Feeding habits of the Guiana dolphin, *Sotalia guianensis* (Cetacea: Delphinidae), in Norte Bay, southern Brazil

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SUMMARY: The stomach contents of 18 Guiana dolphins stranded or accidentally caught by fishing around Norte Bay of Santa Catarina Island between 1990 and 2006 were examined. The small population of Guiana dolphins studied showed a varied diet, and prey was caught disproportionately. The stomach contents of these dolphins consisted of 448 prey remains coming from 18 species and 10 families. Their diet primarily consisted of fish, but also shrimp and squid. The most important species were cutlass fish (*Trichiurus lepturus*) and white mouth croaker (*Micropogonias furnieri*), which together comprised 75% of the total biomass. Although prey size ranged widely from 1.4 to 92.8 cm, a prevalence of prey smaller than 20 cm was observed. There was a predominance of prey living in moderate or large schools. The prey also had a wide vertical distribution in the water column. Our results support the opportunistic feeding habit of the Guiana dolphin, since its diverse diet was clearly guided by the availability and accessibility of resources in its habitat.

Keywords: diet, stomach contents, Guiana dolphin, prey availability, southern Brazil.

RESUMEN: ALIMENTACIÓN DEL DELFÍN COSTERO, *SOTALIA GUIANENSIS* (CETACEA: DELPHINIDAE), EN LA BAHÍA NORTE AL SUR DE BRASIL. – Se estudiaron los contenidos del estómago de 18 delfines costeros capturados accidentalmente por redes de pesca o encontrados encallados alrededor de la bahía Norte de la isla de Santa Catarina entre 1990 y 2006. La composición de la dieta de los delfines fue variada, pero con predominio de algunas presas. Los contenidos estomacales consistieron en 448 restos de presas, que correspondieron a 18 especies y 10 familias. La mayoría de las presas fueron principalmente peces, pero también estuvieron representados cefalópodos y crustáceos. Las especies más importantes fueron el pez sable (*Trichiurus lepturus*) y la corvina rubia (*Micropogonias furnieri*), que juntos representaron un 75% de la biomasa total. Aunque el tamaño medio de las presas varió entre 1.4 y 92.8 cm, hubo una prevalencia de presas más pequeñas de 20 cm. Se observó un predominio de presas que viven agregadas en cardúmenes de mediano a gran tamaño y con amplia distribución vertical en la columna de agua. Nuestros resultados apoyan el hábito alimenticio oportunista de *Sotalia guianensis*, ya que su variada dieta está claramente guiada por la disponibilidad y accesibilidad de los recursos en su hábitat.

Palabras clave: dieta, contenidos estomacales, *Sotalia guianensis*, disponibilidad de presas, sur de Brasil.

INTRODUCTION

Diet studies of marine predators provide important information on their ecology and ecosystem, as well as on the biology of their prey (Katona and Whitehead, 1988). Some aspects to consider are the identification of key prey and prey availability (Silva, 1999). In general, predator behavior is a response to the distribution and abundance of feeding resources (Krebs, 2001). Food availability is thought to be the most important factor determining spatial patterns, behavior and foraging strategies of Delphinidae (e.g. Wells *et al.*, 1980; Shane, 1990). Thus, knowledge of feeding habits is required to understand the influences of their prey on the ecology of small cetaceans.

The Guiana dolphin, *Sotalia guianensis* (P.J van Bénéden, 1864), is widely and continuously distributed along the central and southwestern Atlantic coast (Borobia *et al.*, 1991). The species occurs in bays and estuaries from Honduras (Silva and Best, 1996) to Norte Bay of Santa Catarina Island in southern Brazil (Simões-Lopes, 1988), where a small population (around 60 individuals) shows a high degree of site fidelity (Flores, 1999; Daura-Jorge *et al.*, 2007). Previous studies have described the role played by seasonal variation in the behavior of Guiana dolphins, such as spatial distribution and movements (Daura-Jorge *et al.*, 2005, 2007; Wedekin *et al.*, 2007). The authors proposed that the behavior pattern was strongly driven by seasonal variations in prey abundance. However, the lack of information about the feeding habits of this species in the area make it impossible to test this hypothesis.

Recently, some efforts have been made to describe the diet of the Guiana dolphin along the entire Brazilian coast (e.g. Borobia and Barros, 1989; Santos and Haimovici, 2001; Santos *et al.*, 2002; Gurjão *et al.*, 2003; Di Beneditto and Siciliano, 2007). These studies, despite the small sample size in most cases, revealed that the composition of prey differed between habitats and geographic areas. To provide additional data on the feeding habits of the Guiana dolphin, specifically on the small population from Norte Bay of Santa Catarina Island, we present a qualitative description of their diet. Aware of the limited sample size, we have attempted to make some inferences regarding feeding ecology.

MATERIALS AND METHODS

Study area

Norte Bay of Santa Catarina Island (27°30'S and 48°35'W) in southern Brazil (Fig. 1) is a protected coastal bay delimited by a mosaic of rocky shores, sandy beaches and mangroves. Its oceanographic parameters are similar to those of the adjacent open waters (Cerutti, 1996), and it is strongly influenced by tidal and drift currents, as well as by the flow of freshwater (Alongi, 1998). It is also an important nursery habitat for many fish species. The water temperature varies markedly between seasons (15 to 29ºC; Cerutti, 1996).

Data sample

The stomach contents of 20 Guiana dolphins found stranded throughout the study area between 1990 and 2006 were examined. The recovered carcasses were measured and sexed during the necropsy (according to Norris, 1961). The stomachs were removed and frozen for subsequent examination. A total of 18 stomachs containing prey remains were analyzed. The other two were not used because one was from a calf, containing only milk, and the other was in an advanced state of decomposition.
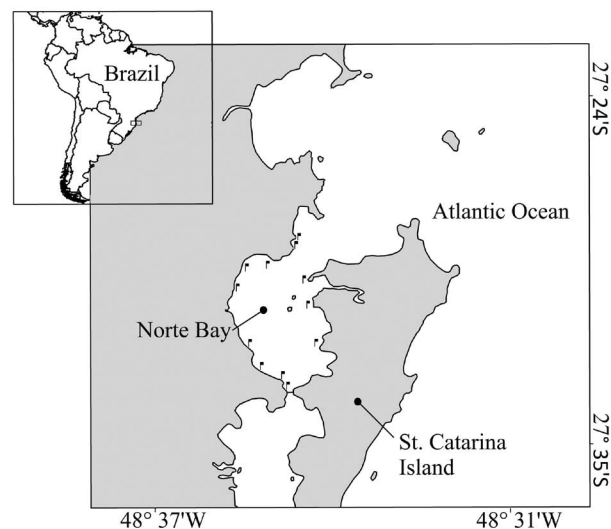

Fig. 1. – Geographic locations of Norte Bay and the stranded Guiana dolphins (flags indicate only the stranded dolphins with exact locations known).

Stomach contents were removed and cleaned with water on a 1 mm mesh sieve (according to Amir *et al.*, 2005). Intact or partially digested prey were identified, measured and preserved in 70% alcohol. Remains of hard parts such as fish otoliths, cephalopod beaks and crustacean carapaces were dried at 60°C for 48 hours. All prey items were identified to the lowest possible taxonomic level (according to Lêmos *et al.*, 1992; Abilhôa and Corrêa, 1993; Corrêa and Viana, 1993; Lêmos *et al.*, 1995a, b). A fish (and otolith) reference collection assembled by NEMAR (Núcleo de Estudos do Mar – Universidade Federal de Santa Catarina) was also used to help identify prey items. Intact or semi-digested prey were identified according to Figueiredo and Menezes (1978, 1980, 2000) and Menezes and Figueiredo (1980, 1985). The minimum number of prey consumed by each dolphin was estimated by counting the left or right otolith (whichever was more numerous) for fish and lower or upper beaks (whichever was more numerous) for cephalopods. Poorly preserved and/or broken otoliths were discarded to avoid identification mistakes and overestimations, as well as to reduce the risk of secondary contamination (Fitch and Brownell, 1968).

A stereomicroscope with an optical micrometer was used to measure prey items. These measurements were inserted into the linear regression equations (LRE) available in the literature for each identified species (see Corrêa and Viana, 1993; Lêmos *et al.*, 1992, 1995a, b; Di Beneditto *et al.,* 2001), to estimate the size and biomass of each prey specimen.

Data analysis

The following three parameters were used to calculate the Index of Relative Importance of each prey specimen (IRI; Pinkas *et al.*, 1971): percentage number

TABLE 1. – Descriptive parameters of prey importance in the diet of the Guiana dolphin from Norte Bay. Abbreviations: Individual number (N), percentage number (%N), frequency of occurrence (FO), percentage of frequency of occurrence (%FO), biomass (B), percentage of biomass (%B), Index of Relative Importance (IRI), not calculated (-); Prey codes (CD), vertical guilds (*VG*), ecological guild (*EG*), size of schools (*SS*) and habitat type (*HT*) – see the significance of codes throughout the text.

Prey species	CD	N	%N	B(g)	%B	%FO	IRI	*VG*	*EG*	*SS*	*HT*
Trichiurus lepturus	Tl	30	16.8	5498	51.8	61.1	4197	dp	mv	ls	ce
Micropogonias furnieri	Mf	48	26.9	2499	23.6	66.7	3368	dn	mj	ms	ce
Cetengraulis edentulus	Ce	26	14.6	485	4.6	44.4	852	pl	mv	ms	ce
Mugil cf. *curema*	Mc	16	8.9	761	7.2	27.8	449	pl	mv	ls	ce
Isopisthus parvipinnis	Ip	9	5.0	183	1.7	33.3	226	dn	mj	ms	ce
Stellifer cf. *rastrifer*	Sr	10	5.6	81	0.8	27.8	177	dn	mj	ss	ce
Lycengraulis grossidens	Lg	10	5.6	282	2.6	11.1	92	pl	rs	ms	ce
Lolliguncula brevis	Lb	6	3.4	67	0.6	22.2	89	dp	mv	st	ce
Porichthys porosissimus	Pp	3	1.7	231	2.2	11.1	43	bt	mv	ss	ct
Pomadasys corvinaeformis	Pc	3	1.7	75	0.7	16.7	40	dn	mj	ls	ce
Cynoscion jamaicensis	Cj	4	2.3	73	0.7	11.1	33	dn	mj	ls	ce
Orthopristis ruber	Or	4	2.3	210	1.9	5.6	23	dn	mj	ls	co
Paralonchurus brasiliensis	Pb	4	2.3	114	1.0	5.6	18	dn	mj	ss	ce
Ctenosciaena gracilicirrhus	Cg	4	2.3	26	0.2	5.6	14	dn	mj	ss	ce
Chloroscombrus chrysurus	Cc	1	0.6	22	0.2	5.6	4	pl	rs	ms	ce
*Citharichthys sp.	Cs	200	-	-	-	11.1	-	bt	rs	st	es
*Anchoa sp.	Ac	3	-	-	-	16.7	-	pl	rs	ms	ce
*Penaoidae	Pe	1	-	-	-	5.6	-	bt	mv	st	ce
*Unidentified		66	-	-	-	61.1	-				
Total		447		10607							

*Not considered in the IRI analysis

(%N), percentage of frequency of occurrence (%FO) and percentage of biomass (%B). This analysis only included species-level identification of those prey with LRE available in order to reduce uncertainty in the analysis.

$$IRI = (\%N + \%B) \,\%FO$$

Despite our small sample size (it is significant considering the population size) we tried to evaluate the degree of feeding specialization using Levins' measure of niche breadth (Krebs, 1998).

Prey species were classified in relation to habits regarding the use of the niche (according to Figueiredo and Menezes, 1978, 1980, 2000; Menezes and Figueiredo, 1980, 1985; Szpilman, 2000), using vertical and ecological guild definitions (adapted from Elliot and Dewailly, 1995). Vertical guilds are related to the depth gradient the prey inhabits and are defined as (bt) benthic (bottom-living), (dn) demersal nektonic (living on the bottom and moving independent of the current), (dp) demersal bentho-pelagic (living on the bottom and up to 200 to 300 m above) and (pl) pelagic (living mostly off the bottom). The ecological guilds correspond to the degree of residency in protected waters and are classified as (rs) resident (occurring at all seasons and life cycles in estuaries and/or bays), (mv) marine visitors (from coastal and marine habits, occurring occasionally during migratory visits to bays and estuaries) and (mj) marine juvenile (staying in bays and/or estuaries to feed when a juvenile). The term *estuary* is used here for convenience since Norte Bay is classified as a coastal bay. The size of fish schools, which was also used as a descriptor, was classified into one of the following four categories:

(st) solitary, (ss) small school, (ms) moderate school and (ls) large school. Prey were also classified according to their habitat type, including (es) estuarine, (ce) coastal/estuarine, (ct) coastal and (co) coastal/ oceanic (Table 1). Each species was classified as either 0 or 1 (presence/absence matrix) in relation to each descriptor.

Statistical analyses

A similarity matrix using the Jaccard coefficient was generated for the cluster analysis in which the habits and habitat descriptors of prey were considered. Clusters were determined based on this matrix using the group-average method (UPGMA). The cluster method and the similarity index were chosen considering the highest cophenetic coefficient (Legendre and Legendre, 1998). After clustering, the IRI was recalculated for each formed group. As we considered all prey, the IRI of groups with prey not identified at the species level may be underestimated (biomass not included).

RESULTS

Sample

We analyzed the stomachs of eight female and ten male Guiana dolphins. Two females were pregnant with developed embryos, and six animals showed evidence of interactions with fishing activities. Prey items were observed in different degrees of digestion. The average number of prey in each stomach was 25.05 (±44.8; range=1-199), and the mean species richness was 3.72 (±2.24; range=1-8).

Diet composition

In 18 stomachs we found 448 prey remains and identified 382 (85.2%), including 16 species of fish (from eight different families), one species of squid and one unknown penaeid shrimp. Of the 16 species of fish, two require further confirmation, they are probably *Mugil curema* (Valenciennes, 1836) and *Stellifer rastrifer* (Jordan, 1889), and two more were identified at the genus level (*Anchoa* sp. and *Citharichthys* sp.). We identified these four prey specimens taking their local habitat and availability into consideration. A sole species of squid, *Lolliguncula brevis* (de Blainville, 1823), was observed in 22% of stomachs; it consisted of 1.3% of the total prey and contributed to 0.6% of the total estimated biomass. The crustaceans were represented in the diet by one shrimp species (unknown) from the Penaoidae family.

The predominant group was fish, which made up 99.4% of all evaluated prey. The most frequent family was Sciaenidae (72.2% of stomachs), followed by Engraulidae (61.1% of stomachs) and Trichiuridae (61.1% of stomachs). The highest overall abundance observed was from Paralichthyidae (44.6% of the prey items), followed by Sciaenidae (17.6% of the prey items) and then Engraulidae (8.7% of the prey items). The abundance of Paralichthyidae was due to the occurrence of 195 *Citharichthys* sp. individuals in one stomach. It was not possible to use the otoliths of *Citharichthys* sp. and *Anchoa* sp. to estimate the size and biomass; thus, these prey were not included in subsequent analysis. Due to the exclusion of the above-mentioned species, the Trichiuridae family presented the highest biomass (51.8%), followed by Sciaenidae (28.1%) and then Engraulidae (7.2%). The family Trichiuridae was represented by one species, *Trichiurus lepturus* (Linnaeus, 1758), which had an abundance of 16.8% and a biomass of 51.8%. The family Sciaenidae had the highest species richness (n=5), with *Micropogonias furnieri* (Desmarest, 1823) and *Isopisthus parvipinnis* (Cuvier, 1830) representing 26.9% and 5.0% of the total amount of prey and 23.6% and 1.7% of the total estimated biomass respectively. *Cetengraulis edentulus* (Cuvier, 1829), family Engraulidae, was 14.6% of the abundance and 4.6% of the total biomass of prey. *Mugil* cf. *curema* was also significant, having an abundance of 8.9% and a biomass of 7.2% (Table 1).

Relative importance and niche breadth

The four most important prey species in the diet of the Guiana dolphin, as identified by the Index of Relative Importance (IRI), comprised 67.2% of the abundance and 87.2% of the estimated total biomass. These species were *Trichiurus lepturus*, *Micropogonias furnieri*, *Cetengraulis edentulus* and *Mugil* cf. *curema*. The first two, *T. lepturus* and *M. furnieri*, represented 75.4% of the total biomass. Biomass was the main factor that contributed to the high IRI of *T.

lepturus, *M. furnieri* and *Mugil* cf. *curema*, whereas abundance increased the IRI of *M. furnieri* and *C. edentulus*. In relation to families, the highest IRI was observed for Trichiuridae, followed by Sciaenidae and then Engraulidae. It is important to note that almost 195 specimens of *Citharichthys* sp. occurred in one stomach, which suggests the effect of the small sample size and/or a possible significance of this prey. Levins' measure of niche breadth was 0.51. This value is exactly between the minimum value (0) and the maximum value (1).

Prey size

It was possible to observe a wide range of prey sizes (1.4 to 92.8 cm); however, 77.4% of all prey were smaller than 20 cm. The average length of prey was 21.4 cm (±21.2 cm). The largest and the smallest fish specimens were *Trichiurus lepturus* (92.8 cm) and *Chloroscombrus chrysurus* (Linnaeus, 1766; 1.4 cm) respectively. *T. lepturus* presented the largest average size (64.0±17.6 cm), followed by *Mugil* cf. *curema* (18.3±3.8 cm) and then *Porichthys porosissimus* (Cuvier, 1829) (17.6±7.5 cm). Prey weight ranged from 0.8 g to 511.3 g and averaged 60.3 g (±95.3 g). However, the majority of prey (71.9%) weighed less than 50 g. One *Trichiurus lepturus* was the heaviest prey recorded (511.3 g) and this species also showed the largest average weight (183.3±129.3 g), followed by *P. porosissimus* (76.9 ± 86.4 g) and then *Orthopristis ruber* (Cuvier, 1830) (52.5±9.7 g). *Ctenosciaena gracilicirrhus* (Metzelaar, 1919) had the lowest average weight (6.5 g), and *Stellifer* cf. *rastrifer* was the smallest prey specimen (0.8 g; Table 1).

Prey habits

Prey species came from estuarine, coastal and oceanic habitats. A wide range of vertical use by the prey was observed, including pelagic, demersal bentho-pelagic and nektonic species. The represented ecological guilds showed a functional diversity of prey; for example, prey included species that were occasional marine visitors to estuaries, migrating species and species that were temporarily visiting as juveniles.

Based on the cluster analysis, at least four groups of prey were observed in relation to these descriptors, and three species formed an "outlier group" (Fig. 2). This outlier group includes species that do not form fish schools, are benthic, inhabit estuaries and are occasional marine visitors. Prey from the second group form small fish schools, are nektonic/demersal, have coastal habitats and use the estuaries and bays as juveniles. The third group is similar to the second group, although prey in the third group form moderate to large schools. The fourth group includes species that form fish schools of moderate to large size, are pelagic and are either estuarine residents or occasional marine visitors. Finally, the fifth group includes prey species that
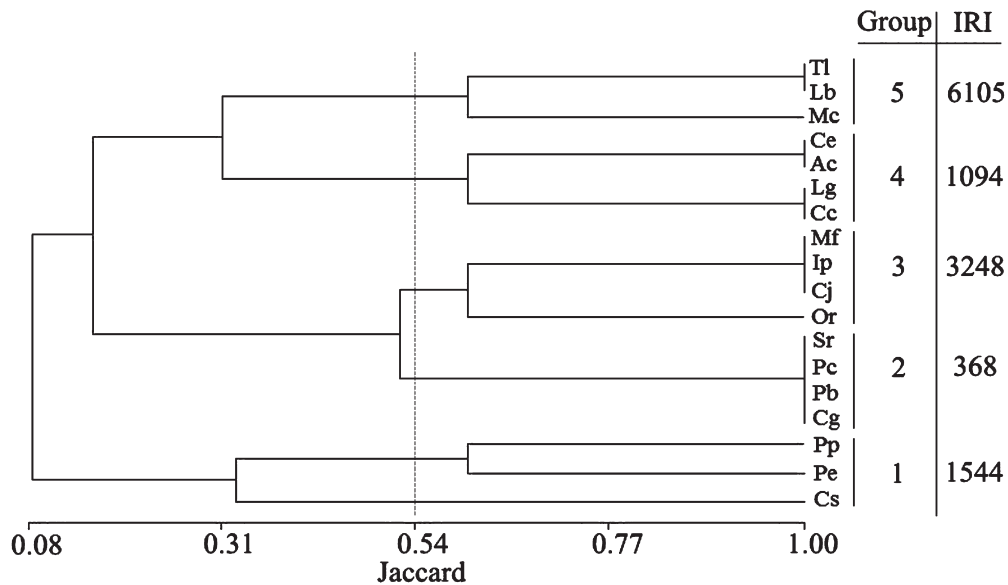
FIG. 2. – Dendrogram of prey species of the Guiana dolphin in Norte Bay in relation to behavior descriptors. Samples were clustered using the Jaccard index. The cophenetic correlation was 0.903. Abbreviations: Index of Relative Importance (IRI). Prey codes in Table 1. Each group is described in the text.

form large to moderate schools, are pelagic or bentho-pelagic and are either occasional marine visitors or visitors during migration periods.

The four most important prey species are in the fifth (Tl and Mc), fourth (Ce) and third groups (Mf). Considering only these prey groups, Guiana dolphins mainly eat prey that form moderate to large schools, inhabit estuarine and coastal habitats, have a wide range of vertical distribution and visit the estuary occasionally, either as juveniles or during defined migrations. Nevertheless, the other groups were also well represented in the dolphin's diet. This confirms flexibility and opportunism in the feeding strategies of the Guiana dolphin.

DISCUSSION

The piscivorous habit observed in Guiana dolphins from Norte Bay has been described in other studies of this species along the Brazilian coast (e.g. Borobia and Barros, 1989; Di Beneditto *et al.*, 2001; Santos *et al.*, 2002; Cremer, 2007; Di Beneditto and Siciliano, 2007), and is common in the diet of small cetacean species (e.g. Young and Cockcroft, 1994; Barros and Wells, 1998; Silva, 1999; Santos and Haimovici, 2001; Amir *et al.*, 2005; De Pierrepont *et al.*, 2005). The cephalopod species *Lolliguncula brevis* was frequent in the present study, but its contribution in terms of biomass was minimal (0.7%). *L. brevis* is a typical coastal and estuarine species that is cited as a frequent prey of the Guiana dolphin (Santos and Haimovici, 2001); however, this prey species is of small relative importance. Crustaceans are seldom recorded in the diet of the Guiana dolphin. Accordingly, we found only one species of shrimp in the diet of the Norte Bay dolphin population.

Although a diversity of prey was observed in the diet, two species were apparently very important: *T. lepturus* and *M. furnieri* had the highest IRIs and represented 75% of the total biomass. Both species were common in other studies on the diet of the Guiana dolphin. *T. lepturus* was also the most important prey species in the diet of Guiana dolphins from the central and northern coasts of the state of Rio de Janeiro, and *M. furnieri* was among the top five most important prey species along the central coast of the same state (Di Beneditto *et al.*, 2001; Di Beneditto and Siciliano, 2007). *C. edentulus* and *Mugil* cf. *curema* were other important prey species occurring in Norte Bay. *C. edentulus* was the fourth most important prey species for Guiana dolphins from Paranaguá Bay (Zanelatto, 2001). *Mugil* cf. *curema* showed little importance in all the areas it was registered (Di Beneditto *et al.*, 2001; Di Beneditto and Siciliano, 2007). Due to the importance of *T. lepturus*, the Trichiuridae family showed the highest IRI, followed by Sciaenidae (with six species) and Engraulidae (with three species). The importance of these families as prey of the Guiana dolphin is supported by the literature. One or more of these species is commonly identified as the most important prey in the diet of the studied populations (e.g. Di Beneditto *et al.*, 2001; Zanelatto, 2001; Oliveira, 2003; Di Beneditto and Siciliano, 2007; Pansard, 2009).

The possibility of a methodological bias that overestimates the importance of these families should be taken into consideration. It is known that Sciaenidae otoliths are larger than the otoliths from other families (Corrêa and Vianna, 1993). This feature could slow down their digestion rate, and therefore increase their chances of being identified and measured. Thus, Sciaenidae's importance for the Guiana dolphin's diet may

be overestimated (review in Pierce *et al.*, 1991). Similarly, *T. lepturus* may also be overestimated because of the easy identification of its supraoccipital bone. Finally, a predatory habit of a prey may lead to the overestimation of a prey species. For example, the fact that *T. lepturus* eats sciaenid and engraulid fish (Martins *et al.*, 2005) suggests the possibility of a secondary contamination (Fitch and Brownell, 1968). Independently, the importance of these families in the diet of the population studied here was remarkably high.

Although the size and weight of prey varied, there was a prevalence of prey smaller than 20 cm and lighter than 50 g. The apparent higher consumption of smaller prey could be due to their high availability; for example, estuaries and coastal bays are generally occupied by marine species at a juvenile stage or by small-sized resident species (Chaves and Bouchereau, 2000). A diversity of prey sizes has been observed in other areas, also with a prevalence of small-sized juvenile prey (Di Beneditto *et al.*, 2001; Santos *et al.*, 2002; Di Beneditto and Siciliano, 2007). *T. lepturus* was the largest prey observed, probably due to its elongated ribbon-shaped body (Figueiredo and Menezes, 2000). *Porichthys porosissimus* and *Mugil* cf. *curema* had the second largest length and weight respectively. Some of these specimens, and others like *M. furnieri* and *O. ruber*, could be considered adults (according to Menezes and Figueiredo, 1980, 1985; Figueiredo and Menezes, 1998), but most were juveniles.

Guiana dolphins most commonly eat species that form moderate to large schools, inhabit estuarine and coastal habitats, and have a wide range of vertical distribution and a functional relationship with the estuary. Nevertheless, analyses of the behavior and habitat of prey suggest that there is some flexibility in the feeding behavior of the Guiana dolphin. The diversity of prey behavior has been reported previously for this species (Di Beneditto *et al.*, 2001; Santos *et al.*, 2002). The importance of prey that form schools, however, has not received much attention in previous studies. Foraging on aggregated prey could be advantageous for dolphins, as it is likely to increase rates of both prey encounter and prey capture. In a study with *T. truncatus*, Gannon *et al.* (2005) suggested that passive listening, instead of energetically costly echolocation, could be used to locate prey. This hypothesis explains the high occurrence of noisy prey in the diet of *T. truncatus* (Barros and Wells, 1998), and it may also explain the high occurrence of prey that form moderate to large schools, given the sounds produced by schools.

The prevalence of certain species in the diet was corroborated by a niche breadth analysis that showed an intermediary value. Oliveira (2003) identified a similar result using the same analysis for the Guiana dolphins from Paranaguá/Cananéia. Considering our results, along with existing knowledge of local fish communities, we suggest that the Guiana dolphin population from Norte Bay has a wide diet range although with an apparent opportunistic feeding habit, consuming prey with high availability or accessibility in their habitat. Care should be taken when interpreting our results since the large temporal scale suggests a possible change in local communities that may be reflected in diet composition. However, our results still represent an important contribution concerning this small population at the southernmost limit of the species distribution, and are in accordance with other studies on the species. Further study is needed to better understand some diet variations, resource availability dynamics, and the feeding ecology of the Guiana dolphin.

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