2010), but in that study the species had no estimated biomass, and showed lower values of F (20%) and N (1.2%). No direct comparisons of the food items found in this study with those found in the study of Di Beneditto et al. (2001) were possible because their results were not presented in IRI by the authors quoted.

The most representative fish species in the diet of *S. frontalis* in studies conducted in Brazilian waters do not seem to include the most economically important ones (see DA SILVA; VIANNA, 2009). *Porichthys porosissimus* and *O. ruber*, the most important fish species in the studies of Melo et al. (2010) and Di Beneditto et al. (2001), respectively, are not among the ten most commercially important species in southeastern Brazil (see DA SILVA; VIANNA, 2009). On the south and southeast Brazilian coast, there is no fishery directed to the Atlantic cutlassfish. In southern Brazil, this species is commonly discarded (MAGRO, 2005). However, the lack of information about the artisanal fishery economy may be responsible for an underestimation of the importance of the Atlantic cutlassfish in Brazilian fishery statistics (MAGRO, 2005). When cephalopods are taken into consideration, the overlap quoted is to be observed. *D. plei*, which is a cephalopod of great commercial value (PEREZ et al., 2005), was reported to be the most important cephalopod prey in

the three studies that presented more than one stomach content of *S. frontalis* (DI BENEDITTO et al., 2001; MELO et al., 2010; present study). When considering its importance in fisheries in general, this species is not listed as one of the ten most economic important products (see DA SILVA; VIANNA, 2009). Based on these first evidences, it seems that spotted dolphins are not exploiting important economic targets of the fisheries in southeastern Brazil directly.

Studies on feeding habits give interesting information regarding the importance of marine mammals in their respective ecosystems, thus contributing to our understanding of them and their conservation. More studies on the feeding habits of the Atlantic spotted dolphin are, therefore, necessary to enhance our understanding of their trophic roles. Additionally, the various different techniques available must be exploited so as to provide the complementary information necessary to enrich our understanding of the diet of *S. frontalis*.

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References

ABILHÔA, V.; CORRÊA, M. F. M. Catálogo de otólitos de Carangidae (Osteichthyes-Perciformes) do litoral do Estado do Paraná, Brasil. **Nerítica**, v. 7, n.1-2, p. 119-131, 1992/93.

BARROS, N.; CLARKE, M. R. Diet. In: PERRIN, W. F.; WÜRSIG, B.; THEWISSEN, J. G. M. (Ed.). **Encyclopedia of Marine Mammals**. San Diego, CA: Academic Press, 2009. p. 323-327.

BENOIT-BIRD, K. J.; GILLY, W. F.; AU, W. W. L.; MATE B. Controlled and in situ target strengths of the jumbo squid *Dosidicus gigas* and identification of potential acoustic scattering sources. **J. Acoust. Soc. Am.**, v. 123, p. 1318–1328, 2008.

BITTAR, V. T.; DI BENEDITTO, A. P. M. Diet and potential feeding overlap between *Trichiurus lepturus* (Osteichthyes, Perciformes) and *Pontoporia blainvillei* (Mammalia, Cetacea) in northern Rio de Janeiro, Brazil. **Rev. Bras. de Zool.**, v. 26, p. 374-78, 2009.

BUDGE, S. M.; IVERSON, S. J.; KOOPMAN, H. N. Studying trophic ecology in marine ecosystems using fatty acids: a primer on analysis and interpretation. **Mar. Mamm. Sci.**, v. 22, n. 4, p. 759-801, 2006.

CLARKE, M. R. The identification of cephalopod "beaks" and the relationship between beak size and total body weight. **Bull. Br. Mus. (Nat. Hist.)**, v. 8, n. 10, p. 419-480, 1962.

CLARKE, M. R. Cephalopods in the diet of odontocetes. In: BRYDEN, M. M.; HARRISON, R. (Ed.). **Research on Dolphins**. Oxford: Claredon Press, 1986. p. 281-321.

CORRÊA, M. F. M.; VIANNA, M. S. Catálogo de otólitos de Sciaenidae (Osteichthyes-perciformes) do litoral do Estado do Paraná. **Nerítica**, v. 7, n. 1-2, p. 13-40, 1992/93.

COSTA, R. C.; FRANSOZO, A.; MELO, G. A. S.; FREIRE, F. A. M. Chave ilustrada para identificação dos camarões dendobranchiata do litoral norte do estado de São Paulo, Brasil. **Biota Neotrópica,** v. 3, n. 1, 2003. Published on-line<http://www.biotaneotropica.org.br/v3n1/pt/abstract?identification-key+BN01503012003>2003.

DA SILVA, A. O. A.; VIANNA, M. 2- A produção pesqueira do estado do Rio de Janeiro. In. VIANNA, M. (Ed.). **Diagnóstico da cadeia produtiva da pesca marítima no estado do Rio de Janeiro: relatório de pesquisa**. Rio de Janeiro: FAERJ: SEBRAE-RJ, 2009. p. 47-60.

DANILEWICZ, D.; TAVARES, M.; MORENO, I. G.; OTT, P. H. E TRIGO, C. C. Evidence of feeding by the humpback whale (*Megaptera novaeangliae*) in mid latitude waters of the western South Atlantic. **Mar. Biodiversity Rec., 2**. doi:10.1017/S1755267209000943. Published on-line by Cambridge University Press. 2009.

DEAGLE, B. E.; TOLLIT, D. J.; JARMAN, N. J.; HINDELL, M. A.; TRITES, A.; GALES, N. J. Molecular scatology as a tool to study diet: analysis of prey DNA in scats from captive Steller sea lions. **Mol. Ecol.**, v. 14, p. 1831-1842, 2005.

DI BENEDITO, A. P. M.; RAMOS, R. M. A. Biology of the marine tucuxi dolphin (*Sotalia fluviatilis*) in South-eastern Brazil. **J. mar. Biol. Assoc. U. K.**, v. 4, p. 1245-1250, 2004.

DI BENEDITTO, A. P. M.; SICILIANO, S. Stomach contents of the marine tucuxi dolphin (*Sotalia guianensis*) from Rio de Janeiro, south-eastern Brazil. **J. Mar. Biol. Assoc. U. K.**, v. 87, p. 253-254, 2007.

DI BENEDITTO, A. M.; RAMOS, R. M. A.; SICILIANO, S.; SANTOS, R. A.; BASTOS, G.; FAGUNDES-NETTO, E. Stomach contents of delphinids from Rio de Janeiro, southeastern Brazil. **Aquat. Mamm.**, v. 27, n. 1, p. 24-28, 2001.

FERNÁNDEZ, R.; SANTOS, M. B.; CARRILLO, M.; TEJEDOR, M.; PIERCE, G. J. Stomach contents of cetaceans stranded in the Canary islands 1996-2006. **J. Mar. Biol. Assoc. U. K.**, v. 89, n. 5, p. 873-883, 2009.

FERTL, D.; WURSIG, B. Coordinated feeding by Atlantic spotted dolphins (*Stenella frontalis*) in the Gulf of Mexico. **Aquat. Mamm**., v. 21, p. 3-5, 1995.

FIGUEIREDO, J. C.; MENEZES, N. A. **Manual de peixes marinhos do sudeste do Brasil. VI. Teleostei (5)**. São Paulo: Museu de Zoologia da Universidade de São Paulo, 2000. 116p.

FITCH, J. E.; BROWNELL, R. L. Fish otoliths in cetacean stomachs and their importance on interpreting feeding habits. **J. Fish. Res. Board Can.**, v. 25, n. 12, p. 1561-1574, 1968.

GURJÃO, L. M.; NETO, M. A. A. F.; SANTOS, R. A.; CASCON, P. Feeding habits of marine tucuxi, *Sotalia fluviatilis*, at Ceará state, northeastern Brazil. **Lat. Am. J. Aquat. Mamm.**, v. 2, n. 2, p. 117-122, 2003.

HAIMOVICI, M; PEREZ, J. A. A. The coastal cephalopod fauna of southern Brazil. **Bull. Mar. Sci.**, v. 49, p. 221-230, 1991.

HAMMOND, P. S.; BEARZI, G.; BJORGE, A.; FORNEY, K.; KARCZMARSKI, L.; KASUYA, T.; PERRIN, W. F.; SCOTT, M. D.; WANG, J. Y.; WELLS, R. S.; WILSON, B. STENELLA FRONTALIS. In: **IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4.** Downloaded on 23 November 2010.

HENRIQUE-GARCIA, J. **Ecologia alimentar da toninha, *Pontoporia blainvillei* (Mammalia – Pontoporidae) ao longo de sua área de distribuição**. Monography, Universidade do Vale do Itajaí, SC, Brazil, 2010. 98 p.

HERZING, D. L. Vocalizations and associated underwater behavior of free-ranging Atlantic spotted dolphins, *Stenella frontalis* and bottlenose dolphins, *Tursiops truncatus*. **Aquat. Mamm**., v. 22, n.2, p. 61-79, 1996.

IVERSON, S. J.; FIELD, C. F.; DON BOWEN, W.; BLANCHARD, W. Quantitative fatty acid signature analysis: a new method of estimating predator diets. **Ecol. Monogr.**, v. 74, n. 2, p. 211-235, 2004.

JOBLING, M.; BREIBY, A. The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. **Sarsia**, v. 71, n. 3-4, p. 265-274, 1986.

LÊMOS, P. H. B.; CORRÊA, M. F. M.; ABILHÔA, V. Catálogo de otólitos de Gerreidae (Osteichthyes-Perciformes) do litoral do Estado do Paraná, Brasil. **Nerítica**, v. 7, n. 1-2, p. 109-117, 1992/93.

LÊMOS, P. H. B.; CORRÊA, M. F. M.; PINHEIRO, P. C. Catálogo de otólitos de Engraulidae (Clupeiformes-Perciformes) do litoral do Estado do Paraná, Brasil. **Braz. Arch. Biol. Technol.**, v. 38, n. 3, p. 731-745, 1995a.

LÊMOS, P. H. B.; CORRÊA, M. F. M. E PINHEIRO, P. C. Catálogo de otólitos de Clupeidae (Clupeiformes-Perciformes) do litoral do Estado do Paraná, Brasil. **Braz. Arch. Biol. Technol.**, v. 38, n. 3, p. 747-759, 1995b.

MADSEN, P. T.; JOHNSON, M.; AGUILAR DE SOTO, N.; ZIMMER, W. M. X.; TYACK, P. L. Biosonar performance of foraging beaked whales (*Mesoplodon densirostris*). **J. Exp. Biol.**, v. 208, p. 181-194, 2005.

MAGRO, M. *Trichiurus lepturus* Linnaeus, 1758. In: CERGOLE, M.C.; ÁVILA-DA-SILVA, A. O.; ROSSI-WONGTSCHOWSKI, C. L. D. B. (Ed.). **Análise das Principais Pescarias Comerciais da Região Sudeste-Sul do Brasil:** Dinâmica Populacional das Espécies em Explotaçao - Serie Revizee-Score sul. São Paulo: Editora Ulhoa Cintra. 2005. p. 162-166.

MELO, C. L. L.; SANTOS, R. A.; BASSOI, M.; ARAÚJO, A. C.; LAILSON-BRITO, J.; DORNELES, P. R.; AZEVEDO, A. F. Feeding habits of delphinids (Mammalia:Cetacea) from Rio de Janeiro State, Brazil. **J. Mar. Biol. Assoc. U. K.**, v. 90, n. 8, p. 1509-1515, 2010.

MORENO, I. B. **Ecologia alimentar de golfinhos (Cetacea – Delphinidae) no litoral norte do Rio Grande do Sul, Brasil**. Monography, Universidade Federal do Rio Grande do Sul, Rio Grande do Sul, Brazil, 1999. 35p.

MORENO, I. B.; DANILEWICZ, D.; BORGES-MARTINS, M.; OTT, P. H.; CAON, G.; OLIVEIRA, L. R. Fraser's dolphin (*Lagenodelphis hosei* Fraser, 1956) in Southern Brazil. **Lat. Am. J. Aquat. Mamm.**, v. 2, n. 1, p. 39-46, 2003.

MORENO, I. B.; ZERBINI, A. N.; DANILEWICZ, D.; SANTOS, M. C. DE O.; SIMÕES-LOPES, P. C.; LAILSON-BRIO JR., J.; AZEVEDO, A. F. Distribution and habitat characteristics of dolphins of the genus *Stenella* (Cetacea: Delphinidae) in the southwest Atlantic Ocean. **Mar. Ecol. Prog. Ser.**, v. 300, p. 229-240, 2005.

NEWSOME, S. D.; CLEMENTZ, M. T.; KOCH, P. L. (2010) Using stable isotope biogeochemistry to study marine mammal ecology. **Mar. Mamm. Sci.**, v. 26, n. 3, p. 509-572, 2010.

PEREZ, J. A. A.; GASALLA, M. A., AGUIAR, D. C.; OLIVEIRA, U. C.; MARQUES, C. A. E TOMÁS, A. R. G. *Loligo plei* (Blainville, 1823). In:CERGOLE, M.C.; ÁVILA-DA-SILVA, A. O.; ROSSI-WONGTSCHOWSKI, C. L. D. B. (Ed.). **Análise das Principais Pescarias Comerciais da Região Sudeste-Sul do Brasil:** Dinâmica Populacional das Espécies em Explotaçao. Serie Revizee-Score sul. São Paulo: Editora Ulhoa Cintra, 2005. p. 62-68.

PERRIN, W. F. *Stenella frontalis*. **Mamm. Species**. v. 702, p. 1-6, 2002.

PERRIN, W. F.; CALDWELL, D. K.; CALDWELL, M. C. Atlantic spotted dolphin *Stenella frontalis*. (G. Cuvier, 1829). In: RIDGWAY, S. H.; HARRISON, R. (Ed.). **Handbook of Marine Mammals.** v. 5: The First Book of Dolphins. New York: Academic Press, 1994. p. 173-190.

PINEDO, M. C.; BARRETO, A. S.; LAMMARDO, M. P.; ANDRADE, A. L. V.; GERACITANO, L. Northernmost records of the spectacled porpoise, Layard's beaked whale, Commerson's dolphin, and Peale's dolphin in the southwestern Atlantic Ocean. **Aquat. Mamm.**, v. 28, n. 1, p. 32-37, 2002.

RAMOS, R. M. A.; SICILIANO, S.; RIBEIRO, R. **Monitoramento da biota marinha em navios de sísmica:** seis anos de pesquisa (2001-2007). Vitória, ES: Everest Tecnologia em Serviços, 2010. 1151 p.

ROPER, C. F. E.; SWEENEY, M. J.; NAUEN, C. E. FAO Species Catalogue. Vol. 3. Cephalopods of the World. An annotated and illustrated catalogue of species of interest to fisheries**. FAO Fish. Synop.**, v. 3, n. 125, p.277, 1984.

SANTOS, M. C. DE O.; ROSSO, S.; SANTOS, R. A. DOS; LUCATO, S. H. B.; BASSOI, M. Insights on small cetacean feeding habits in southeastern Brazil. **Aquat. Mamm.**, v. 28, n. 1, p. 38-45, 2002.

SANTOS, R. A.; HAIMOVICI, M. Trophic relationships of the long-finned squid *Loligo sanpaulensis* on the southern Brazilian shelf. **S. Afr. J. mar. Sci.**, v. 20, p. 1-19, 1998.

SANTOS, R. A.; HAIMOVICI, M. Cephalopods in the diet of marine mammals stranded or incidentally caught along southeastern and southern Brazil (21-34ºS). **Fish. Res.**, v. 52, p. 99-112, 2001.

SECCHI, E. R.; BARCELLOS, L.; ZERBINI, A. N.; ROSA, L. D. Biological observations on a dwarf minke whale, *Balaenoptera acutorostrata*, caught in southern Brazilian waters, with a new record of prey for the species. **Lat. Am. J. Aquat. Mamm.**, v. 2, n. 2, p. 109-115, 2003.

SYMONDSON, W. O. C. Molecular identification of prey in predator diets. **Mol. Ecol.**, v. 11, n. 4, p. 627-641, 2002.

VÁZ-DOS-SANTOS, A. M.; ROSSI-WONGTSCHOWSKI, C. L. D. B. *Merluccius hubbsi* Marini, 1993. In: CERGOLE, M.C.; ÁVILA-DA-SILVA, A. O.; ROSSI-WONGTSCHOWSKI, C. L. D. B. (Ed.). **Análise das Principais Pescarias Comerciais da Região Sudeste-Sul do Brasil:** Dinâmica Populacional das Espécies em Explotação. Serie Revizee-Score sul. São Paulo: Editora Ulhoa Cintra, 2005. p. 88-93.

ZERBINI, A. N.; SECCHI, E. R.; BASSOI, M.; DALLA ROSA, L.; HIGA, A.; DE SOUSA, L.; MORENO, I. B.; MÖLLER, L. M.; CAON, G. **Distribuição e abundância relativa de cetáceos na Zona Econômica Exclusiva da Região Sudeste-Sul do Brasil.** Série Revizee-Score Sul. São Paulo: Instituto Oceanográfico da USP, 2004. 40 p.

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