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Feeding habits of delphinids (Mammalia: Cetacea) from Rio de Janeiro State, Brazil

C.L.C. MELO[1,2], R.A. SANTOS[3], M. BASSOI[4], A.C. ARAÚJO[1], J. LAILSON-BRITO[1], P.R. DORNELES[1,5] AND A.F. AZEVEDO[1]

[1]Laboratório de Mamíferos Aquáticos e Bioindicadores 'Prof[a]. Izabel Gurgel' (MAQUA), Faculdade Oceanografia, Universidade do Estado do Rio de Janeiro (UERJ), Rua São Francisco Xavier, 524/4002E, Maracanã, 20550013, Rio de Janeiro, RJ, Brazil, [2]Programa de Pós-Graduação em Oceanografia, Universidade do Estado do Rio de Janeiro (UERJ), Brazil, [3]Centro de Pesquisa e Gestão de Recursos Pesqueiros do Litoral Sudeste e Sul, Instituto Chico Mendes de Conservação da Biodiversidade (CEPSUL/ICMBio), Brazil, [4]Census of Antarctic Marine Life (CAML), Departamento de Zoologia, Universidade Federal do Rio de Janeiro (UFRJ), Avenida Pau Brasil, 211, Cidade Universitária, 21941-590, Rio de Janeiro, RJ, Brazil, [5]Instituto de Biofísica Carlos Chagas Filho, Universidade Federal do Rio de Janeiro (UFRJ), Brazil

Stomach content analyses were performed in 28 dolphins stranded between 1994 and 2007 on the beaches of Rio de Janeiro State (23°06′S 44°18′W/22°14′S 41°54′W), Brazil, comprising six delphinid species: Stenella frontalis *(N = 10),* Steno bredanensis *(N = 7),* Tursiops truncatus *(N = 4),* Delphinus delphis *(N = 5),* Lagenodelphis hosei *(N = 1) and* Stenella coeruleoalba *(N = 1). Fish otoliths and cephalopod beaks were used to identify the prey species and to estimate the original length and weight. Seven different cephalopod species from six families and 15 fish species belonging to 10 families were identified. Although the fish contribution could be underestimated, cephalopods constituted the group of higher importance, revealing that these invertebrates may represent an important source of energy for delphinids in the region. In this context, the squid* Loligo plei *should be highlighted due to its important contribution. Most preys were coastal and demersal, and such consumption could indicate coastal foraging habits of the quoted dolphin species. Although dolphins consumed many species of prey in common, they fed on different size-classes of prey. The foraging area of the dolphins could be the same region used by fishing operations, which would represent a risk for incidental capture.*

Keywords: diet, south-west Atlantic Ocean, Brazil, cephalopod, teleost fish, Cetacea

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INTRODUCTION

Studies of marine mammal diet are useful to understand the food web interactions. They can provide some insight on cetacean feeding behaviour and trophic relationships (Clarke, 1986a). The diet of some delphinids seems to change according to areas (Silva, 1999), sometimes reflecting the prey abundance and distribution.

Delphinids occur in oceanic and coastal waters, and they are very common in the South Atlantic Ocean (Jefferson *et al.*, 2008). Sixteen out of the 19 delphinid species reported for Brazil occur in Rio de Janeiro State, including the species presented in this study: Atlantic spotted dolphin (*Stenella frontalis* Cuvier, 1829), rough-toothed dolphin (*Steno bredanensis* Lesson, 1828), bottlenose dolphin (*Tursiops truncatus* Montagu, 1821), short-beaked common dolphin (*Delphinus delphis* Linnaeus, 1758), Fraser's dolphin (*Lagenodelphis hosei* Fraser, 1956) and striped dolphin (*Stenella coeruleoalba* Meyen, 1833).

In southern Brazil, most sightings of *S. coeruleoalba* were recorded in shallow (30–100 m) waters (Moreno *et al.*, 2005). However, among the species of the genus *Stenella*, *S. frontalis* is reported as the most coastal species, inhabiting nearshore shallow waters, although this dolphin can also be seen in deeper waters. Records of the latter species indicate a discontinuous distribution along the Brazilian coast, with a gap from 6°S until 21°S (Moreno *et al.*, 2005). The presence of *T. truncatus* in shallow waters and bays is common on the central and south coast of Brazil (Barreto, 2000), and *D. delphis* also seems to present oceanic and coastal habits with depths ranging from 18–70 m (Tavares, 2006). *Steno bredanensis* and *L. hosei* present oceanic habits predominantly (Jefferson *et al.*, 2008), even though, in Brazil, *S. bredanensis* has been seen in shallow waters as well, from 2 to 43 m of depth (Bastida *et al.*, 2007).

Despite the records of those delphinids on the south-eastern Brazilian coast, their biology is poorly known, as well as their feeding habits. Santos *et al.* (2002) reported the prey largehead hairtail (*Trichiurus lepturus*) and the squid (*Loligo plei*) for *T. truncatus* and *D. capensis*, and also the cephalopod *Octopus vulgaris* for *T. truncatus* collected in southern waters (25°S). Santos & Haimovici (2001) studied the consumption of cephalopods by some delphinid species in the southern area of Rio de Janeiro, including *T. truncatus, D. delphis, S. frontalis* and *S. bredanensis*. In the latter study, consumption of the squid *Loligo plei* was reported for all the investigated species, as well as the predation on *O. vulgaris* by *T. truncatus*. Di Beneditto *et al.* (2001) analysed the feeding habits of six delphinid species stranded on the Rio

Corresponding author:
C.L.C. Melo
Email: claudialucasmelo@gmail.com

de Janeiro coast. The stomach contents of *S. frontalis* indicated a teuthophagous diet, while for *T. truncatus* an ichthyophagous diet was observed. Only largehead hairtails were found in the stomachs of *S. bredanensis* and only loliginid squids were found in the stomach of *L. hosei*.

This study provides new data on the feeding habits of six delphinid species collected along Rio de Janeiro State coast, using stomach contents retrieved from animals found stranded between 1994 and 2007.

MATERIALS AND METHODS

Stomach contents of 28 delphinids were analysed, including *Stenella frontalis* (N = 10), *Steno bredanensis* (N = 7), *Tursiops truncatus* (N = 4), *Delphinus delphis* (N = 5), *Lagenodelphis hosei* (N = 1) and *Stenella coeruleoalba* (N = 1) (Table 1). The animals were found stranded on the beaches of Rio de Janeiro State (Figure 1), between 23°06′S 44°18′W and 22°14′S 41°54′W, from 1994 to 2007. Dolphins were necropsied and classified in stages 2 and 3 according to Geraci & Lounsbury (1993). The stomachs were collected and kept frozen until analyses.

All stomach compartments were examined and the contents were washed through 1 mm mesh sieves. The items found in the stomach contents were stored in 70% glycerin for cephalopod beaks, and fish otoliths and bones were stored dry.

Fish otoliths and cephalopods beaks were identified to the lowest possible taxonomic level, using a local reference collection and published studies (Bastos, 1990; Corrêa & Vianna, 1992/1993; Lêmos *et al.*, 1995; Santos, 1999; Di Beneditto, 2000). The minimum number of fish species in each stomach was estimated as the highest number of either right or left otoliths, added to the half of the otoliths when side could not be determined. Similarly, the maximum number of upper or lower beaks was used to estimate the minimum number of cephalopods ingested.

Fish and cephalopods had their total length (cm) and mantle length (mm), respectively, and total weight (g) estimated based on the major axis length (mm) of fish otoliths and rostral or hood length (mm) of cephalopods beaks, calculated using regression curves found in the literature (Clarke, 1986b; Bastos, 1990; Santos, 1999; Di Beneditto, 2000; Bassoi, 2005). To avoid errors associated with the erosion by gastric acids, only undamaged otoliths and beaks were measured.

The relative importance of prey taxa in the diet was estimated for each delphinid species using: (1) frequency of occurrence (%FO), expressed as the percentage of stomachs in which the prey occurred; (2) percentage number of a prey (%N), in relation to the total number of prey consumed; (3) percentage weight of a prey (%W), in relation to the total weight ingested; and (4) index of relative importance (IRI), meaning (%N + %W) × %FO (Pinkas & Iverson, 1971).

The Shapiro–Wilk *W* test was used in order to test data normality. Differences between the size and weight of preys consumed by each dolphin species were compared using the Kruskal–Wallis test ($P < 0.05$) and *a posteriori* comparison of medians.

Table 1. Data on delphinids found stranded on the beaches of Rio de Janeiro State (N = 28). Total length (TL), stranding date and location, sex and number of items (N) found in each stomach. (M) Male; (F) Female.

Dolphin species	ID number	TL (cm)	Date (D/M/Y)	Sex	Stranding location	Otoliths (N)	Beacks (N)	*Trichiurus lepturus* bones
Delphinus delphis	Dd #01	190	01/06/94	M	Região dos Lagos	290	11	
	Dd #02	216	10/11/03	M	Rio de Janeiro	1	61	
	Dd #03	228	11/11/03	M	Rio de Janeiro	3	50	
	Dd #04	186	03/01/04	F	Rio de Janeiro		56	
	Dd #05	210	03/06/05	F	Baía de Guanabara		1348	
Stenella frontalis	Sf #01	214	07/08/94	F	Ilha Grande	2	7	1
	Sf #02	151	09/11/95	M	Ilha Grande	1	1	
	Sf #03	197	15/07/96	–	Ilha Grande		3	1
	Sf #04	188	01/08/96	F	Região dos Lagos	7		
	Sf #05	197	02/08/98	M	Região dos Lagos	6		
	Sf #06	216	02/10/98	M	Região dos Lagos		1	
	Sf #07	175	13/03/99	M	Rio de Janeiro	3	66	
	Sf #08	178	17/03/99	F	Região dos Lagos	10	41	
	Sf #09	196	20/02/01	M	Região dos Lagos	315	33	
	Sf #10	181	06/08/07	M	Rio de Janeiro	12	1	
Steno bredanensis	Sb #01	283	11/02/95	M	Região dos Lagos		9	1
	Sb #02	195	02/04/00	F	Região dos Lagos		2	
	Sb #03	256	03/08/00	F	Baía de Guanabara			1
	Sb #04	194	11/01/03	F	Rio de Janeiro		3	
	Sb #05	245	06/04/05	M	Rio de Janeiro		7	1
	Sb #06	226	30/03/06	M	Rio de Janeiro		8	
	Sb #07	204	15/06/07	F	Região dos Lagos		9	1
Tursiops truncatus	Tt #01	287	24/05/95	M	Região dos Lagos			1
	Tt #02	266,5	26/12/95	–	Ilha Grande	108		
	Tt #03	240,5	15/02/00	M	Região dos Lagos			1
	Tt #04	198	06/02/07	F	Rio de Janeiro	3	4	
Lagenodelphis hosei	Lh #01	245	14/11/97	F	Região dos Lagos		20	
Stenella coeruleoalba	Sc #01		20/05/99	M	Região dos Lagos		2	

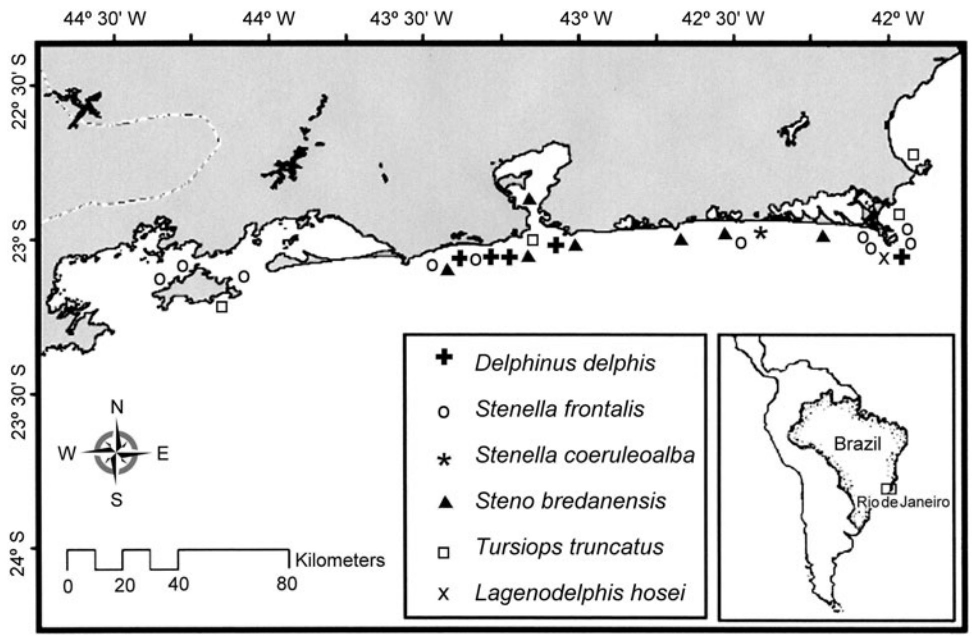

Fig. 1. Map indicating the locations of the small cetacean strandings in Rio de Janeiro State.

RESULTS AND DISCUSSION

Remains of at least 1337 preys were retrieved from the 28 stomachs. Seven different cephalopod species from six families and fifteen fish species belonging to ten families were identified (Table 2). When the contribution of cephalopods and fish was compared, the former group was shown to be of greater importance than the latter. The cephalopod group occurred in 78.6% of the stomachs with food remains and comprised 954 individuals (71.4%), while the teleost group occurred in 64.3% of the stomachs, comprising 383 specimens (28.6%). However, such comparisons should be

Table 2. Overall importance of prey species identified from stomach contents of dolphins stranded on the beaches of Rio de Janeiro State (N = 28). The importance is expressed as percentage weight (%W), frequency of occurrence (%FO), percentage number (%N) and the index of relative importance (IRI) for all stomachs combined.

Family	Species	%W	%FO	%N	IRI
Teleosts					
Batrachoididae	*Porichthys porosissimus*	68.11	14.29	49.09	1674.28
Paralichthyidae	*Syacium* sp.	8.46	10.71	3.13	124.23
Sparidae	*Pagrus pagrus*	12.91	3.57	18.28	111.38
Carangidae	*Trachurus lathami*	3.30	7.14	4.44	55.29
Sciaenidae	*Cynoscion guatupuca*	1.33	7.14	1.04	16.94
Sciaenidae	*Cynoscion jamaicensis*	2.87	3.57	0.78	13.03
Serranidae	*Dules auriga*	0.55	7.14	0.78	9.52
Ophidiidae	*Raneya fluminensis*	0.76	3.57	1.04	6.43
Carangidae	*Chloroscombrus chrysurus*	1.28	3.57	0.26	5.51
Sciaenidae	*Micropogonias furnieri*	0.36	3.57	0.52	3.17
Sciaenidae	*Stellifer* sp.	0.07	3.57	0.26	1.18
Engraulidae	*Engraulis anchoita*	–	3.57	0.52	–
Mugilidae	*Mugil* sp.	–	3.57	0.26	–
Sciaenidae	*Pogonias cromis*	–	3.57	0.52	–
Trichuridae	*Trichiurus lepturus*	–	28.57	2.09	–
Unidentified		–	17.86	16.97	–
Total		100.00	71.43	100.00	–
Cephalopods					
Loliginidae	*Loligo plei*	95.22	60.71	88.78	11171.83
Loliginidae	*Loligo sanpaulensis*	1.92	42.86	7.55	405.89
Argonautidae	*Argonauta nodosa*	0.70	7.14	2.62	23.74
Thysanoteuthidae	*Thysanoteuthis rhombus*	0.58	10.71	0.52	11.78
Octopodidae	*Octopus vulgaris*	1.31	7.14	0.21	10.84
Ommastrephidae	*Ornithoteuthis antillarum*	0.26	3.57	0.10	1.30
Sepiolidae	*Semirossia tenera*	0.01	3.57	0.21	0.78
Total		100.00	78.57	100.00	–

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seen with caution because cephalopod beaks probably remain undigested for a longer time than fish bones and otoliths (Clarke, 1996).

Four fish species did not have their weights estimated. That was the case for the Argentine anchoita (*Engraulis anchoita*) and mullets (*Mugil* sp.), since the otoliths were found to be excessively damaged. The black drum (*Pogonias cromis*) did not have its regression curve found in the literature for this region, and the largehead hairtail (*Trichiurus lepturus*) had its presence verified by remaining bones rather than otoliths.

Among cephalopods, the squid *Loligo plei* was the most important prey species (N = 847). It constituted 95.2% of the cephalopod weight ingested. The second most important cephalopod species was the squid *Loligo sanpaulensis*. Concerning fish, three taxa were the most important: the Atlantic midshipman (*Porichthys porosissimus)*, the flounder (*Syacium* sp.) and the common seabream (*Pagrus pagrus*).

Fish seem to constitute an important prey group for some delphinids, as has been largely seen for *Sotalia guianensis* (Santos *et al.*, 2002; Di Beneditto & Ramos, 2004; Di Beneditto & Siciliano, 2007). In this study, bottlenose dolphins seem to be preferentially ichthyophagous, preying upon demersal fish (Table 3). Regarding occurrence in *T. truncatus* stomachs, fish presented a higher contribution than cephalopods (80%). Two fish species constituted 99.6% of the fish weight ingested, the Atlantic midshipman and the flounder. This is the first record of *Syacium* sp. and *Dules auriga* in *T. truncatus* stomachs in Brazil. Studies in other countries also found that the diet of *T. truncatus* was characterized by demersal fish as the most important preys, followed by cephalopods (Gannon & Waples, 2004; Santos *et al.*, 2007).

Concerning *S. frontalis*, the consumption of cephalopods and fish were almost equivalent, representing 51.8% and 48.3% of the ingested biomass, respectively. When the weight consumed by this predator is taken into account, the fish Atlantic midshipman and the squid *L. plei* were the most important preys. Among the 18 species consumed by this delphinid, only four had already been reported as its preys in Brazil, including *L. plei* as the most important prey for *S. frontalis* (Di Beneditto *et al.*, 2001).

The squid *L. plei* occurred in all *D. delphis* stomachs, representing the major cephalopod species ingested according to its weight (W = 99.2%), followed by the squid *L. sanpaulensis*. Among fish, the common sea bream was the most important prey (W = 76.2%). The five fish species found in *D. delphis* stomachs and the squid *Thysanoteuthis rhombus* increase the range of species consumed by this dolphin in Brazil. The cephalopods *L. plei, L. sanpaulensis* and *Semirossia tenera* had already been reported as *D. delphis* preys on the Brazilian coast, as well as five others species of cephalopods and one of fish (*T. lepturus*) that were not found in this study, thus characterizing a teuthophagous diet (Santos & Haimovici, 2001; Santos *et al.*, 2002; Santos & Haimovici, 2002). In other areas of the world, *D. delphis* has shown a preference for small schooling fish, with pelagic habits rather than demersal (Silva, 1999; Pusineri *et al.*, 2007).

When the IRI is taken into account, *Steno bredanensis* also had the squid *L. plei* as the major prey, followed by *L. sanpaulensis*. Although it has not been possible to obtain an IRI ranking number for the fish largehead hairtail due to the lack of length and weight estimations, this fish also constituted an important prey species for *S. bredanensis*, considering its large occurrence in stomachs (57.1%). This fish is a common species on the Brazilian coast (Figueiredo & Menezes, 2000) and other authors had already reported this species as an important prey for dephinids (e.g. *T. truncatus* and *S. guianensis*; Di Beneditto *et al.*, 2001; Di Beneditto & Ramos, 2004), especially for *S. bredanensis* (Di Beneditto *et al.*, 2001).

The stomach content analyses of *Lagenodelphis hosei* and *Stenella coeruleoalba* were restricted to one stomach for each species. The former had consumed 14 individuals of *L. sanpaulensis* and the latter had preyed upon only two squids of the species *L. plei*. It is important to remark the presence of coastal preys in the stomach of dolphins with oceanic habit. However, a greater number of sampled specimens would be necessary for the achievement of strong conclusions related to this finding.

Regarding the average weight and length estimated for cephalopods, significant differences were verified between *D. delphis* and the other two predators: *S. frontalis* and *S. bredanensis*, since *D. delphis* preyed on larger cephalopods than the other delphinid species (Kruskal–Wallis test, $P < 0.05$; *a posteriori* comparison of medians, $P < 0.001$). Additionally, with reference to the weight and length of the fish consumed, significant differences were observed for all predators ($P < 0.001$), since *T. truncatus* preyed on the largest fish, followed by *S. frontalis* and *D. delphis* (Kruskal–Wallis test, $P < 0.05$; *a posteriori* comparison of medians, $P < 0.001$) (Figure 2).

The investigated dolphin species showed a large overlap of preys; however, they seemed to feed on different size-classes. Most fish and cephalopod preys were smaller than the size normally caught by fisheries. Nevertheless, it is important to consider that the foraging area of these dolphins could be the same area used by fishing operations. This would represent a risk for incidental catches, since the captures have been a threat for coastal dolphin populations in Brazilian waters (Reeves *et al.*, 2003).

Although the dolphins preyed upon several species, a dominance of few preys could be observed, since one or two comprised the major biomass ingested (weight percentage). This dominance can be the result of either a preference for a few prey species or just the consumption of the most available prey, or even a result of both aspects. Because dolphins stranded in different locations and seasons, as well as due to the small sample size, it was not possible to achieve further conclusions.

The family Loliginidae, specially the squids *Loligo plei* and *L. sanpaulensis* are the most abundant cephalopods on neritic areas along the south-eastern Brazilian coast (Haimovici & Perez, 1991). Some studies have shown that these two squids seem to form reproductive aggregations in shallow waters during the spring and summer, for spawning (Costa & Fernandes, 1993; Perez *et al.*, 2002; Rodrigues & Gasalla, 2008). These aggregations occur under the influence of the South Atlantic Central Water (SACW), which brings nutrient-rich waters onto the shelf. For *L. plei*, the larger-sized and matured individuals concentrate closer to the coast, taking advantage of the high temperature and high food availability to spawn associated with SACW intrusion. The opposite occurs with *L. sanpaulensis*, since the size of the individuals and the predominance of mature specimens increase with depth, and decrease again after 100 m of depth (Rodrigues & Gasalla, 2008).

Most of the preys were coastal and demersal, indicating coastal habits of the predators. Three cephalopods species

Table 3. Ranking of prey species for each predator, according to the index of relative importance (IRI) values. The preys were identified from stomach contents of dolphins stranded on the beaches of Rio de Janeiro State (N = 28). The importance is expressed using the percentage weight (%W), the frequency of occurrence (%FO), the percentage of the number of specimens found (%N) and the IRI.

	Prey species	%W	%FO	%N	IRI
Stenella frontalis (N = 10)	Teleosts				
	Porichthys porosissimus	86.79	30.00	85.12	5157.38
	Cynoscion jamaicensis	5.53	10.00	1.79	73.13
	Syacium sp.	0.94	20.00	1.19	42.53
	Chloroscombrus chrysurus	2.47	10.00	0.60	30.67
	Cynoscion guatupuca	2.31	10.00	0.60	29.04
	Dules auriga	0.83	10.00	1.19	20.24
	Micropogonias furnieri	0.70	10.00	1.19	18.93
	Trachurus lathami	0.43	10.00	0.60	10.21
	Trichiurus lepturus	–	20.00	1.19	–
	Engraulis anchoita	–	10.00	3.57	–
	Mugil sp.	–	10.00	1.19	–
	Pogonias cromis	–	10.00	0.60	–
	Unidentified	–	20.00	1.19	–
	Cephalopods				
	Loligo plei	44.97	60.00	53.85	5928.80
	Argonauta nodosa	11.68	20.00	27.47	783.15
	Loligo sanpaulensis	8.50	20.00	12.09	411.81
	Thysanoteuthis rhombus	8.81	20.00	4.40	264.12
	Octopus vulgaris	21.74	10.00	1.10	228.40
	Ornithoteuthis antillarum	4.29	10.00	1.10	53.93
Steno bredanensis (N = 7)	Teleosts				
	Trichiurus lepturus	–	57.14	100.00	–
	Cephalopods				
	Loligo plei	69.75	71.43	64.00	9553.46
	Loligo sanpaulensis	30.25	42.86	32.00	2667.92
	Octopus vulgaris	–	14.29	4.00	57.14
Delphinus delphis (N = 5)	Teleosts				
	Pagrus pagrus	76.17	20.00	46.05	2444.52
	Trachurus lathami	18.19	20.00	10.53	574.24
	Raneya fluminensis	4.46	20.00	2.63	141.91
	Cynoscion guatupuca	0.76	20.00	1.97	54.77
	Stellifer sp.	0.41	20.00	0.66	21.39
	Unidentified	–	40.00	38.16	–
	Cephalopods				
	Loligo plei	99.17	100.00	95.24	19440.99
	Loligo sanpaulensis	0.77	100.00	4.40	516.37
	Semirossia tenera	0.01	20.00	0.24	5.10
	Thysanoteuthis rhombus	0.05	20.00	0.12	3.43
Tursiops truncatus (N = 4)	Teleosts				
	Porichthys porosissimus	74.06	25.00	76.27	3758.37
	Syacium sp.	25.56	25.00	16.95	1062.76
	Dules auriga	0.38	25.00	1.69	51.75
	Trichiurus lepturus	0.00	50.00	3.39	–
	Unidentified	–	25.00	1.69	–
	Cephalopods				
	Loligo sanpaulensis	100.00	25.00	100.00	5000.00
Lagenodelphis hosei (N = 1)	Cephalopods				
	Loligo sanpaulensis	100.00	100.00	100.00	–
Stenella coeruleoalba (N = 1)	Cephalopods				
	Loligo plei	100.00	100.00	100.00	–

consumed by *S. frontalis* constituted exceptions (*Argonauta nodosa, Thysanoteuthis rhombus* and *Ornithoteuthis antillarum)*, since they occur farther than the 200 m isobath and are typically epipelagic (Haimovici & Perez, 1991). The short-beaked common dolphin, *D. delphis*, also ingested *Thysanoteuthis rhombus*. The presence of cephalopods that occur farther than the 200 m isobath in stomach contents of *S. frontalis* strengthened a previously raised hypothesis that

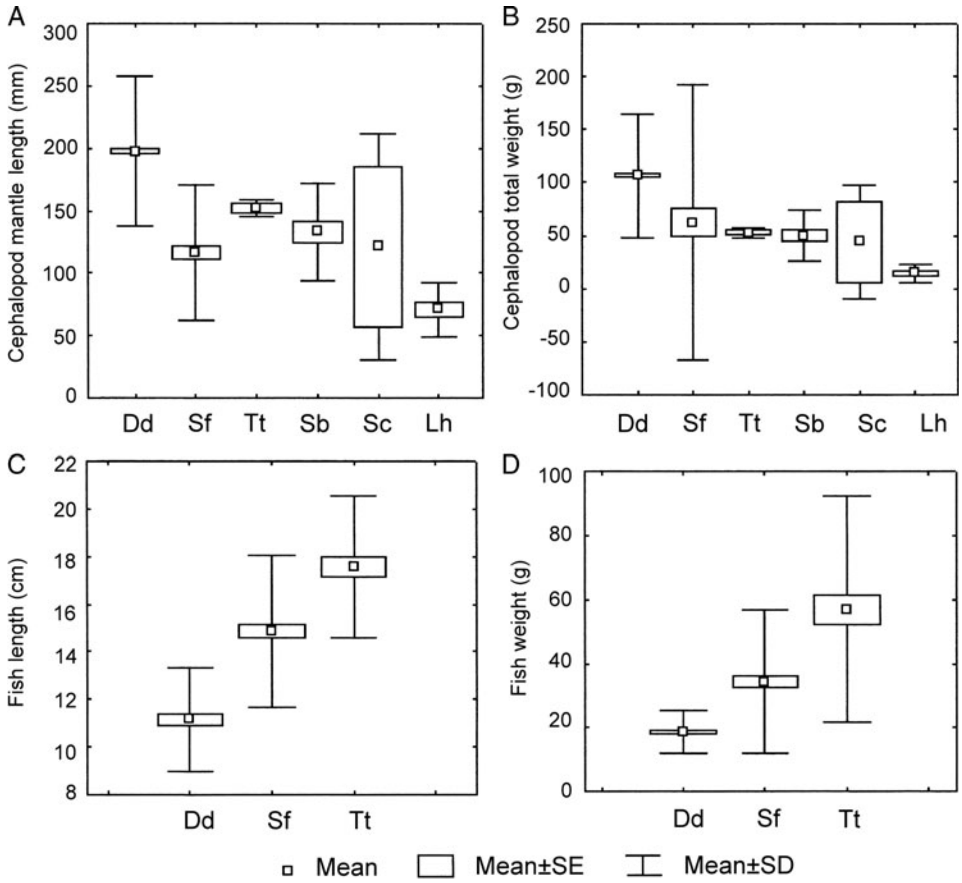

Fig. 2. Estimation of length and weight of the fish and cephalopods consumed by delphinids stranded in Rio de Janeiro State (attention to different scales). (A) Cephalopod mantle length (mm); (B) cephalopod total weight (g); (C) fish length (cm); (D) fish weight (g); (Dd) *Delphinus delphis* (N = 5); (Sf) *Stenella frontalis* (N = 10); (Tt) *Tursiops truncatus* (N = 4); (Sb) *Steno bredanensis* (N = 7); (Sc) *Stenella coeruleoalba* (N = 1); (Lh) *Lagenodelphis hosei* (N = 1).

the species also preys on oceanic species. Cadmium concentrations of *S. frontalis* suggested that the species may have access to oceanic preys in Brazilian waters (Dorneles *et al.*, 2007a). In fact, these findings corroborate the information obtained through sightings in Brazilian oceanic waters, since *S. frontalis* were also observed in deep water regions (Moreno *et al.*, 2005). Some investigations have demonstrated the possibility of using cadmium as an auxiliary tool for understanding feeding ecology of marine mammals (e.g. Bustamante *et al.*, 2004; Lahaye *et al.*, 2005). The information with regard to cadmium concentrations of squid-eating odontocetes from Brazilian waters indicates the occurrence of lower concentrations in coastal species, which are well known to prey on loliginids, than in oceanic cetaceans that feed on cephalopods that belong to other taxonomic families (Dorneles *et al.*, 2007a,b). Therefore, our results corroborate these studies on cadmium concentrations, since cadmium levels found in *T. truncatus* and *S. bredanensis* were lower than those verified in oceanic dolphins, such as those belonging to the genus *Stenella* (Dorneles, 2007a).

Since it was not possible to estimate length and weight of some preys, and consequently the IRI could not be calculated, the importance of fish in the diet could be underestimated. Moreover, cephalopod beaks tend to remain for longer periods of time in cetacean stomachs (Clarke, 1996). Nevertheless, it can be concluded that these invertebrates represent an essential source of energy for these dolphin species.

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Correspondence should be addressed to:
C.L.C. Melo
Laboratório de Mamíferos Aquaticos e Bioindicadores (MAQUA)
Rua São Francisco Xavier, 524/4002E, Maracanã, 20550-013
Universidade do Estado do Rio de Janeiro (UERJ)
Brazil
email: claudialucasmelo@gmail.com

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