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Feeding habits of Guiana dolphins, *Sotalia guianensis*, from south-eastern Brazil: new items and a knowledge review

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This study presents new information on feeding habits of Guiana dolphins, Sotalia guianensis*, in south-eastern Brazil, together with new regression equations to evaluate the weight and length of fish from otoliths, showing an overview on the knowledge about this species' diet in this area. Eighteen stomach contents had been analysed and compared to 180 samples collected in another eight feeding studies. The analysed specimens were either incidentally caught in gillnets used in coastal waters by the fleet based in the Cananéia main harbour (25°00′S 47°55′W), south of São Paulo State, or found dead in inner waters of the Cananéia estuary between 2003 and 2009. Based on the index of relative importance analysis, the most important fish species were the banded croaker,* Paralonchurus brasiliensis. Doryteuthis plei *was the most representative cephalopod species.* Stellifer rastrifer *was the most important fish species observed in dolphins in inner estuarine waters and* P. brasiliensis *in recovered dolphins from coastal waters.* Loliguncula brevis *is the only cephalopod species reported from dolphins found in inner estuarine waters up to date.* Doryteuthis plei *was the most important cephalopod species observed in coastal dolphins. When considering other feeding studies, the most representative fish family in the diet of* S. guianensis *was Sciaenidae, which is mainly represented by demersal fishes. The main preys of* S. guianensis *are abundant in the studied areas, which may indicate an opportunistic feeding habit. The majority of them are not the most important target species by the commercial fishery in south-eastern Brazil.*

Keywords: *Sotalia guianensis*, feeding habits, Guiana dolphin, Cetacea, Brazil

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INTRODUCTION

Assessing the feeding habits of marine mammals is important to define their ecological role, and determine their position within food webs (Pauly *et al.*, 1998). There are various methods of studying feeding habits in marine mammals (see Barros & Clarke, 2009). The analysis of food remains present in scats, dead animal stomach contents, and in live animal vomits, represents traditional methods which have still been widely used (Barros & Clarke, 2009). Several other methods have been used, for example stable isotopes (e.g. Newsome *et al.*, 2010), 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). Identifying and measuring items in vomits, scats and stomach contents have several disadvantages. Cephalopod beaks and fish otoliths remain in the gastrointestinal tracts of marine mammals during different periods of time, therefore the food remains found in one stomach cannot be considered from the same meal. There is also the possibility of contamination with the prey stomach contents. Besides that, prey lacking hard parts may be under-represented (Fitch & Brownell, 1968; Clarke, 1986). Even considering these disadvantages, the analysis of food remains provides more information at a considerably lower cost than other methods, and could not be replaced effectively by any other method until now (Barros & Clarke, 2009). The structures used in prey identification are more resistant to digestion and usually present variation in shape and size among species. Considering stomach content analysis, the most commonly used structures are fish otoliths and cephalopod beaks. Otoliths and beaks enable investigators to estimate the size and weight of the consumed prey (see Clarke, 1962, 1986; Fitch & Brownell, 1968; Jobling & Breiby, 1986). Through

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the size and weight of the prey it is possible either to investigate characteristics on the spatial distribution of predators, providing possibilities to monitor alterations in the predator feeding habits, or to investigate the dynamics between prey and predator.

In the western South Atlantic, the knowledge about small cetacean feeding habits comes mainly from studies based on the stomach content analysis. The Guiana dolphin, *Sotalia guianensis* (Van Benéden, 1864), has been the focus of several studies since the 1960s (e.g. Carvalho, 1963; Borobia & Barros, 1989; Schmiegelow, 1990; Barros & Teixeira, 1994). In the past ten years, a considerable amount of studies had contributed to the knowledge about the diet of this species, mostly in south-eastern Brazil (e.g. Zanelatto, 2001; Santos *et al.*, 2002; Gurjão *et al.*, 2003; Oliveira, 2003; Di Beneditto & Ramos, 2004; Cremer, 2007; Daura-Jorge, 2007; Di Beneditto & Siciliano, 2007; Rosas *et al.*, 2010). A total of eight investigations had carefully evaluated 180 stomachs collected in south-eastern Brazil from 1963 to 2005. Information on *S. guianensis* feeding habits is spatially scattered and should be joined together to better understand its role in trophic interactions. The Brazilian south-eastern coast is inserted in the range of *S. guianensis* along the coasts of South and Central America (Flores & Da Silva, 2009). This species is categorized as 'data deficient' by the *IUCN Red List of Endangered Species* (IUCN, 2010). Throughout its range, human impacts, such as incidental captures in fishing operations, boat traffic, noise pollution, and habitat degradation, have been threatening several populations (see Siciliano, 1994; Santos & Rosso, 2007; Azevedo *et al.*, 2008; Nery *et al.*, 2008). It is deemed important to evaluate the main prey items of the quoted populations, as well as to compare such items that are economically important along its distribution.

Based on the described scenario, the present study aims to evaluate the stomach contents of 18 individuals collected on the Brazilian south-eastern coast from 2003 to 2009, and to present a comparative review on the knowledge about *S. guianensis* feeding habits in this area.

MATERIALS AND METHODS

Field work and study area

Cananéia (25°00′S and 47°55′W) is located on the southern coast of São Paulo State, Brazil (Figure 1). The Cananéia gillnet fleet had been monitored to evaluate cetacean incidental captures from 2004 to 2007. Boat operations had been surveyed by the crew captain, who had been engaged to fill charts on the following data: GPS position where nets were set, net dimensions, water depth, soaking time, list of captured fish species and number of cetacean incidental capture events. When the cetacean incidental capture had been detected, the individual(s) was/were identified following a log-book and, when possible, was/were brought to land to the research team for natural history studies. Part of the analysed stomachs (N = 10) was recovered from coastal waters by the fishing fleet. Other samples (N = 8) were recovered from dead stranded or floating dolphins, both found in inner waters of the Cananéia estuary. All samples had been recovered from 2003 to 2009 (see Table 1).

Laboratory analyses

Stomach contents 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 dried stored, cephalopod beaks in 1:1 solution of glycerin and 70% alcohol, and the fragments and whole

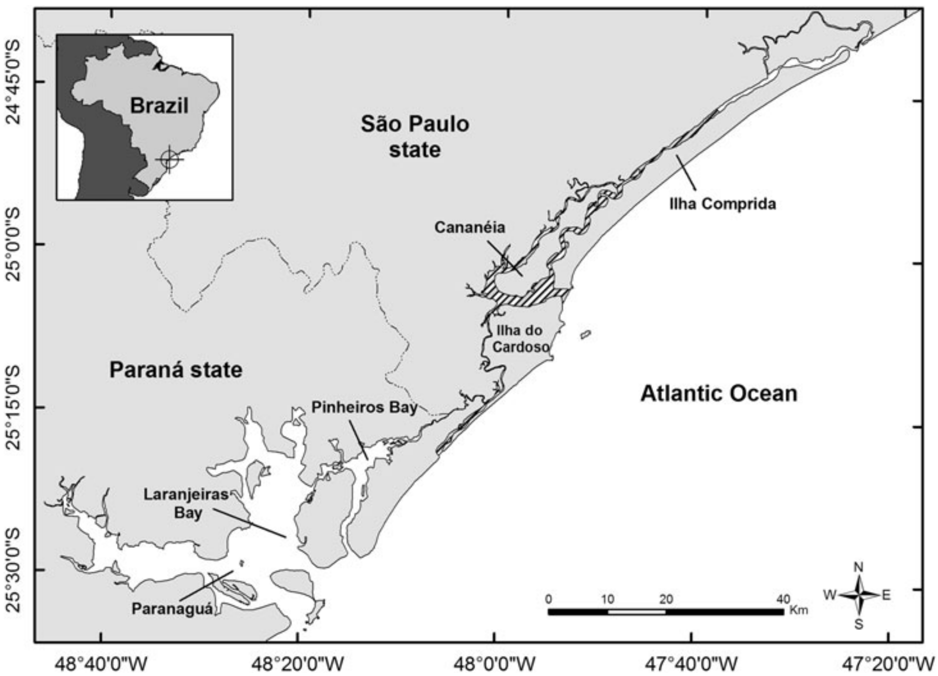

Fig. 1. Sites where Guiana dolphins analysed in the present study were obtained. The individuals considered to be found in inner estuarine waters were the ones obtained in the striped area around Cananéia Island. The individuals considered to be found in coastal waters were the ones incidentally captured in fisheries on the southern coast of São Paulo and northern coast of Paraná.

Table 1. List of Guiana dolphins, *Sotalia guianensis*, collected from 2003 to 2009. The field number of each specimen, date and source of event (S, stranding; B, by-catch; F, found floating in the estuary), water depth (m) of incidental capture, sex and total length (cm) of each are presented.

Number	Date	Event	Water depth (m)	Sex	Total length (cm)
PA-153	19-Oct-03	S		M	189
PA-154	13-May-04	S		M	183
PA-169	04-Aug-05	S		F	101.5
PA-178	08-Aug-05	B	13	F	175
PA-185	17-Sep-05	S		M	124
PA-186	21-Sep-05	B	26	M	150
PA-184	08-Oct-05	B		M	124
PA-187	16-Sep-05	B	18	M	159
PA-192	31-Oct-05	S		M	150
PA-193	Nov/Dec-05	B		F	191
PA-217	18-May-06	B	18	M	145.5
PA-216	03-Jun-06	B	13	M	163
PA-235	01-Nov-06	S		M	172
PA-236	19-Dec-06	B	20	F	146
PA-263	31-Mar-07	B	15	M	146
PA-260	08-Apr-07	B	20	M	148
PA-283	21-Aug-09	B*		M	136.5
PA-284	16-Oct-09	F		M	132

*, bottom longline in inner waters of the Cananéia estuary; M, male; F, female.

preys were kept in 70% alcohol, after 24 hours in a solution of 10% formalin.

The otoliths were used to identify consumed teleost fishes. Prey identification was made through several catalogues (e.g. Bastos, 1990; Abilhôa & Corrêa, 1992–1993; Corrêa & Vianna, 1992–1993; Lêmos *et al.*, 1992–1993, 1995a, b). Measurements were taken using a stereomicroscope with metric precision of 0.1 mm. The total length of each otolith was the greatest longitudinal distance toward the groove. The otolith which was used either for identification or for the measurements was the sagitta, also used to estimate the number of fishes consumed by each species. In the genus *Stellifer*, lapillus otoliths were also found in stomach contents, though these otoliths were neither used to identify species nor to estimate the total number of preys in order to avoid overestimating fishes belonging to this genus. The number of consumed fishes was estimated through the highest number between 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 Brasileiro do Meio Ambiente e dos Recursos Renováveis (CEPSUL/ICMBIO)'. The measurements of lower rostral length (LRL) and upper rostral length (URL) were taken using a stereomicroscope with ocular micrometer and precision of 0.1 mm to estimate the mantle length (ML, in mm) and weight (WT, in g) of squids. When beaks were found, those with highest number (upper or lower) were used to estimate the number of consumed cephalopods and their respective length and weight. Crustaceans were identified by using the identification key of Costa *et al.* (2003).

Regression equations

Based on the identified food items found in the present study, samples of fishes with different sizes were obtained in the local market. Fishes were measured, weighted and had their otoliths extracted. Only one otolith sagitta of each individual (right or left) was measured. Standard length (SL) is the distance from the anterior tip to the insertion of caudal fin. The SL was used due to the fact that the majority of species had their caudal fin damaged during the capture, making the total length measurement impossible. When a fish species was not available in adequate numbers, equations gathered in other areas were used (see Bassoi, 2005; Conceição *et al.*, 2005; Bittar, 2007). In the case of cephalopods, equations were compiled from Santos (1999) and CEPSUL/ICMBIO.

Prey importance

Index of relative importance (IRI) was calculated based on the following formula:

$$IRI = (N + W) \times F,$$

where N is the numerical percentage, W is the estimated weight percentage and F is the frequency of occurrence percentage. The numerical, estimated weight and frequency of occurrence percentages and the IRI were analysed separately for fish and cephalopods, since cephalopod beaks remain in cetacean stomachs for a longer period of time than otoliths (Clarke, 1986).

Review on the knowledge about *S. guianensis* diet in south-eastern Brazil

Using the 18 samples of this study and nine from a previous one (Santos *et al.*, 2002), a comparison of food items surveyed from dead dolphins recovered in 'inner estuarine' ($N = 12$) and 'coastal' waters ($N = 15$) was conducted using the IRI. The sites considered as 'inner estuarine' and 'coastal' are presented in Figure 1. In order to compare the differences between the lengths of fishes and cephalopods found as prey of *S. guianensis* from both sites, the Mann–Whitney *U*-test was used. Cephalopods and fishes were analysed separately since they represent preys with different characteristics.

Published studies, theses and dissertations about Guiana dolphin feeding habits in south-eastern Brazilian were revised. Abstracts presented in conferences were not considered. The main food items were evaluated to investigate potential habitat preferences of Guiana dolphin. Also, a comparison between main preys of *S. guianensis* and species known to be the most commercially valuable was conducted. Only studies that showed IRI or F and N were considered.

RESULTS

From the 18 analysed stomachs, 39% had only fish remains, 11% only cephalopod remains, 28% fish and cephalopod remains, 17% fish and shrimp remains and about 5% fish, cephalopod and shrimp remains. A total of 1414 otoliths and 538 cephalopod beaks were found in the stomachs of *Sotalia guianensis*. From all otoliths, 130 were lapillus from the genus *Stellifer* and therefore were not used to estimate the total number of prey. Twelve shrimps, 305 cephalopods and 757 fishes were estimated to be ingested by the dolphins. Prey species recorded for *S. guianensis* are presented in

Table 2. List of prey items of 18 stomach contents of Guiana dolphins (*Sotalia guianensis*) found dead in south-eastern Brazil from 2003 to 2009. The number of stomachs in which prey items were found (o), frequency of occurrence percentage (F), number of each prey found (n), numerical percentage (N), estimated weight percentage (W), index of relative importance (IRI) and IRI percentage (IRI%) are shown.

Prey species	O	F	N	N	W	IRI	IRI%
Fishes							
Gerreidae							
Diapterus lineatus	3	16.67	9	1.08	0.45	36.06	1.13
Haemulidae							
Orthopristis ruber	1	5.56	1	0.12	0.29	2.67	0.08
Trichiuridae							
Trichiurus lepturus	6	33.33	8	0.96	7.09	286.91	8.96
Carangidae							
Trachurus lathami	1	5.56	6	0.72	1.03	12.05	0.38
Unidentified Carangidae	1		4				
Engraulidae							
Anchoa tricolor	1	5.56	91	10.95	0.12	96.78	3.02
Anchoa filifera	1	5.56	1	0.12	0.05	1.33	0.04
Anchoa sp.	3	16.67	4	0.48	0.16	15.32	0.48
Cetengraulis edentulus	1	5.56	36	4.33	1.99	49.10	1.53
Unidentified Engraulidae	5		105				
Sciaenidae							
Umbrina canosai	3	5.56	134	0.12	0.28	2.62	0.08
Micropogonias furnieri	1	16.67	1	0.84	0.47	29.99	0.94
Cynoscion virescens	3	5.56	7	1.2	0.89	15.51	0.48
Paralonchurus brasiliensis	1	16.67	10	16.13	42.67	1135.78	35.45
Stellifer sp.	5	27.78	73	8.78	6.78	573.93	17.91
Isopisthus parvipinis	2	11.11	3	0.36	0.43	11.10	0.35
Nebris microps	1	5.56	2	0.24	11.17	64.15	2.00
Ctenosciena gracilicirrhus	1	5.56	2	0.24	0.39	4.26	0.13
Unidentified Scianidae	5		15				
Mugilidae							
Mugil sp.	3	16.67	4	0.48	6.86	126.99	3.96
Clupeidae							
Sardinella brasiliensis	3	16.67	134	16.13	18.88	739.33	23.08
Achiridae	1		10				
Bothidae	1		2				
Ophichtidae	5		25				
Unidentified fishes	10		70				
Cephalopods							
Loliginidae							
Doryteuthis plei	7	38.89	285	31.41	69.16	3910.8	97.40
Loliguncula brevis	3	16.67	19	5.29	0.97	104.48	2.60
Unidentified Loliginidae	1		1				
Crustaceans							
Penaoidea							
Litopenaeus schmitti	1		1				
Farfantepenaeus paulensis	2		4				
Unidentified Penaoidea	2		7				

Table 2. Guiana dolphins preyed on at least 19 different fish species, two species of cephalopod and two species of shrimp. The fish minimum length was 1.86 cm and the maximum length was 95.16 cm. The cephalopod ML range was from 1.99 cm to 38.45 cm.

The following preys were reported for the first time as food items of *S. guianensis* in south-eastern Brazil: rough scad, *Trachurus lathami*, mojarra, *Diapterus lineatus* and the families Ophictidae and Bothidae. The regression equations to evaluate the weight and length of fishes, and weight and ML of squids are described in Table 3. From 58 equations, 18 (31.03%) are presented for the first time in the study area.

Fishes with higher importance in this study were the banded croaker, *Paralonchurus brasiliensis*, the orangespot sardine, *Sardinella brasiliensis* and the rake stardrum, *Stellifer* sp. (Table 2). The most commonly reported family was Sciaenidae. It is also important to consider the high F value found for the Atlantic cutlassfish, *Trichiurus lepturus* (Trichiuridae) (see Table 2). *Doryteuthis plei* was the most common cephalopod, due to its higher values of F, N, W and IRI when compared to *Lolliguncula brevis. Litopenaeus schmitti* and *Farfantepenaeus paulensis* were the reported shrimp species.

Stellifer rastrifer was the most important fish species, followed by *P. brasiliensis* and *S. brasiliensis*, when considering samples from inner estuarine waters (Table 4). Only one cephalopod species was recorded in inner estuarine waters: *L. brevis*. *Paralonchurus brasiliensis* was the most important fish species found in the stomach of dolphins collected in coastal waters. It was followed by *T. lepturus*. From the two

Table 3. Regression equations used to estimate fish standard length (SL) or total length (TL), cephalopod mantle length (ML) and fish and cephalopod weight (W). Sample size, R^2 and sources are shown. Otolith length is represented by 'x', lower rostral length of cephalopod beaks by 'LRL' and upper rostral length of cephalopods beaks by 'URL'.

Species	Length			Weight			Source
	Sample size	Regression	R^2	Sample size	Regression	R^2	
Fishes							
Anchoa filifera	35	$SL = 1.9674x + 1.0401$	0.716	35	$W = 0.2984x^{2.4207}$	0.689	D
Anchoa sp.	82	$SL = 1.831x + 1.297$	0.671	82	$W = 0.244x^{2.527}$	0.694	E
Anchoa tricolor	81	$SL = 1.8311x + 1.2976$	0.672	81	$W = 0.2443x^{2.5275}$	0.694	E
*Cetengraulis edentulus**	–	–	–	3820	$W = 0.0000003TL^{3.6708}$	0.981	B
Ctenosciena gracilicirrhus	33	$SL = 1.9064x - 1.3718$	0.96	33	$W = 0.0496x^{3.5123}$	0.97	C
Cynoscion jamaicensis	12	$SL = 1.7202x - 1.1392$	0.996	12	$W = 0.0288x^{3.4318}$	0.994	D
Cynoscion virescens	23	$SL = 1.4033x + 0.4989$	0.99	23	$W = 0.1029x^{2.5646}$	0.95	D
Diapterus lineatus	37	$SL = 1.8788x + 0.2867$	0.88	37	$W = 5.3656e^{0.13x}$	0.88	E
Eucinostomus argenteus	15	$SL = 2.0642x + 0.8002$	0.761	15	$W = 0.9062x^{2.2507}$	0.767	D
Isopisthus parvipinnis	30	$SL = 1.8563x - 0.7437$	0.97	30	$W = 0.0477x^{3.2867}$	0.97	D
Larimus breviceps	35	$SL = 1.4164x - 1.1364$	0.991	35	$W = 0.0519x^{3.0227}$	0.985	D
Macrodon ancylodon	20	$SL = 2.0416x - 4.1130$	0.659	20	$W = 0.0089x^{3.8605}$	0.733	D
Micropogonias furnieri	33	$SL = 2.0304x - 2.2003$	0.969	33	$W = 0.0445x^{3.3544}$	0.968	E
Mugil sp.	16	$SL = 0.6505x^{1.69}$	0.61	16	$W = 0.00412x^{5.16}$	0.63	E
Nebris microps	22	$SL = 3.0319x - 10.226$	0.97	22	$W = 0.0040x^{4.5565}$	0.98	D
Orthopristis ruber	41	$SL = 1.9896x + 0.8337$	0.717	41	$W = 0.4409x^{2.6658}$	0.659	E
Paralonchurus brasiliensis	39	$SL = 2.016x - 1.8970$	0.98	39	$W = 0.0195x^{3.8099}$	0.98	D
Porichthys porisissimus	54	$TL = 24.263x^{1.0254}$	0.994	54	$W = 0.0809x^{3.3225}$	0.991	C
Sardinella brasiliensis	55	$SL = 3.5811x + 3.6082$	0.603	55	$W = 5.3731e^{0.71x}$	0.6	E
Stellifer brasiliensis	30	$SL = 2.2654x - 1.9308$	0.963	30	$W = 0.0324x^{3.9782}$	0.969	D
Stellifer rastrifer	30	$SL = 2.9422x - 3.796$	0.932	30	$W = 0.0356x^{4.2559}$	0.944	D
Stellifer sp.	127	$SL = 1.6064x^{1.09\ 47}$	0.83	127	$W = 0.0813x^{3.4157}$	0.83	E
Trachurus lathami	45	$TL = 20.417x^{1.1571}$	0.825	45	$W = 0.0548x^{3.5828}$	0.815	C
Trichiurus lepturus	19	$SL = 17.533x - 15.885$	0.99	19	$W = 0.1042x^{4.6079}$	0.99	D
Umbrina canosai	30	$SL = 2.0137x^{1}$	0.8	30	$W = 7.4652e^{0.33x}$	0.83	E
Cephalopods							
Doryteuthis plei	–	$ML = 67.431URL^{1.2908}$	0.961	–	$W = 8.8096URL^{2.8564}$	0.980	A
	–	$ML = 64.303LRL^{1.3143}$	0.953	–	$W = 7.9418LRL^{2.908}$	0.973	A
Loliguncula brevis	50	$ML = 41.3751URL + 3.3180$	0.938	53	$W = 6.0749URL^{2.4677}$	0.904	F
	51	$ML = 42.8967LRL + 1.8382$	0.968	53	$W = 5.9731LRL^{2.5789}$	0.918	F

*, *Cetengraulis edentulus* found in the stomach contents were not digested and therefore were measured and had their weight estimated from the total length. Sources: (A) Santos (1999) (ML in 'mm' and W in 'g'); (B) Conceição *et al.* (2005) (TL in 'mm' and W in 'g'); (C) Bassoi (2005) (TL in 'mm' and W in 'g'); (D) Bittar (2007) (SL in 'cm' and W in 'g'); (E) present study (SL in 'cm' and W in 'g'); (F) Reference collection of CEPSUL/IBAMA (ML in 'mm' and W in 'g').

species of cephalopods found in the coastal dolphin diet, *D. plei* was the most important item.

Prey specimens were larger in the coastal dolphin diet, with significant differences between fish lengths and cephalopod MLs of prey specimens found in stomach contents of dead dolphins in inner estuarine waters (1.86 cm to 28.1 cm; mean ± standard deviation (SD) = 7.56 ± 3.73 cm) and in coastal waters (3.21 cm to 95.16 cm; mean ± SD = 11.87 ± 8.28 cm) (fishes: $U_{(\alpha=0.05)} = 45065.00$; $P = 0.0001$/cephalopods: $U_{(\alpha=0.05)} = 13691.00$; $P = 0.0001$).

The species observed in this study as the most important preys were also reported in the majority of the studies regarding *S. guianensis* feeding habits (see Table 5). However, among the different sites few differences were observed. For instance, in the studies conducted in the State of Rio de Janeiro north coast (~22°S), the Atlantic cutlassfish was the most important prey (see Di Beneditto & Ramos, 2004; Di Beneditto & Siciliano, 2007). On the other hand, in the majority of the studies conducted in the south of São Paulo State and north of Paraná State (~24 to 25°S), fishes from the genus *Stellifer* were the most important prey (see Schimegelow, 1990; Santos *et al.*, 2002; Oliveira, 2003; present study).

The species of cephalopods reported as *S. guianensis* prey items were mainly squids from the family Loliginidae, except for one octopus, *Argonauta nodosa*, reported by Zanellato (2001). In the majority of the studies, based on the comparison of the IRI, F and N values, *D. plei* corresponded to one of the most important cephalopods in the Guiana dolphin diet (see Zanelatto, 2001; Oliveira, 2003; Di Beneditto & Ramos, 2004; Di Beneditto & Siciliano, 2007; present study).

On the coast of of Rio de Janeiro State, when considering the most important commercial fish species such as *S. brasiliensis*, *Cetengraulis eduntulus*, *Katsuwonus pelamis*, *Micropogonias furnieri*, *Scomber japonicus* and *Balistes* spp. (see Da Silva & Vianna, 2009), only *M. furnieri* was recorded as one of the five most important Guiana dolphin preys (see Di Beneditto & Ramos, 2004; Di Beneditto & Siciliano 2007). In south São Paulo and north Paraná, *S. brasiliensis*, *M. furnieri*, *Cynoscion jamaiscensis*, *Anchoa* spp., *Anchoviella* spp., *Lycengraulis grossidens* and *Menticirrhus* spp. were listed among the most important commercial fishes (see Da Silva & Vianna, 2009). When considering four studies conducted in the area (Zanelatto, 2001; Santos

Table 4. Numerical percentage (N), frequency of occurrence percentage (F), estimated weight percentage (W), index of relative importance (IRI) and IRI percentage (IRI%) of preys observed in the stomachs of Guiana dolphins (*Sotalia guianensis*) recorded in inner estuarine and coastal waters of south-eastern Brazil. Sources: Santos *et al.* (2002) and present study.

Prey species	Inner estuarine waters					Coastal waters				
	N	F	W	IIR	IIR%	N	F	W	IIR	IIR%
Teleostean fishes										
Sciaenidae										
Ctenosciena gracilicirrhus						0.78	6.67	0.50	8.51	0.17
Cynoscion jamaicensis	0.17	16.67	0.43	9.92	0.25					
Cynoscion virescens						3.89	6.67	1.14	33.57	0.67
Isopisthus parvipinnis	6.37	25	3.04	235.32	5.89	1.17	13.33	0.37	20.51	0.41
Larimus breviceps	0.08	8.33	0.30	3.20	0.08	1.95	6.67	0.92	19.15	0.38
Macrodon ancylodon	0.08	8.33	1.43	12.55	0.31					
Micropogonias furnieri	1.1	41.67	3.05	172.83	4.32	1.95	13.33	3.98	79.02	1.58
Nebris microps						0.78	6.67	14.34	100.85	2.01
Paralonchurus brasiliensis	4.33	25	25.50	745.76	18.66	54.47	33.33	55.26	3657.43	72.96
Stellifer brasiliensis	4.42	16.67	5.54	166.07	4.16					
Stellifer rastrifer	55.56	25	18.12	1842.00	46.09	10.12	13.33	0.68	143.91	2.87
Stellifer sp.	4.25	25	3.57	195.47	4.89	8.95	13.33	5.81	196.79	3.93
Umbrina canosai						0.39	6.67	0.36	5.01	0.10
Haemulidae										
Orthopristhis ruber	0.08	8.33	0.06	1.20	0.03	0.78	13.33	0.40	15.76	0.31
Gerreidae			0.00	0.00	0.00					
Eucinostomus argenteus	0.08	8.33	0.08	1.30	0.03					
Diapterus rhombeus	0.25	16.67	0.36	10.22	0.26	2.33	6.67	0.29	17.45	0.35
Engraulidae										
Anchoa filifera						0.39	6.67	0.06	3.03	0.06
Anchoa sp.	0.25	25	0.11	8.90	0.22	7	20	0.74	154.78	3.09
Anchoa tricolor	7.73	8.33	0.19	65.98	1.65					
Cetengraulis edentulus	3.06	8.33	3.15	51.75	1.29					
Mugilidae										
Mugil sp.	0.42	25	4.47	122.33	3.06	0.39	6.67	5.29	37.89	0.76
Clupeidae										
Sardinella brasiliensis	11.05	8.33	28.94	333.08	8.33	1.56	13.33	0.76	30.88	0.62
Trichiuridae										
Trichiurus lepturus	0.08	8.33	0.04	0.97	0.02	3.11	40	9.10	488.42	9.74
Carangidae										
Trachurus lathami	0.51	8.33	1.63	17.80	0.45					
Cephalopods										
Loliginidae										
Lolliguncula brevis						34.93	33.33	4.55	1315.94	14.94
Doryteuthis plei						66.07	46.67	95.45	7491.02	85.06

et al., 2002; Oliveira 2003; present study), just a few items such as *M. furnieri*, *Anchoa* sp. and *S. brasiliensis* were listed among one of the five most important Guiana dolphin preys in at least one of the studies.

DISCUSSION

The present study introduced new food items to the knowledge about the Guiana dolphin diet, even working with a number of stomachs that could be considered small when analysing cetacean feeding habits. It also presented new regression equations to evaluate the weight and standard length of fishes found as Guiana dolphin preys. This is useful information either for predator–prey studies in general, or other studies such as population management and archaeology (Harvey *et al.*, 2000). For the first time, items recovered from stomach contents of dead dolphins found in inner estuarine waters were compared to the ones recovered from coastal dolphins, showing evidences of differences in prey sizes. This study also provided a review of the knowledge about Guiana dolphin diet in south-eastern Brazil, comparing most prey items with the main targets of fisheries.

Considering the 18 analysed stomachs, the fish family with highest species richness in *Sotalia guianensis* feeding habits was Sciaenidae. This family is commonly found in shallow waters near the coast and some species present great importance in fishery (Menezes & Figueiredo, 1980). The large representation of Sciaenidae fish in the Guiana dolphin diet has been recorded in previous studies conducted in Brazil (see Table 5). *Paralonchurus brasiliensis* and *Stellifer* sp. are demersal fishes associated with sandy or muddy bottoms. Comparing the presented information with a previous study conducted in the same area (Santos *et al.*, 2002) there was apparently no shift in fishes consumed by *S. guianensis* over the past ten years. Though, due to the samples size, caution must be taken when reaching conclusions about the changes in the dolphin feeding habits over time.

The IRI analysis of individuals found in inner and coastal waters showed differences in their feeding habits, this last also applied to prey on larger items. Maciel (2001) observed that *Stellifer rastrifer*, the most common prey from dolphins

Table 5. List of preys consumed by Guiana dolphins (*Sotalia guianensis*) found dead in south-eastern Brazil. Sources, location where dolphins were found (RJ, Rio de Janeiro; SP, São Paulo; PR, Paraná), and number of stomachs used in each study are presented.

Source	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
State	**RJ/ES**	**RJ**	**RJ**	**SP**	**SP**	**SP**	**SP/PR**	**SP/PR**	**PR**
Number of stomachs	**4**	**77**	**10**	**9**	**3**	**18**	**7**	**35**	**35**
Teleostean fishes									
Sciaenidae									
Ctenosciaena gracilicirrhus		x	x			x			x
Cynoscion acoupa								x	
Cynoscion jamaicencis	x	x	x	x					x
Cynoscion leiarchus				x				x	
Cynoscion striatus	x								
Cynoscion virescens		x	x	x		x			
Cynoscion guatucupa		x	x						x
Cynoscion sp.	x								
Isopisthus parvipinnis		x	x	x		x	x	x	x
Larimus breviceps				x			x	x	
Macrodon ancylodon		x	x	x					
Menticirrhus americanus		x	x					x	x
Micropogonias furnieri		x	x	x		x	x	x	x
Nebris microps		x				x			
Paralonchurus brasiliensis		x	x	x		x		x	x
Pogonias cromis		x						x	
Stellifer brasiliensis		x		x				x	
Stellifer rastrifer		x	x	x				x	x
Stellifer sp.		x				x	x	x	x
Umbrina sp.								x	
Umbrina canosai		x				x			
Unidentified Sciaenidae	x				x	x	x		
Haemulidae									
Orthopristhis rubber		x	x	x		x			x
Haemulon steidachneri							x		x
Pomadasys corvinaeformis				x					x
Conodon nobilis		x	x						
Genyatremus luteus								x	x
Gerreidae									
Eucinostomus argenteus				x				x	
Eucinostomus gula							x	x	
Eucinostomus melanopterus								x	
Diapterus rhombeus								x	x
Diapterus lineatus						x			
Unidentified Gerreidae							x		
Engraulidae									
Anchoa filifera		x	x			x			
Anchoa tricolor						x		x	
Anchoa sp.				x		x			x
Anchoviela lepidentostole								x	
Cetengraulis edentulus						x			x
Lycengraulis grossidens			x					x	x
Unidentified Engraulidae						x	x		
Mugilidae									
Mugil sp.		x		x		x	x	x	
Mugil curema							x		
Paralichthydae									
Paralichthys orbignyanus				x					
Paralichthys sp.									x
Citharicthys sp.								x	x
Batracoididae									
Porichthys porosissimus	x	x	x	x			x	x	x
Clupeidae									
Pellona harroweri	x	x						x	x
Harengula clupeola							x		
Sardinella brasiliensis		x				x		x	x
Unidentified Clupeidae					x		x		
Trichiuridae									
Trichiurus lepturus	x	x	x	x		x	x	x	x

Continued

Table 5. Continued

Source **State** **Number of stomachs**	**A** **RJ/ES** **4**	**B** **RJ** **77**	**C** **RJ** **10**	**D** **SP** **9**	**E** **SP** **3**	**F** **SP** **18**	**G** **SP/PR** **7**	**H** **SP/PR** **35**	**I** **PR** **35**
Congridae									
Ariosoma opisthophthalma		x	x						
Ophichthidae									
Myrophis punctatus									x
Ophichthus gomesii								x	
Unidentified Ophicthidae									
Carangidae									
Oligoplites sp.									x
Oligoplites saliens							x		
Selene setapinnis									x
Chloroscombrus chrysurus									x
Trachurus lathami						x			
Unidentified Carangidae						x			
Gadiidae									
Urophycis brasiliensis		x							x
Bardiella ronchus									x
Lutjanidae									
Lutjanus griseus									x
Synodontidae									
Synodus foetens									x
Atherinidae									
Atherinella brasiliensis									x
Serranidae									
Dules auriga							x		
Ariidae									
Bagre bagre		x					x		
Achiridae									
Achirus sp.								x	
Unidentified Achiridae						x			
Bothidae						x			
Ophichtidae						x			
Unidentified fishes	x	x		x		x	x	x	
Cephalopods									
Loliginidae									
Lolliguncula brevis	x	x		x		x		x	x
Doryteuthis plei		x	x			x	x	x	x
Doryteuthis sanpaulensis		x	x					x	x
Doryteuthis sp.	x								
Unidentified Loliginidae						x	x		
Argonautidae									
Argonauta nodosa									x
Unidentified cephalopods								x	
Crustaceans									
Penaeoidea									
Farfantepenaeus paulensis				x		x			
Farfantepenaeus brasiliensis							x	x	
Litopenaeus schmitti				x		x			
Unidentified shrimps				x					

Sources: (A) Borobia & Barros (1989); (B) Di Beneditto & Ramos (2004); (C) Di Beneditto & Siciliano (2007); (D) Santos *et al.* (2002); (E) Carvalho (1963); (F) present study; (G) Schmiegelow (1990); (H) Oliveira (2003); (I) Zanelatto (2001).

found in inner estuarine waters, was the most abundant species collected by bottom trawling in the Cananéia estuary. The Atlantic cutlassfish (*Trichiurus lepturus*) did not represent an important species in the feeding habits of Guiana dolphins found in inner estuarine waters. However, it was the second prey in importance for the individuals found in coastal waters. *Trichiurus lepturus* is distributed from coastal waters to 300 m of depth (Magro, 2005). The observation of smaller preys in estuarine dolphins could be related to the common presence of juvenile fishes in the estuary, which is an important breeding area for several fish species (Besnard, 1950; Schaeffer-Novelli *et al.*, 1990).

The only cephalopod species reported from the individuals found in inner estuarine waters was *Loligunculla brevis*; meanwhile this species and *Doryteuthis plei* were reported for coastal dolphins. *Doryteuthis plei* occurs at depths of up to 370 m and is not common in estuaries (Roper *et al.*, 1984). This squid also corresponds to one of the most common cephalopod species on the Brazilian coast (see Perez *et al.* 2005; Haimovici *et al.*, 2007; Rodrigues & Gasalla, 2008).

Lolliguncula brevis corresponds to a coastal species found at depths up to 20 m. It tolerates salinities as low as 8.5 ppm for brief periods, and is particularly abundant in shallow bays and estuaries (Roper *et al*., 1984). The significant difference in the estimated consumed cephalopods size could also be related to the differences between the two species consumed. *Lolliguncula brevis* is a small squid with 12 cm maximum ML for females and 8 cm for males, and *D. plei* is larger, with 35 cm maximum ML for males and 22 cm for females (Roper *et al*., 1984). *Doryteuthis plei* was observed only for individuals found in coastal waters and, therefore, this surveyed Guiana dolphin group presented larger MLs in their stomachs. The difference between the consumption of cephalopods by coastal and inner estuarine waters dolphins may represent a difference in feeding site. The absence of *D. plei* beaks in stomachs of inner estuarine Guiana dolphins may represent that this group had not fed in coastal waters for some time before they were found, since cephalopod beaks remain for long periods in stomach contents. Even with such compelling evidences, caution must be taken when reaching conclusions about differences between feeding habits of individuals found in inner estuarine and coastal waters, because the location where individuals were found stranded does not necessarily represent the place they fed. Thus, more studies using stomach content analysis and also other techniques should be deployed for evaluating differences in feeding habits regarding Guiana dolphins in inner and coastal waters.

All the most important prey species in *S. guianensis* diet are abundant in the studied areas, which represents evidence of opportunistic feeding habit. The difference among the species composition reported in diverse studied areas reflects the different biota composition in those sites. When considering the studies presented in Table 4, the most representative fish family was Sciaenidae, which is predominantly demersal (Menezes & Figueiredo, 1980). Most of the species found as important preys of *S. guianensis* are associated with the sea bottom. Even species such as *T. lepturus* and *D. plei*, which also present pelagic habits, may be associated with the bottom based on their vertical migration. Large adults of Atlantic cutlassfish usually feed near the surface in daytime and migrate to the bottom at night; meanwhile juveniles form schools near the bottom during the day and feed near the surface at night (Figueiredo & Menezes, 2000). *Doryteuthis plei* concentrates near the bottom during the day, but disperses into the water column at night (Roper *et al*., 1984). Considering the applied methodology, it is not possible to describe in which day period, and, therefore, where *S. guianensis* consumed these two preys. Thus, coastal and estuarine substrates seem to be important to Guiana dolphins' feeding activities. Disturbances that affect the sea bottom (e.g. estuarine mouth dredging and bottom trawling) may decrease prey availability and possibly affect the feeding activity, one of the vital processes for this species' survival.

It is also important to consider that the overlap between Guiana dolphin preys and fisheries' main targets appears not to occur when fishes are taken into consideration. Sciaenidae, the most representative family in *S. guianensis* diet, is abundant and is commercially important (Souza, 2004). Notwithstanding, the species which were found to be more frequently ingested by Guiana dolphins (e.g. *Stellifer* sp. and *P. brasiliensis*) did not represent the most important target species from the commercial fishery (see Menezes & Figueiredo, 1980; Mendonça, 1998; Mendonça *et al*., 2003, 2004; Da Silva & Vianna, 2009), even though they are frequent in bottom trawl fisheries by-catch. *Trichiurus lepturus* is commercially important around the world, but in Brazil it still has low commercial values (Bittar, 2007).

In Rio de Janeiro State, the overlap between the Guiana dolphin diet and fishery targets had been observed when considering *Micropogonias furnieri* (see Di Beneditto & Siciliano, 2007). Nevertheless, *M. furnieri* presented a low value of the IRI when compared to the four most important species in that study (*T. lepturus*, *Cynoscion guatocupa*, *Isopisthus parvipinnis* and *Porichthys porosissimus*). These four species corresponded to 86.3% of the total biomass reported, 74.3% of all the preys consumed and each species was reported in at least 30% of the analysed stomachs, suggesting that *M. furnieri* has a lower importance in Guiana dolphins' feeding habits. In south São Paulo and north Paraná, the situation was similar to the one observed in Rio de Janeiro. Even though listed among the five most important species, *Sardinella brasiliensis* (present study) and *M. furnieri* (Santos *et al*., 2002) appear not to be of greatest importance in Guiana dolphins' feeding habits. In the present study, *S. brasiliensis* was reported as an important prey due to one individual that consumed 130 of 134 reported orangespot sardines. *Micropogonias furnieri* presented a higher value of F (44.4%) in the study of Santos *et al.* (2002), but presented an extremely low value of N (1.1%).

When considering the cephalopods alone, the overlap with fisheries had been observed, *D. plei* has a high commercial value (Perez *et al*., 2005). Though, when considering the general importance in fishery, this species does not represent one of the ten most import products in the south-eastern Brazilian fishery (see Da Silva & Vianna, 2009).

The feeding habit studies enhance our knowledge about marine mammals in the ecosystems, hence contributing to information for future conservation issues. Currently, the *S. guianensis* studies in Brazil have been concentrated mostly in the south-eastern region. Therefore, studies in other areas along the Guiana dolphin distribution are necessary to better understand either its trophic interactions, or its interaction with commercial fishery. The use of different available techniques (e.g. stable isotopes and fatty acids) to evaluate long-term diet and energy consumption would also provide complementary information to better understand the Guiana dolphin diet along its distribution, and perhaps between different stocks.

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