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Feeding habits of the shortnose guitarfish, *Zapteryx brevirostris* (Müller and Henle, 1841) (Elasmobranchii, Rhinobatidae) in southeastern Brazil

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(With 3 figures)

Abstract

The feeding habits of the shortnose guitarfish, *Zapteryx brevirostris,* were studied based on 382 specimens from the northern São Paulo coast, southeast Brazil. The diet showed a predominance of crustaceans (carideans and amphipods), polychaete annelids, and occasionally small fish, sipunculids, and cephalopods. The diets of males and females were similar; however, differences in the proportion of prey items were found among juveniles, subadults, and adults. Differences in the ingestion of prey items were found during the year, probably influenced by oceanographic parameters, although in general, the species feeds mostly on crustaceans and polychaetes.

Keywords: Batoidea, diet, stomach contents, São Paulo.

Hábito alimentar da raia-viola-de-focinho-curto, *Zapteryx brevirostris* (Müller e Henle, 1841) (Elasmobranchii, Rhinobatidae) no sudeste do Brasil

Resumo

Foram estudados os hábitos alimentares da raia-viola-de-focinho-curto, *Zapteryx brevisrostris,* com base em 382 espécimes coletados no litoral norte de São Paulo, sudeste do Brasil. A dieta mostrou predominância de crustáceos (carídeos e anfípodes), anelídeos poliquetos e ocasionalmente pequenos peixes, sipunculídeos e cefalópodes. A dieta de machos e fêmeas mostrou-se similar, entretanto, juvenis, subadultos e adultos demonstraram diferenças na composição de presas. As frequências dos itens diferiram ao longo do ano, provavelmente influenciadas por fatores oceanográficos, embora, em geral, a espécie se alimente predominantemente de crustáceos e poliquetos.

Palavras-chave: Batoidea, dieta, conteúdo estomacal, São Paulo.

1. Introduction

Elasmobranch fishes are top predators, feeding on a wide range of prey items. The feeding habits of batoids (skates and rays) involve predation on benthic communities, especially on small- to medium-sized fish and numerous invertebrate taxa (Ellis et al., 1996). Along the Brazilian coast, a few batoid species are caught for commercial purposes, mostly as bycatch of the shrimp trawling and gillnet fisheries (Graça Lopes et al., 2002; Chaves et al., 2003).

Batoid feeding habits have been the subject of several studies (McEachran et al., 1976; Muto et al., 2001; Brickle et al., 2003; Braccini and Perez, 2005; Robinson et al., 2007; Moura et al., 2008). The study of feeding ecology and habitat use of these fishes provides the knowledge of basic aspects of their biology which is important to understand the dynamics and ecology of populations and communities (Krebs, 1998).

Members of the f Rhinobatidae, distributed mostly along tropical coastal waters of the Atlantic, Indian and Pacific Oceans, are often important components of coastal marine ecosystems (Kyne and Bennett, 2002). They live in shallow tropical and subtropical coastal waters of all oceans, with four genera and 40 species known. (Bigelow and Schroeder, 1953; McEachran and Carvalho, 2002). In Brazil, two genera and four species are known: *Zapteryx brevirostris (*Müller and Henle, 1841); *Rhinobatos percellens* (Walbaum, 1792); *Rhinobatos horkelli* Müller and Henle, 1841; and *Rhinobatos lentiginosus* Garman, 1880 (Menezes et al., 2003).

The shortnose guitarfish *Zapteryx brevirostris* is a small endemic species, about 550 mm in total length, inhabiting sandy bottoms of coastal waters (2 to 60 m deep), in the western South Atlantic, from Rio de Janeiro to Argentina (Figueiredo, 1981; Carvalho Filho, 1999). It is a viviparous lecithotrophic species, producing between two and eight embryos per litter, measuring 130 to 160 mm in total length (Batista, 1992). Males and females mature at 400-473 mm and 370-522 mm, respectively (Batista, 1992; Abilhoa et al., 2007). Despite the wide distribution and abundance in the Brazilian coast, trophic aspects of *Z. brevirostris* are poorly known, representing an obstacle for implementations of actions aimed at the management and conservations of natural resources.

A few studies deal with the feeding biology of *Z.brevirostris*, such as the study by Castello (1971), in which the diet represented only a percentage of the organisms found in the stomach, Soares et al. (1992) compared the feeding habits of *Z. brevirostris* with five other species of rays collected along the inner shelf of Ubatuba, Bornatowski et al. (2005) studied the food composition of this species captured on the coast of Santa Catarina and Barbini (2006) researched in the Buenos Aires Province and Uruguay coast.

Because of the sparse available information on trophic aspects in different seasons and during ontogeny, the present study analysed the dietary changes with seasonal variables and ontogeny, and compared the diets of males and females of *Z. brevirostris* caught on the northern São Paulo coast, southeast Brazil.

2. Materials and Methods

The study was conducted in two regions, Ubatuba, (23° 26'; 23° 31' S and 44° 55'; 45° 03' W) and Caraguatatuba (23° 36'; 23° 43' S and 45° 20'; 45° 00' W). Ubatuba has an open shoreline, with several small islands; whereas Caraguatatuba is located in a sheltered bay.

The northern coast of Sao Paulo is subject to the strongly seasonal influence of three water masses, which together modify the temperature, salinity, and nutrients, and consequently the presence and abundance of organisms (Carvalho Filho, 1999).

Samples were obtained monthly between January and December 2002, along seven transects at depths between 5 and 35 m (Figure 1), from small shrimp trawlers. All specimens were measured for Total Length (TL) and dissected to check the gonad stage. Maturity categories were determined according to clasper calcification in the males and follicle maturation in the females, as described by Stehmann (2002).

Stomachs were removed, frozen, and analysed in the laboratory. The importance of prey items was evaluated using the percentage frequency of occurrence (%FO) and the percentage in number (%NF) (Hyslop, 1980). Prey species were identified to the lowest taxonomic level possible and quantified from their remains (e.g., complete prey items, otoliths, skull bones, crustacean exoskeletons) according to Braga et al. (2005), Costa et al. (2003), and Amaral and Nonato (1996). Only a few individuals could be identified to species level, but because of their importance as food items they are included in Table 1. Prey items are listed by taxonomic criteria, at the lowest taxonomic level possible.

In order to determine differences (seasonal and ontogenetic variations) of prey consumed, the Kruskal-Wallis test was used (Zar, 1999). The Mann-Whitney U test with a Bonferroni adjustment was used to compare feeding of females and males. Statistical analyses were conducted with PAST version 1.99. All statistical tests used a significance level of 5%.

Morisita's Simplified Index of Similarity adapted by Horn (1966) was used with the statistical routine PAST 1.99 (Hammer and Harper, 2003), to assess the possible feeding overlap among major zoological groups (crustaceans, polychaetes, fish, and cephalopods). According to Langton (1982), values obtained by the overlap index range from 0 to 1; values between 0 and 0.29 indicate low overlap; values between 0.30 and 0.59 indicate partial overlap; and values between 0.60 and 1.0 indicate a high overlap between diets.

Prey diversity was calculated for all seasons, using the Shannon–Weiner index (Zar, 1999), with PAST 1.99 (Hammer and Harper, 2003). These indices were calculated for the species and major groups.

The diets from the two areas were analysed separately. However, because they did not differ significantly ($p < 0.05$), the data were pooled.

3. Results

The maturity categories used were juveniles (134-408 mm), subadults (386-452 mm) and adults (380-540 mm). A total of 382 individuals were analysed, measuring between 134 and 536 mm TL; of which 229 were juveniles, 18 were subadults, and 135 were adults. The distribution of total length frequencies was bimodal,

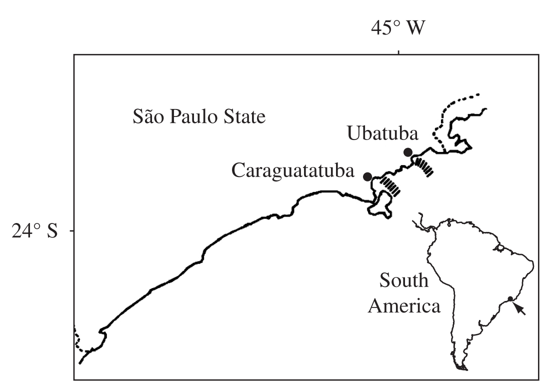

Figure 1. Map of the sampling locations of *Zapteryx brevirostris* at Ubatuba and Caraguatatuba, southeast coast of Brazil.

Table 1. Prey items of *Zapteryx brevirostris*: frequency of occurrence (**%FO**) and percentage in number (**%NF**) for the major prey taxa and identifiable dietary categories.

		Summer 01 n = 56		**Autumn n = 49**		**Winter n = 138**		**Spring n = 113**		**Summer 02 n = 26**		**Total n = 382**	
		%FO	%NF	%FO	%NF	%FO	%NF	%FO	%NF	%FO	%NF	%FO	%NF
Crustacea												**99.5**	**87.9**
Caridea	Hippolytidae	53.4	10.8	70.0	43.1	91.3	66.9	61.1	16.2	50.0	4.3	71.1	41.6
Amphipoda		72.4	32.1	58.0	27.1	48.5	12.4	74.3	22.8	73.0	27.3	62.6	19.8
	Gammaridea												
	Ampelisca sp.												
	Hiperiidae												
	Caprellidae												
Cumacea	Diastylidae	13.8	5.1	14.0	3.0	26.8	5.6	65.5	29.8	73.0	36.3	37.6	13.5
Brachyura		65.5	12.3	18.0	4.9	11.6	1.4	38.9	9.5	57.7	18.2	31.7	6.3
	Portunidae												
	Portunus sp.												
	Callinectes sp.												
	Majoidea												
	Libinia sp.												
	Leucosiidae												
	Persephona sp.												
Isopoda		43.1	7.7	26.0	3.8	22.4	3.6	33.6	8.8	26.9	3.8	29.6	5.3
Stomatopoda		5.2	0.6	4.0	0.0	0.0	0.7	4.4	0.3	7.7	0.5	3.1	0.2
Ostracoda		0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera		0.0	0.0	0.0	0.1	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
Sergestoidea		0.0	3.5	0.0	0.3	4.0	0.5	5.0	0.5	8.8	0.0	4.1	0.5
Penaeoidea		0.0	0.0	0.0	0.0	0.9	0.3	5.8	0.7	4.4	0.9	4.9	0.4
	Penaeidea												
	Artemesia longinaris												
	Rimapenaeus constrictus												
	Xiphopenaeus kroyeri												
	Sicyoniidae												
	Sicyonia dorsalis												
	S. typica												
Polychaeta		**62.0**	**21.6**	**50.0**	**13.9**	**39.8**	**7.1**	**60.2**	**9.5**	**42.3**	**7.2**	**50.6**	**10.6**
	Afroditacea												
	Sigalionodae												
	Polynoidea												
Sipuncula		**34.4**	**2.8**	**16.0**	**3.2**	**4.3**	**0.3**	**7.9**	**0.5**	**7.9**	**0.9**	**12.4**	**0.9**
Teleostei		**13.7**	**2.8**	**10.0**	**1.1**	**2.1**	**0.3**	**0.8**	**0.4**	**0.0**	**0.5**	**4.4**	**0.7**
Cephalopoda		**6.9**	**0.4**	**2.0**	**0.2**	**1.4**	**0.0**	**1.7**	**0.0**	**3.8**	**0.1**	**2.6**	**0.2**

with a high proportion of juveniles (71%) in the total catch in Caraguatatuba, and adults in Ubatuba (53%) (Figure 2). No sexual segregation was observed in the two areas.

The diet in both areas together was composed of 5854 items (Table 1). Prey items were sorted into major categories to facilitate comparisons.

The narrow food spectrum of *Z. brevirostris* was represented mainly by shrimp (Caridea), amphipods (Gammaridae), and polychaetes (Figure 3). In general, the Kruskal Wallis test showed differences in the diet between juveniles, subadults, and adults ($H = 8.25$ $p = 0.01$ for %NF; $H = 9.63$ $p = 0.008$ for %FO). However, when comparing the ingestion of the both most important items, no significant differences were found ($p > 0.05$). Shrimp were the predominant item in relation %FO in all of the three categories; In relation of %NF, Amphipods dominated in the diet of juveniles, polychaetes in adult and brachyuran in subadults diets. The other items were observed with frequencies below or around 50% in these categories. Amphipods were found in several stomachs of adult specimens, although in low quantities (Figure 3).

Cumaceans and isopods were more important for juveniles, decreasing as predator body size increases (Figure 3). Fish were very occasional, and were important only for adult specimens (Figure 3). Although we found a high dietary overlap between individuals of different size classes, the diets of adults and subadults were more similar (CH 0.94 for %FO and CH = 0.90 for %NF) than between juveniles and subadults (CH = 0.81 for %NF; and CH = 0.84 for %FO). The lowest values occurred between juveniles and adults in relation to frequency of occurrence (CH = 0.79).

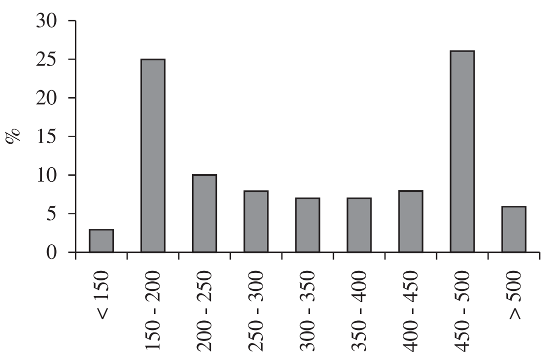

Figure 2. Length distribution of *Zapteryx brevirostris* in southeastern Brazil (n = 382).

The diets of males and females did not differ significantly ($H = 1.8$ $p = 0.2$ for %NF and $H = 0.5$ $p = 0.48$ for %FO), with a high dietary overlap between males and females (CH = 0.97 for %NF; CH = 0.98 for %FO).

Seasonal changes were observed in the prey items ($H = 10.7$ $p = 0.02$), but not in relation to numerical frequency ($H = 3.4$ $p = 0.48$). In summer 01, amphipods, brachyurans, and polychaetes were the predominant items ingested. Isopods were found in several stomachs during the year, but mainly in summer (Table 1). Fish, sipunculids, and cephalopods were found with high importance in summer samples. Summer 01 was the most diverse period (Table 2).

In autumn and winter, carideans, amphipods, and polychaetes were the predominant items. Remarkably, penaeoids were found only in autumn and winter samples. The species found were *Artemesia longinaris*, *Rimapenaeus constrictus, Sicyonia dorsalis, S. typical,* and *Xiphopenaeus kroyeri.* Interestingly, some carideans eaten in fall, spring, and mostly during winter were carrying eggs. In winter the lowest values of prey diversity were found (Table 2). In spring and summer 02, cumaceans and amphipods were the most important item ingested, and also polychaetes and brachyurans were found abundantly (Table 1).

The seasonal diets showed similarity between summer 02 and spring, and between autumn and winter. The lowest values of similarity were between winter and summer 02. (Table 3).

4. Discussion

The presence of crustaceans in the stomach contents of batoid elasmobranchs is relatively common, as found in several other studies, for instance of *Z. brevirostris* (Soares et al., 1992), *Psammobatis extenta* (Garman, 1913), and *Rioraja agassizii* (Müller and Henle, 1841) for the same area (Muto et al., 2001); *P. extenta* in Argentina (Braccini and Perez 2005); *Raja rhina* Jordan and Gilbert, 1880 in California (Robinson et al., 2007); *Z. brevirostis* on the Argentina and Uruguay coasts (Barbini, 2006);

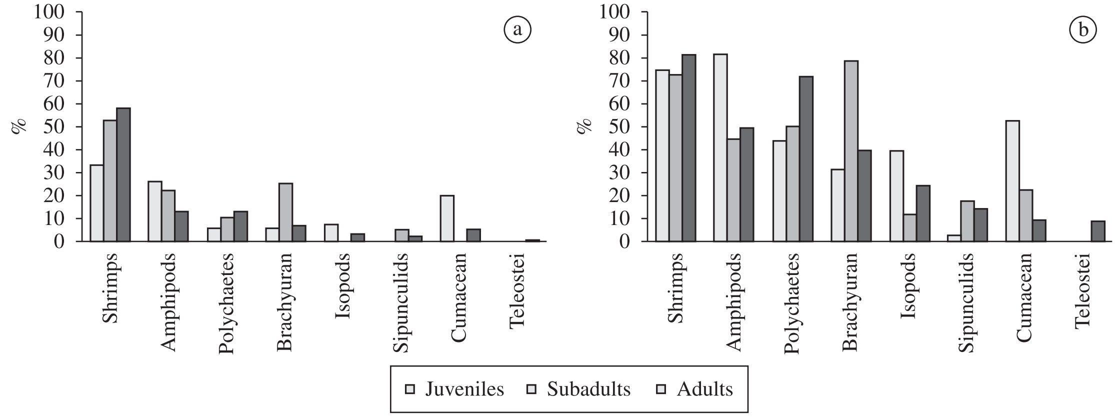

Figure 3. Diets of juveniles, subadults, and adults. Percentages in a) number; and b) frequency of occurrence.

and *R. undulata* Lacépède, 1802 off the coast of Portugal (Moura et al., 2008). Carideans and gammarideans were the main prey groups consumed by both sexes and all size classes of *Rhinobatos horkelli* (Muller and Henle, 1841) analysed in the state of Rio Grande do Sul in southern Brazil (Lessa, 1982).

According to Santos and Pires-Vanin (2004), the most diverse benthic fauna in the Ubatuba region is composed by crustaceans. Benthic polychaetes are another important component of the local fauna, and are dominant where the sandy bottom is the main substrate between 10 and 40 m (Pires-Vanin, 1993). Soares et al. (1992), Bornatowski et al. (2005), and Barbini (2006) also observed the predominance of crustaceans and polychaetes ingested by *Z. brevirostris* caught off the coast of Ubatuba, the Santa Catarina coast, and the Argentina and Uruguay coasts respectively.

The very small numbers of fish and cephalopods found in the stomachs suggest that *Z. brevirostris* does not search for prey in the water column just above the bottom, although several families of demersal fishes, mainly Sciaenidae, Engraulididae, and Carangidae, and squid (*Lolligungula brevis*) are very abundant in coastal waters of São Paulo (Graça-Lopes et al., 2002). The reason why *Z. brevirostris* preys mainly on crustaceans and polychaetes and not fish and squids may be associated not only with their abundance and size of the prey, but mostly because they can dig into the substratum and capture infaunal prey by suction (Wilga and Motta, 1998).

Table 2. Seasonal diversity of prey items calculated by the Shannon-Weiner Index (H'), obtained from percentage in number (%NF) and frequency of occurrence (%FO).

Prey items by season	%NF (H')	%FO (H')
Summer 1	H' = 1.98	H' = 2.27
Autumn	H' = 1.65	H' = 2.19
Winter	H' = 1.19	H' = 1.97
Spring	H' = 1.85	H' = 2.25
Summer 2	H' = 1.62	H' = 2.21

Table 3. Niche overlap calculated by Morisita's Simplified Index of Similarity (CH) percentage in number (%NF), and frequency of occurrence (%FO).

Groups compared	(CH) %NF	(CH) %FO
Summer 1/Autumn	0.88	0.91
Summer 1/Winter	0.73	0.77
Summer 1/Spring	0.85	0.84
Summer 1/ Summer 2	0.81	0.85
Autumn/Winter	0.92	0.94
Autumn/Spring	0.82	0.87
Autumn/ Summer 2	0.68	0.83
Winter/Spring	0.76	0.86
Winter/ Summer 2	0.64	0.80
Spring/ Summer 2	0.94	0.97

The diets of the three ontogenetic stages showed differences in the prey proportion, although generally, it is clear that all size classes prey upon crustaceans and polychaetes, apart from other benthic organisms. Nevertheless, substitution of prey items according to body size was observed in skates (Rajidae) in the same region (Muto et al., 2001), most remarkably for amphipods, which decreased in importance for adults, as also observed for other skates (McEachran et al., 1976; Braccini and Perez, 2005; Barbini, 2006; Moura et al., 2008). According to Lessa (1982), juveniles of the guitarfish *R. horkelli* prey on carideans and polychaetes, while adults prey mainly on brachyurans and polychaetes during the year.

The increasing importance of fish with increased predator size is observed in several other batoids, as in the Gulf of Gabès in Tunisia for two species of *Rhinobatos* (Capapé and Zaouali, 1979), *Raja radiata* (Berestovskiy, 1989), *R. agassizii* in Ubatuba (Muto et al., 2001), *Aptychotrema rostrata* (Shaw, 1794) in Australia (Kyne and Bennett 2002), *R. rhina* in California (Robinson et al., 2007), and this study. Probably fish are a more high-energy food, and larger rays can catch larger and mobile prey as a consequence of the increase in size of the pectoral fin. Kyne and Bennett (2002) mentioned the increased mouth-opening capacity associated with the ingestion of fish, as another factor in the increase in their frequency in the diet.

Several authors have compared the diet of skates between sexes (Capapé and Zaouali, 1979; Braccini and Perez, 2005; Robinson et al., 2007), and in the majority of species, males and females fed on similar prey items. For skates, where females and males occur in the same habitat, grow to similar sizes and have similar predatory capabilities, it is expected that males and females have similar diets and ecological roles (Martin et al., 2007).

A few studies have analysed the seasonal changes of diet in skates and rays, including Muto et al. (2001) with *R. agassizzi* and *P. extenta* along the continental shelf of Ubatuba, Martin et al. (2007) with *Psammobatis bergi,* and Braccini and Perez (2005) with *P. extenta*, both on the Argentina coast. Seasonal patterns of diet are directly related to the abundance of prey (Martin et al. 2007), and the density and diversity of organisms are strongly influenced by oceanographic changes (Pires-Vanin, 1992). According to Moura et al. (2008), seasonal differences in food sources are common, especially in coastal species, probably because of the greater influence of water masses.

Petti and Nonato (2000), Pires-Vanin (1992, 2001), and Santos and Pires-Vanin (2004) found indications of macrofauna seasonality. In summer, temperature and salinity decrease because of the influence of the South Atlantic Coastal Water. Epifaunal species such as amphipods and polychaetes are quite abundant in this period along the coast of São Paulo, probably because they are more tolerant to environmental changes (Pires-Vanin, 1993). The high proportion of polychaetes eaten by *Z. brevirostis* in summer may also be associated with increased anthropogenic activities on the coast. Polychaetes are considered a good indicator of organic contamination, because of their ability to adapt to the effects of environmental stress (Santos and Pires-Vanin, 2004).

Cumaceans showed high importance in summer, and are found mainly in high densities in this period and in this region (Petti and Nonato, 2000; Santos and Pires-Vanin, 2004). Brachyurans were more preyed upon in the spring and summer; however, Leite and Turra (2003) did not find clear patterns of seasonality of this group in the region.

In autumn, along the northern coast of São Paulo, there is a slight decrease in the abundance of prey in general; however, shrimp increase in density (Pires-Vanin, 1992, 2001). In winter, the entrance of Coastal Water (CW) brings large numbers of shrimp close to the coast, making them an important source of food. Winter cold fronts also increase current dynamics, churning the substrate and leaving the shrimp more exposed to predation (Pires-Vanin, 1993).

The occurrence of eggs in some carideans eaten in fall, spring, and mainly during winter, may indicate that they were approaching the coast for spawning, making them an abundant source of food. Muto et al. (2001) studying two rajoids in the same region, found that shrimp were the predominant food item in winter.

In conclusion, *Z. brevirostris* is a bottom-dwelling predator that during its different ontogenetic phases and the local oceanographic parameters, exploits the abundant local prey represented mainly by shrimp, amphipods, and polychaetes.

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