ARTÍCULO DE INVESTIGACIÓN / RESEARCH ARTICLE                    ZOOLOGÍA

# FEEDING HABITS OF *Paralonchurus brasiliensis* (PERCIFORMES: SCIAENIDAE) FROM SOUTH OF BRAZIL

## Hábitos Alimentarios de *Paralonchurus brasiliensis* (Perciformes: Sciaenidae) del sur del Brasil

**Mário Cesar SEDREZ** [1,2] *, **Germano Henrique Costa BARRILLI** [1]; **Evelise Nunes FRAGOSO-MOURA** [3]; **João Pedro BARREIROS** [4]; **Joaquim Olinto BRANCO** [1,5]; **José Roberto VERANI** [1,3].

[1] Programa de Pós-Graduação em Ecologia e Recursos Naturais, Universidade Federal de São Carlos; Rodovia Washington Luis, Km 235, CP 676, São Carlos, SP

[2] Instituto Federal de Santa Catarina - Rua dos Imigrantes, n° 445, Rau, Jaraguá do Sul/SC.

[3] Departamento de Hidrobiologia, Universidade Federal de São Carlos; Rodovia Washington Luis, Km 235, CP 676, São Carlos, SP

[4] CE3C /ABG – Centre for Ecology, Evolution and Environmental Changes/Azorean Biodiversity Group. University of the Azores, 9700-042 Angra do Heroísmo, Portugal.

[5] Universidade do Vale do Itajaí (UNIVALI), Escola do Mar, Ciência e Tecnologia, Rua Uruguai, 458 - Centro/ Itajaí - SC CEP: 88302-901.

* *For correspondence:* mario.sedrez@ifsc.edu.br

## ABSTRACT

Shrimp trawling directly impacts target species and non-target species, altering micro-habitats and marine trophic webs. Thus, the objective of the present research was to analyze the feeding habits of *Paralonchurus brasiliensis* as a tool to evaluate the impact of trawling on the food chains in marine environments, in the South Atlantic of Brazil. One thousand and nineteen stomachs of *P. brasiliensis* were dissected after being captured as bycatch of shrimp *Xiphopenaeus kroyeri*, in Penha, on the north central coast of Santa Catarina, Brazil. The number of stomachs was enough to describe the feeding habits of *P. brasiliensis*, characterizing it as a carnivorous species and predominantly invertivorous. They also revealed that this species has a diversified and constant diet, with greater consumption of polychaetes, crustaceans, and ofiuroides, among other components of the macrobentos, all closely related to the sediment. It was also found that the target species *X. kroyeri* is not an important prey in the diet of *P. brasiliensis*, despite occupying the same habitat. According to the present study, *P. brasiliensis* can be characterized as a demersal-benthic species, predator, opportunistic and broad trophic spectrum. This work contributes to the understanding of trophic chains of the coastal ecosystems, using the *P. brasiliensis* as a model.

**Keywords:** Accompanying fauna, Bottom trawling, conservation, fish, fisheries.

## RESUMEN

La pesca de arrastre de camarón afecta directamente a la especie de interes y a otras que no lo son, pero tambien quedan atrapadas, alterando los micro-hábitats y las vías tróficas marinas. Así, el presente estudio tuvo como objetivo analizar los hábitos alimentarios de *Paralonchurus brasiliensis*, como herramienta para evaluar el impacto de la pesca de arrastre sobre las cadenas alimentarias en ambientes marinos, en el Atlántico sur de Brasil. Se disecaron 1219 estómagos de *P. brasiliensis* capturados con "bycatch" del camarón *Xiphopenaeus kroyeri*, en Penha, litoral centro-norte de Santa Catarina, Brasil. El número de estómagos fue suficiente para la descripción de los hábitos alimentarios de *P. brasiliensis*, caracterizándola como una especie carnívora, predominantemente invertívora. Los resultados revelaron además que esta especie posee una dieta diversificada y constante, con mayor consumo de poliquetas, crustáceos y ofiuroides, entre otros componentes del macrobentos, todos íntimamente relacionados al sedimento. Se constató también que la especie de interes *X. kroyeri* no es una presa importante en la dieta de *P. brasiliensis*, a pesar de ocupar el mismo hábitat. De acuerdo con el presente estudio, *P. brasiliensis* puede ser caracterizada como una especie demersal bentónica, predadora, oportunista y de amplio espectro trófico. Este trabajo contribuye a la comprensión de las cadenas tróficas de los ecosistemas costeros, utilizando el caso de *P. brasiliensis* como modelo.

**Palabras clave**: Fauna acompañante, arrastre de fondo, conservación, peces, pesquerías.

Mário Cesar Sedrez, Germano Henrique Costa Barrilli, Evelise Nunes Fragoso-Moura, João Pedro Barreiros, Joaquim Olinto Branco, José Roberto Verani

## INTRODUCTION

Marine fishery generates an average of 38.5 million tons of bycatch per year worldwide, a number that represents more than 40 % of total catches (Davies *et al.*, 2009). In the South Atlantic and the Gulf of Mexico, the bycatch rates of shrimp fishery reach 64 % and Brazil accounts for about 60 % of all marine catches (Davies *et al.*, 2009, Keledjian *et al.*, 2014).

The adverse ecological impacts of fishing on marine ecosystems are widely recognized, resulting in a reduction of catches, especially in bottom trawling fishery (Alverson *et al.*, 1994; Kelleher, 2005; Davies *et al.*, 2009; Keledjian *et al.*, 2014).

In the state of Santa Catarina, southern Brazil, the largest national producer of fish and crustaceans from marine fisheries (IBGE, 2019), the situation is equally worrisome. In the municipality of Penha, our study site, the proportion between fish biomass and seabob shrimps (*Xiphopenaeus kroyeri* Heller, 1862) varies from 0.3:1 to 4.7:1 (Barrilli *et al.*, 2021b).

In this area, the sciaenid *Paralonchurus brasiliensis* (Steindachner, 1875), a non-targeted fish of low commercial value that is sympatric to *X. kroyeri*, represents the highest bycatch in terms of landed biomass (Branco *et al.*, 2005; Bail and White, 2007). *Paralonchurus brasiliensis* is an epi-benthic species that inhabits coastal regions of sandy-muddy bottoms, up to 100m deep, and has been reported all along the Western Atlantic from Panama to Argentina, including all the Brazilian shoreline (Menezes and Figueiredo, 1980).

*Paralonchurus brasiliensis* was identified in the stomach contents of top predators in coastal ecosystems, such as large fish (Trichiurids, Sharks and Rays) (Barbini and Lucifora, 2015), marine turtles (Awabdi *et al.*, 2013), marine birds (gannets and petrels) (Colabuono and Vooren, 2007) and marine cetaceans such as *Tursiops truncatus* Montagu, 1821 (Milmann *et al.*, 2016).

Previous studies of the stomach contents of *P. brasiliensis* revealed that its prey consisted mainly of crustaceans, echinoderms and polychaetes, being considered as a key species in marine food webs (Soares and Vazzoler, 2001; Branco *et al.*, 2005; Araújo *et al.*, 2014). Besides, *P. brasiliensis* has been shown to be a relevant bioindicator in studies on bioaccumulation and trophic transfer of trace elements along the marine food chains (Kehrig *et al.*, 2013).

In view of this, a concern arises especially with the impact of trawling fishery on non-target species and its reflex on the trophic chains in coastal ecosystems. As feeding is determinant in the abundance and structure of the fish community (Piet *et al.*, 1998), detailed studies of their natural diet contribute to understanding their trophic ecology and existing functional groups (Criales-Hernández *et al.*, 2006).

Thus, through the study of the feeding habits of a species, it is possible to define its functional role in the food chains (Barreiros and Santos, 1998), besides allowing inferences about the availability and accessibility of organisms to food resources (Wootton, 1990).

According to Pillay (1952), the best method to assessing the food habits of a species is the analysis of the stomach contents. This procedure is common in fish trophic ecology studies. For this, Berg (1979) suggests the use of a large number of samples because, although tropical fish exhibit great trophic plasticity, their diet may vary with season, latitude and ontogeny.

Several methods of analysis of the stomach contents of fish were developed to better understand the food spectrum, pointing out the importance of each item and the probable interrelationships associated with environmental characteristics. The most used traditional methods for the analysis of fish diets are numerical, volumetric, gravimetric, as well as subjective estimation techniques such as the point system, used in analyzes of the stomach volume (Hynes, 1950; Hyslop, 1980). In addition to these methods, it is common to use the relative importance index (IRI) to infer the importance of prey (Pinkas *et al.*, 1971) and, more recently, stable isotopes of carbon and nitrogen (Buchheister and Latour, 2010). However, regardless of the chosen method, the most appropriate is the one that allows a better comparison and interpretation of the results (Berg, 1979).

Despite the ecological importance of *P. brasiliensis* found in the shrimp fishery area (*X. kroyeri*), studies on the feeding habits of this species are still not well documented (Robert *et al.,* 2017). Thus, in this study we analyze the feeding habits and trophic ecology of *P. brasiliensis* in the South Atlantic of Brazil as a contribution to understanding its biology.

## MATERIALS AND METHODS

### Study area

The study was conducted in the municipality of Penha (26° 46' 10" S; 48° 38' 45' W), Santa Catarina, Brazil (Fig. 1).

### Sampling

Sampling of *Paralonchurus brasiliensis* (Steindachner, 1875) followed the methodology adopted by Branco *et al.* (2005) and modified by Sedrez *et al.* (2013), under license from SISBIO N ° 324642.

The samples were composed of 1219 specimens collected between July/2013 and June/2014 through monthly dragging, lasting 30 minutes each, and in the 10, 20, and 30-meter isobaths (Fig. 1). In these places, small-scale fishing fleets operate, which obtain shrimp of the species *X. kroyeri* as their main resource.

The weight of each specimen of *P. brasiliensis* was recorded by means of a semi-analytical electronic scale (0.01 g of precision) and its total length was measured by an ichthyometer (0.1 cm of precision). The background water
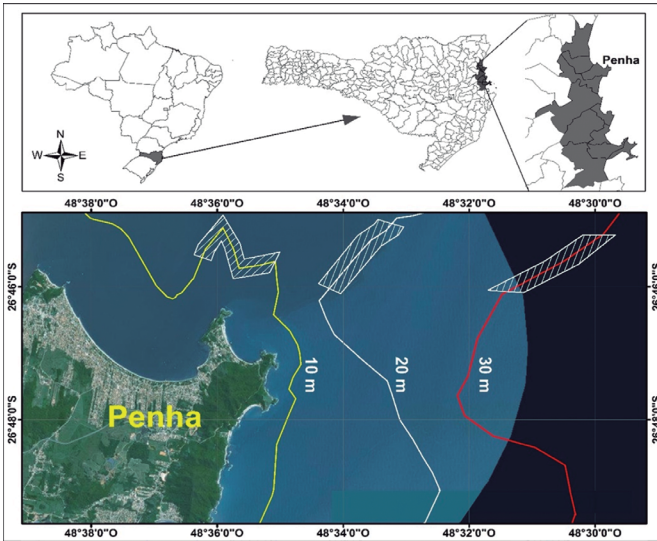
**Figure 1.** Trawling areas used for the *Xiphopenaeus kroyeri* shrimp in Penha, South Brazil. Isolines show isobaths of 10, 20 and 30 m and the cross-sectional area where our sampling was obtained.

was collected with the vertical van Dorn bottle and the temperature measured by a thermometer (0.1 °C precision) and the salinity determined with an optical refractometer (0.5 % precision). The specimens were packed in plastic bags, identified, kept in isothermal boxes with ice in order to stop digestive processes, transported to the laboratory and frozen. For analyzes of the stomach contents, they were thawed at room temperature and the stomachs removed, the digestive tube being sectioned between the esophagus and the pyloric valve. Then, the stomachs were opened, their contents removed in a Petri dish and examined macroscopically.

The items found were identified using specific guides and those in which the degree of digestion did not permit identification were considered as unidentified organic matter. Inorganic matter such as sand was also quantified.

### Sample representativeness

In order to evaluate the sample sufficiency of the food items found in the dissected stomachs, the food items accumulation curve was plotted as a function of the number of stomachs accumulated, following the methodology of Colwell and Coddington (1994) with the Jackknife 2 estimator (Palmer, 1991).

### Diet description

The composition of the diet was described according to the methodology used by several authors (*e.g.* Branco *et al.*, 2005; Machado *et al.*, 2014), applying a quantitative method, the Points Method (PM), a qualitative method, the Frequency of Occurrence (FO) used by Hynes (1950), Berg (1979), Williams (1981), Wear and Haddon (1987) and Haefner Jr (1990) and a combined method, the Alimentary Index (IAi) of Kawakami and Vazzoler (1980).

For PM, five degrees of repletion were adopted, and the respective percentage points were attributed: empty (0.00 %), partially empty (<0.25 %), medium (<0.50 %), partially full (<0.75 %) and full (1.00 %), according to the volume of food items of the stomach contents of each specimen.

The percentage points totaled for each food item "i" (% PM) were expressed according to Berg (1979) and Williams (1981):

$$\% \ PM = a_{ij} / A * 100$$

where, PM = Points Method; $a_{ij}$ = number of points of the food item "i" in the stomachs examined; A = total number of points for all items.

The relative FO of each food item "i" (% FO) was obtained through the equation:

$$\% \ FO = n_i / N * 100$$

where, FO = Frequency of Occurrence; $n_i$ = number of stomachs containing item "i"; N = total number of analyzed stomachs.

The importance of each food item in the diet, the Alimentary Index (IAi) was calculated according to the equation proposed by Kawakami and Vazzoler (1980):

$$IAi = FO * PM / \sum_{i=1}^{n} (FO * PM)$$

where, IAi = Alimentary Index; i = 1, 2, 3 ... number of food item; FO = frequency of occurrence of the item "i" in %; PM = total of the average points of item "I".

The calculated variables (% FO, % PM and % IAi) quantify the importance of each item in the diet of the species under study, considering the volume occupied in the stomach and the amount of different food items (Castro *et al.*, 2015). With this method, we estimate the food preference of the species *Paralonchurus brasiliensis*.

For the analysis of the general composition of the food items, the groups with IAi less than 0.01 % were grouped as Others, in order to facilitate the interpretation of the results and provide a better understanding of the most representative food items in the diet of *P. brasiliensis*.

### Data analysis

As the frequency of food items was heterogeneous, it was expected that variance values, standard deviations, coefficient of variation and mean standard error would be high. To check this, we clustered the most expressive groups and determined their dominance by calculating FO, PM and IAi percentiles.

The One-Way ANOVA (Sokal and Rohlf, 1995) analysis of parametric variance using the PAST software was applied to verify the existence of significant differences between the environmental variables in the isobaths and seasons ($p < 0.05$).

Mário Cesar Sedrez, Germano Henrique Costa Barrilli, Evelise Nunes Fragoso-Moura, João Pedro Barreiros, Joaquim Olinto Branco, José Roberto Verani

These variances were tested for variance homogeneity (Bartlett's test) and normality of distribution (Kolmorov-Smirnov's test). The contrast of the means, through the Tuckey-Kramer test was applied in the occurrence of significant differences to indicate the source that caused the variations (Branco and Verani, 2006).

To test the existence of ontogenetic differences in relation to the diet of *P. brasiliensis*, the specimens were grouped into four-in-four cm classes and the ANOSIM statistical test ($p<0.05$) was applied, using the Bray-Curtis Similarity Index. Additionally, with the same analysis we tested the differences between food items in the isobaths.

Seasonal analyzes were considered as seasons of the year: spring (October, November and December), summer (January, February and March), fall (April, May and June) and winter (July, August and September).

## RESULTS

### Temperature

The bottom water temperature fluctuated between depths and seasons (Fig. 2a-b). The lowest recorded value was 16 °C, in the 30 m, in the winter of 2013 and the highest of 28 °C, at 10 m, in the summer of 2014. No significant
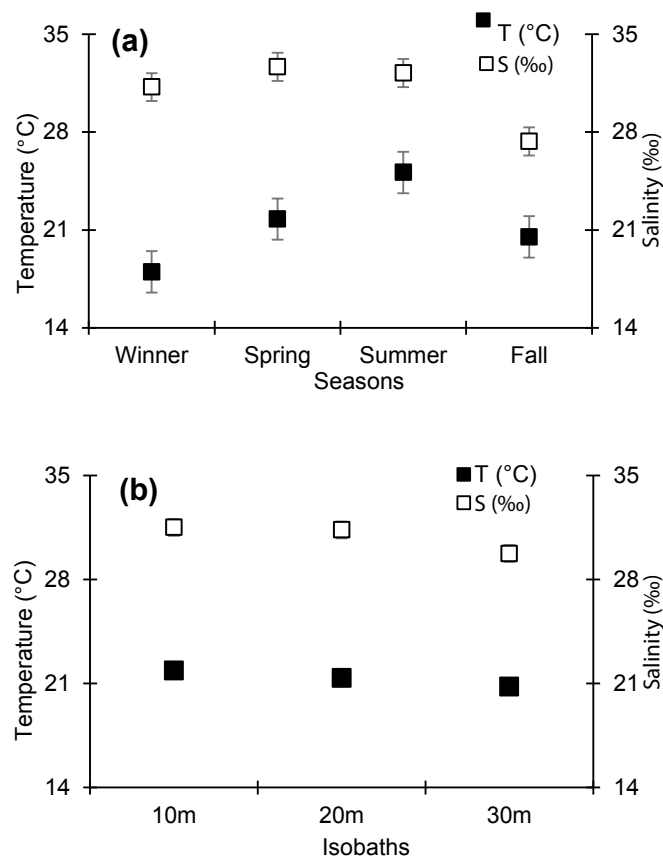
**Table 1.** Frequency of occurrence of empty and with content stomachs in females, males and juveniles with undetermined sex of *P. brasiliensis* in Penha, South Brazil.

| Stomachs | Empty | | With content | | | |
|---|---|---|---|---|---|---|
| | N | % | N | % | Total | % |
| Females | 10 | 2.43 | 402 | 97.57 | 412 | 33.80 |
| Males | 10 | 3.91 | 246 | 96.09 | 256 | 21.00 |
| Indeterminate | 32 | 5.81 | 519 | 94.19 | 551 | 45.20 |

differences were found between different isobaths (F2-33 = 0.3253; $p \geq 0.05$), but significant differences exist between the seasons (F3-8 = 74.3370; $p<0.05$).

### Salinity

The salinity of the bottom water recorded seasonal fluctuations and in the isobaths (Fig. 2a-b). The lowest salinity record was 25 %, at 30m, in the fall of 2014 and the highest was 35 %, at 10m, in the winter and spring of 2013. No significant differences were found between the isobaths (F2-33 = 1.4780, $p \geq 0.05$), but seasonal differences were significant (F3-8 = 8.0020, $p<0.05$).

Since the ANOVA applied to food items showed no significant differences ($p \geq 0.05$) in their composition in the stomach contents in the different isobaths (F3-48 = 0.0067) and seasons (F2-36 = 0.0018), we opted to present the data grouped.

### Stomach repletion

Of the 1219 specimens evaluated, 412 (33.80 %) were females, 256 (21.00 %) males and 551 (45.20 %) were sexually indeterminate (Table 1). The length amplitude varied between 2.7 and 23.3 cm, with an average of 12.3 ± 3.5 cm and the weight between 0.17 and 116.65 g, with an average of 19.32 ± 18.64 g.

Macroscopic analysis revealed that among the 1219 stomachs of the dissected specimens, 1167 (96.73 %) contained identifiable prey and/or food remains (Table 1).

Considering the degree of repletion of all the stomachs of the original sample (Fig. 3), 419 (34.37 ± 2.33 %) were full, 314 (25.76 ± 3.28 %) partially full, 307 (25.18 ± 5.70 %) medium and 127 (10.42 ± 2.33 %) partially empty. Only 52 stomachs analyzed were empty (4.27 ± 0.88 %).

### Sample representativeness

The accumulated curve of the food items of *P. brasiliensis* showed that the occurrence of all expected items, also pointed out by the Jackknife 2 estimator, was reached with 465 stomachs examined ($p<0.05$), confirming that the number of dissected stomachs was sufficient to describe the diet of the species (Fig. 4).

### Diet description

Table 2 shows the relative importance of food items and the food preference of *P. brasiliensis*. It is observed that the



**Figure 2.** Average variations of the temperature and salinity of the bottom water per season of the year (a) and in the isobaths (b), in Penha, South Brazil.
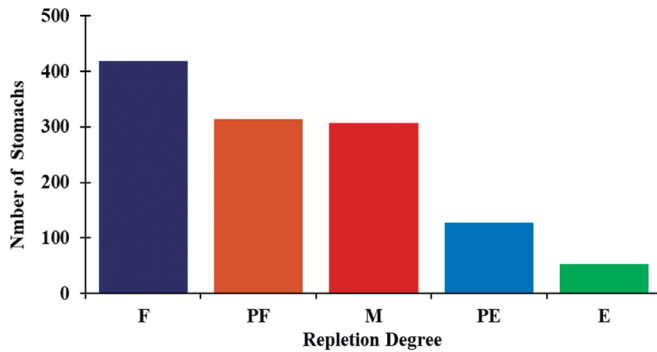
**Figure 3.** Stomach repletion degree from a sample of *Paralonchurus brasiliensis* from Penha, South Brazil. Legend: F (full), PF (partially full), M (medium), PE (partially empty) and E (empty).



**Figure 4.** Cumulative trophic diversity curves of *Paralonchurus brasiliensis* from Penha, South Brazil.

food items can be divided into two large groups, the first consisting of the preys that are prevailing in this diet and the second, of preys less expressive in their diet. Table 2 also shows that this species is an opportunistic predator, with a narrower trophic niche and specialized, mainly, in the ingestion of polychaetes, crustaceans, and ophiuroids.

These macroinvertebrates formed the dominant prey group, both in the frequency of relative occurrence of food items (36.1 %, 34.9 % and 11.2 %), in the average of the points (50.55 %, 33.12 % and 9.27 %), and in the percentages of the alimentary index (58.43 %, 37.01 % and 3.32 %) (Table 2).

The second group, the least representative in the general diet composition of *P. brasiliensis*, involved Nematoda, Osteichthyes, sand, organic matter and those denominated as other (Algae, Cnidaria, Nemertinea, Sipuncula, Mollusca and Scales). Together they contributed with the lowest fractions of FO (17.80 %), PM (7.07 %) and IAi (1.24 %), as shown in Table 2.

The ANOSIM statistical test showed that there were no significant differences in the diet of *P. brasiliensis* among isobaths (R = -0.07, $p \geq 0.05$), and seasons (R = -0.12, $p \geq 0.05$).

## DISCUSSION

Studies involving the analysis of stomach contents of fish are fundamental instruments to determine their eating habits and their niche in the food chains (Barreiros and Santos, 1998; Machado *et al.*, 2014). In addition, food availability and utilization indicate patterns of distribution, migration, reproduction of fish, and ecosystem changes (Amaral and Migotto, 1980; Zavala-Camim, 1996; Soares and Vazzoler, 2001; Araújo *et al.*, 2014).

The methodology used in the analysis of the feeding habits of *P. brasiliensis* in the South Atlantic of Brazil was adequate, as in several studies involving natural fish feeding (Branco *et al.*, 2005; Machado *et al.*, 2014; Castro *et al.*, 2015), although the recognition of prey was restricted to large groups. However, as suggested by Branco and Verani (1997), the most important is to determine the food spectrum of the species and the relation among them.
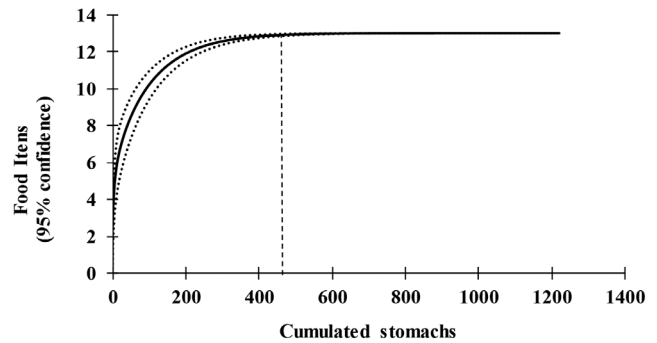
The fluctuations recorded for temperature and salinity of the bottom water are typical of coastal zones (Matsuura, 1986). They may be related to rainfall and to the contributions of the Itajaí Açu River (which is distant about 20 km to the South of the study area), the Coastal Water mass, low salinities (<34 %), high temperatures (19 to 28 °C), and the seasonality of the South Atlantic Central Waters between spring and summer, which favors the increased of primary coastal productivity (Soares-Gomes and Figueiredo, 2002).

*P. brasiliensis* may occupy this area due to the combination of favorable abiotic factors and the diversity of macrobentos as food, as suggested by Souza *et al.* (2008). Also, areas closer to the beach offer mechanisms that provide large amounts of nutrients, since they are regions of high primary productivity, that guarantee resources at lower and higher trophic levels (Araújo *et al.*, 2014).

The food items accumulation curve, constructed in the present study, reached asymptote confirming the adequacy of the number of stomachs dissected to describe the diet of *P. brasiliensis*. In this sense, Zavala-Camin (1996) points out that when carrying out fish diet studies, the size of the sample should not be small enough to lose relevant information but should not be large enough to promote a waste of resources. For Teixeira and Gurgel (2002), small samples reduce the information required whereas exaggerated samples can mean a waste of work and loss of time.

The analysis of the degree of repletion and the stomach contents of *P. brasiliensis* revealed a diversified and constant feeding. The high incidence of full or nearly full stomachs with no significant differences between juveniles and adults in the diet of this species was described by Soares and Vazzoler (2001), as well as Branco *et al.* (2005), who did not find significant differences when comparing the diet between males and females.

The feeding habits of *P. brasiliensis* verified in the present study coincide with previous descriptions for the Brazilian South region (Vazzoler, 1975; Branco *et al.*, 2005; Robert *et al.*, 2007). The results showed that *P. brasiliensis* presents a broad trophic spectrum, consuming more frequently organisms of the group Polychaeta, Crustacea and

Mário Cesar Sedrez, Germano Henrique Costa Barrilli, Evelise Nunes Fragoso-Moura, João Pedro Barreiros, Joaquim Olinto Branco, José Roberto Verani

**Table 2.** Diet composition of *Paralonchurus brasiliensis* (n = 1167 stomachs with contents), from Penha, South Brazil. Values of relative frequency of occurrence (% FO), mean points (% PM) and feeding index (% IAi) for each food item are presented. Items marked with + means values <0.1 %.

| Food items | %FO | %PM | %IAi |
|---|---|---|---|
| Algae | 0.39 | 0.09 | + |
| Cnidaria | 0.39 | 0.12 | + |
| Nemertinea | 0.21 | 0.16 | + |
| Sipuncula | 0.28 | 0.20 | + |
| Nematoda | 5.27 | 1.78 | 0.30 |
| Mollusca | 1.54 | 0.53 | + |
| Polychaeta | 36.10 | 50.55 | 58.30 |
| Crustacea | 34.90 | 33.12 | 37.01 |
| Ophiuroidea | 11.20 | 9.27 | 3.32 |
| Osteichthyes | 0.42 | 0.58 | + |
| Sand | 0.60 | 0.12 | + |
| Scales | 0.46 | 0.09 | + |
| Organic matter | 8.25 | 3.40 | 0.90 |
| Total | 100.00 | 100.00 | 100.00 |

Ophiuroidea, closely related to the sediment. In general, the members of the Sciaenidae family present a wide food diversity, invertebrates being the fundamental dietary items of some marine fish species (Amaral and Migotto, 1980; Branco *et al*., 2005).

Despite a wide food spectrum, our study pointed out a strong trend towards the predation of polychaetes by *P. brasiliensis*. This pattern of diet is consistent with the records of several authors (Amaral and Migotto, 1980; Braga, 1990; Soares and Vazzoler, 2001). According to Robert *et al*. (2007), juveniles and adults of *P. brasiliensis* share the same food items. Therefore, it is possible to infer that there are no significant variations in the composition of food items during the ontogenetic development of this species.

The use of polychaetes as a more important item may be a consequence of a greater availability of these prey in the habitats of *P. brasiliensis* and may be related to the type of sediment in this area, where there is a predominance of silt-clay. According to some studies, areas with this type of sediment contribute to the retention of organic matter and, therefore, to the abundance of organisms that feed on it, such as polychaetes (De Almeida *et al.* 2012, Araújo *et al.,* 2014).

One fact that caught our attention is that the decapod crustacean *X. kroyeri*, target species of the South Atlantic trawling fishery, is not among the more important food items in the diet of *P. brasiliensis*. This can be related to the fact that these shrimps are often buried in the sediment (Simoons *et al.,* 2013), becoming less available to benthic and benthopelagic consumers (Wakabara *et al.,* 1993). In addition, from the anatomical point of view, *P. brasiliensis*

has a morphologically small, inferior and almost horizontal mouth (Fischer *et al*., 2011), that could hinder the ingestion of this type of prey.

As in our studies, Braga *et al*. (1985) identified Ophiuroidea among food items that constitute the diet of *P. brasiliensis* throughout the year, along with polychaetes, and crustaceans, and to a lesser extent fish, and scales. Several studies point to the ophiuroids among the most exploited resources in the diet of this species and of other demersal Sciaenidae (Vazzoler, 1975; Soares and Vazzoler, 2001; Branco *et al.,* 2005; Robert *et al.,* 2007; Araújo *et al.,* 2014).

Sand ingestion may be considered accidental and reinforces the species´ benthic habit (Barrilli *et al*., 2021a). However, it is not possible to discard the hypothesis that sand ingestion is voluntary and continuous when considering the diversity of macrobenths found in marine sediments such as Cnidaria, Nematoda, Polychaeta, Crustacea and Ophiuroidea, among others (Branco and Verani, 1997; Araújo *et al*., 2014). Additionally, the occurrence of sediment particles in the stomach contents suggests that the species actively captures prey that relates to areas of the bottom.

The presence of intact nematodes in the stomach contents of *P. brasiliensis* recorded in our studies suggests a parasitic relationship, as demonstrated by the results of Turra *et al*. (2012), who described nematodes in the stomachs of around 50 % of the intestines of Sciaenidae *Menticirrhus americanus* (Gill, 1861). Other researchers have also reported the presence of this parasite in the *P. brasiliensis* digestive tube (Pinto *et al*., 1992; Luque *et al*., 2003). However, Araujo *et al*. (2014) considered Nematoda as part of the natural diet of eight species of Neotropical Actinopterygii, including Sciaenidae *P. brasiliensis*, *Isopisthus parvipinnis* (Cuvier, 1830), and *Stellifer brasiliensis* (Schultz, 1945).

The relationships between organic matter, sand and other items (Algae, Cnidaria, Nemertinea, Sipuncula, Mollusca, Ostheichthyes and scales), recorded in our study were also described as stomach contents of several marine species by different authors (Branco *et al*., 2005; Araújo *et al*., 2014). For these researchers, both organic matter and sand were included as food items in the function of their considerable occurrence and volume values. However, the other items were not considered because they were treated as rare occurrences or accidental ingestion.

On the other hand, this may be indicative of the opportunistic character of *P. brasiliensis*, due to its great trophic plasticity, especially when there is little availability of the main food source, as indicated by Gerking (1994). According to Araujo *et al*. (2014), most tropical fish are indeed trophic opportunists with a broad food spectrum, and this allows them to adapt rapidly to the availability of other resources. These authors also affirm that this high degree of eurifagia can be associated with the high faunistic diversity on one side and the smaller biomass of each species on the other.

The frequency of occurrence and volume of certain food items in the stomach contents of *P. brasiliensis* suggests their availability in the environment and how these food resources are being exploited by the species, following the Optimal Foraging Theory (MacArthur and Pianka, 1966). Taking into account that *P. brasiliensis* captures a large number of small preys, this habit must compensate for the energetic gain in search, capture, and manipulation of these foods, as described by Bozza and Hahn (2010). As foraging is dependent on prey density, this exercises an in controlling subtidal organisms' populations (Wellenreuther and Connell, 2002).

The response of the ecosystem to bottom trawling depends on whether the abundance of benthos responds to top-down or bottom-up trophic control (van Denderen *et al*., 2013). These researchers have demonstrated that there may be a positive effect of trawling, with increased fish abundance, when their prey (benthos) are also resistant to trawls in controlled systems from the bottom up. An intermediate disturbance can contribute to the maintenance of species, as it removes those that are dominant and therefore allows a better balance between them (Connell, 1978).

The results obtained in this study allow us to conclude that *P. brasiliensis* is a demersal-benthic species with a broad trophic spectrum, predatory, carnivorous, opportunistic, and predominantly invertivorous. With this paper we intend to provide information that contributes to the understanding and discussion of the bycatch of the trawling fishery of *X. kroyeri* shrimp in the trophic chains of coastal ecosystems, using the case of *P. brasiliensis* as a study model.

## CONCLUSIONS

The population of *P. brasiliensis* showed an intense foraging activity and a diversified feeding habit, with higher consumption of polychaetes, crustaceans, and ophiuroides. The presence of sand in the content suggests accidental ingestion since this item can adhere to the surface of the other items. The species might be characterized as a demersal-benthic species, predator, opportunistic, of the broad trophic spectrum and having an important ecological role in the maintenance of marine trophic web in coastal in the South Atlantic of Brazil. We emphasize that studies on ecological aspects are necessary, as they assist in knowing the role of species in environments, conservation issues, and fisheries management.

## ACKNOWLEDGMENTS

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## REFERENCES

Alverson DL, Freeberg MH, Pope JG, Murawski SA. A global assessment of fisheries bycatch and discards (No. 339). Rome: FAO; 1994. 233p.

Amaral ACZ, Migotto AE. Importância dos anelídeos poliquetas na alimentação da macrofauna demersal e epibentônica da região de Ubatuba. Bol Inst Oceanogr. 1980;29(2):31-35. Doi: http://dx.doi.org/10.1590/S0373-55241980000200006

Araújo ME, Lunardon-Branco MJ, Verani JR, Branco JO, Barreiros JP, Christoffersen ML. A trophic analysis of target species of macrobenthos in a subtropical coast community: a taxa relationship essay. Vie Milieu. 2014;64(4):35-46.

Awabdi DR, Siciliano S, Di Beneditto APM. Ingestão de resíduos sólidos por tartarugas-verdes juvenis, *Chelonia mydas* (L. 1758), na costa leste do estado do Rio de Janeiro, Brasil. Biotemas. 2013;26(1):197-200. Doi: https://doi.org/10.5007/2175-7925.2013v26n1p197

Bail GC, White JO. Pesca artesanal do camarão sete-barbas: uma caracterização sócio-econômica na Penha, SC. Braz J Aquat Sci Technol. 2007;11(2):25-32. Doi: http://dx.doi.org/10.14210/bjast.v11n2.p25-32

Barbini SA, Lucifora LO. Big fish (and a smallish skate) eat small fish: diet variation and trophic level of *Sympterygia acuta*, a medium-sized skate high in the food web. Mar Ecol. 2015;37(2):283-293. Doi: https://doi.org/10.1111/maec.12273

Barreiros JP, Santos RS. Notes on the food habits and predatory behaviour of the dusky grouper, *Epinephelus marginatus* (Lowe, 1834) (Pisces: Serranidae) in the Azores. Arquipélago. Life Mar Sci. 1998;16A:29-35.

Barrilli GHC, Vale JG, Stahelin G, Branco JO. Biological and ecological aspects of *Bathygobius soporator* (Valenciennes, 1837) (Perciformes, Gobiidae) from Santa Catarina, Southern Brazil. Pap Avulsos Zool 2021a; 61, e20216115. Doi: https://doi.org/10.11606/1807-0205/2021.61.15

Barrilli GHC, Rodrigues Filho JL, do Vale JG, Port D, Verani JR, Branco, JO. Role of the habitat condition in shaping of epifaunal macroinvertebrate bycatch associated with small-scale shrimp fisheries on the Southern Brazilian Coast. Reg. Stud. Mar. Sci. 2021b; 43, 101695. Doi: https://doi.org/10.1016/j.rsma.2021.101695

Berg J. Discussion of methods of investigating the food of fishes, with reference to a preliminary study of the prey of *Gobiusculus flavescens* (Gobiidae). Mar Biol. 1979;50(3):263-273. Doi: https://doi.org/10.1007/BF00394208

Mário Cesar Sedrez, Germano Henrique Costa Barrilli, Evelise Nunes Fragoso-Moura, João Pedro Barreiros, Joaquim Olinto Branco, José Roberto Verani

Bozza AN, Hahn NS. Use of food resources by juveniles and adults of piscivorous fish species in a neotropical floodplain. Neotrop Biota. 2010;10(3):217-226. Doi: http://dx.doi.org/10.1590/S1676-06032010000300025

Braga FDS. Estudo da mortalidade de *Paralonchurus brasiliensis* (Teleostei, Sciaenidae), em área de pesca do camarão-sete-barbas (*Xiphopenaeus kroyeri*). Bol Inst Pesca. 1990;17:27-35.

Braga FM, Braga MA, Goiten R. Fator de condição e alimentação de *Paralonchurus brasiliensis* (Osteichthyes, Sciaenidae) na região da Ilha Anchieta (lat. 23o33'S, long. 45o05'W), Ubatuba, Estado de São Paulo. Naturalia. 1985;10:1-11.

Branco JO, Lunardon-White MJ, Verani JR. Biological and fishing aspects of *Paralonchurus brasiliensis* Steindachner (Pisces, Sciaenidae), in the Armação do Itapocoroy, Penha, Santa Catarina, Brazil. Rev Bras Zool. 2005;22(4):1063-1071. Doi: http://dx.doi.org/10.1590/S0101-81752005000400035

Branco JO, Verani JR. Dinâmica da alimentação natural de *Callinectes danae* Smith (Decapoda, Portunidae) na Lagoa da Conceição, Florianópolis, Santa Catarina, Brasil. Ver Bras Zool. 1997;14(4):1003-1018. Doi: http://dx.doi.org/10.1590/S0101-81751997000400014

Branco JO, Verani JR. Pesca do camarão sete-barbas e sua fauna acompanhante, na Armação do Itapocoroy, Penha, SC. In: Branco JO, Marenzi AWC, editors. Bases ecológicas para um desenvolvimento sustentável: estudos de caso em Penha, SC. Itajaí: Univali; 2006. p. 153-170.

Buchheister A, Latour RJ. Turnover and fractionation of carbon and nitrogen stable isotopes in tissues of a migratory coastal predator, summer flounder (*Paralichthys dentatus*). Can J Fish Aquat Sci. 2010;67(3):445-461. Doi: https://doi.org/10.3354/aei00061

Castro DN, Lima WMG, Mendes NCB, Nascimento MS, Lutz IAF, Cardoso CDNA, Silva BB. Dieta Natural de *Macrodon ancylodon* (Bloch & Schneider, 1801) capturada por embarcações pesqueiras industriais sediadas no Estado do Pará. Biol Amaz. 2015;5(3):50-54. Doi: http://dx.doi.org/10.18561/2179-5746/biotaamazonia.v5n3p50-54

Colabuono FI, Vooren CM. Diet of Black-browed *Thalassarche melanophrys* and Atlantic Yellow-nosed *T. Chlororhynchos* albatrosses and White-chinned *Procellaria aequinoctialis* and Spectacled *P. conspicillata* petrels of Southern Brazil. Mar Ornithol. 2007;35:9-20.

Colwell RK, Coddington JA. Estimating terrestrial biodiversity through extrapolation. Philos Trans R Soc Lond *B* Biol Sci. 1994; 345(1311):101-118. Doi: https://doi.org/10.1098/rstb.1994.0091

Connell JH. Diversity in tropical rain forests and coral reefs. Science. 1978;199(4335):1302-1310. Doi: http://dx.doi.org/10.1126/science.199.4335.1302

Costa EFS, Teixeira GM, Freire FAM, Fransozo A. Spatial-temporal variation of *Paralonchurus brasiliensis* (Actinopterygii: Sciaenidae) density in relation to some environmental factors on the inner shelf of south-eastern Brazilian coast. J Mar Biol Assoc U K. 2012;92(2):413-420. Doi: https://doi.org/10.1017/S0025315411001627

Criales-Hernández MI, García CB, Wolff M. Flujos de biomasa y estructura de un ecosistema de surgencia tropical en La Guajira, Caribe colombiano. Rev Biol Trop. 2006;54(4):1257-1282. Doi: https://doi.org/10.15517/rbt.v54i4.14399

Davies RWD, Cripps SJ, Nickson A, Porter G. Defining and estimating global marine fisheries bycatch. Mar Pol Bull. 2009;33(4):661-672. Doi: https://doi.org/10.1016/j.marpol.2009.01.003

De Almeida TCM, Vivan JM, Pesserl BH, Da Cunha Lana P. Polychaetes of the north-central Santa Catarina state, Brazil. Check List. 2012;8(2):204-206. Doi: https://doi.org/10.15560/8.2.204

Fischer LG, Pereira LED, Vieira JP. Peixes estuarinos e costeiros. Rio Grande: Pallotti; 2011. 131 p.

Gerking SD. Feeding ecology of fish. California: Academic Press; 1994. 416p.

Haefner Jr PA. Natural diet of *Callinectes ornatos* (Brachyura: Portunidae) in Bermuda. J Crustacean Biol. 1990;10(2):236-246. Doi: https://doi.org/10.1163/193724090X00069

Hynes HBN. The food of fresh-water sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. J Anim Ecol. 1950;36-58. Doi: https://doi.org/10.2307/1570

Hyslop EJ. Stomach contents analysis-a review of methods and their application. J Fish Biol. 1980;17(4):411-429. Doi: https://doi.org/10.1111/j.1095-8649.1980.tb02775.x

IBGE. Brazilian Institute of Geography and Statistics. 2019. Available in: http://www.ibge.gov.br. Cited: 07 May 2019.

Kawakami E, Vazzoler G. Método gráfico e estimativa de índice alimentar aplicado no estudo de alimentação de peixes. Bol Inst Ocean. 1980;29(2):205-207. Doi: http://dx.doi.org/10.1590/S0373-55241980000200043

Kehrig HA, Seixas TG, Malm O, Di Beneditto APM, Rezende CE. Mercury and selenium biomagnification in a Brazilian coastal food web using nitrogen stable isotope analysis: a case study in an area under the influence of the Paraiba do Sul river plume. Mar Pol Bull. 2013;75(1):283-290. Doi: https://doi.org/10.1016/j.marpolbul.2013.06.046

Keledjian A, Brogan G, Lowell B, Warrenchuk J, Enticknap B, Shester G, *et al*. Wasted catch: unsolved problems in US fisheries. Washington D.C.: Oceana - Protecting the World's Oceans; 2014. 44 p.

Kelleher K. Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper (No. 470). Rome: FAO; 2005. 131p.

Luque JL, Alves DR, Ribeiro RDS. Community ecology of the metazoan parasites of Banded Croaker, *Paralonchurus*

*brasiliensis* (Osteichthyes: Sciaenidae), from the coastal zone of the State of Rio de Janeiro, Brazil. Acta Sci. 2003;25(2):273-278. Doi: http://dx.doi.org/10.1590/S1519-69842008000200007

MacArthur RH, Pianka ER. On optimal use of a patchy environment. Am Nat. 1966;603-609. Doi: https://doi.org/10.1086/282454

Machado LF, Nunes D, Ávila M, Vieira RP, Barreiros JP. Feeding strategy and trophic ontogeny in *Scorpaena maderensis* (Scorpaeniformes: Scorpaenidae) from the Azores, NE Atlantic. Cybium. 2014;38(3):163-171.

Matsuura Y. Contribuição ao estudo da estrutura oceanográfica da região sudeste entre Cabo Frio (RJ) e Cabo de Santa Marta Grande (SC). Ciênc Cult. 1986;38(8):1439-1450.

Menezes NA, Figueiredo JL. Manual de peixes marinhos do sudeste do Brasil. IV Teleostei (3). São Paulo: Museu de Zoologia, Universidade de São Paulo; 1980. 96 p.

Milmann L, Danilewicz D, Machado R, Santos RAD, Ott PH. Feeding ecology of the common bottlenose dolphin, Tursiops truncatus, in southern Brazil: analyzing its prey and the potential overlap with fisheries. Braz J Oceanogr. 2016;64(4):415-422. Doi: https://doi.org/10.1590/s1679-87592016116406404

Palmer MW. Estimating species richness: the second-order jackknife reconsidered. Ecology.1991;72(4):1512-1513.

Piet GJ, Pfisterer AB, Rijnsdorp AD. On factors structuring the flatfish assemblage in the southern North Sea. J Sea Res. 1998;40(1):143-152. Doi: https://doi.org/10.1016/S1385-1101(98)00008-2

Pillay TVR. A critique of the methods of study of food of fishes. J Zool Soc India. 1952;4(2):185-200.

Pinkas L, Oliphant MS, Iverson ILK. Food habits of albacore bluefin tuna and bonito in California waters. Cal Dept Fish Game Fish Bull. 1971;152:1-105.

Pinto RM, Vicente JJ, Noronha D. On some family related parasites (Nematoda, Cucullanidae) from the marine fish *Paralonchurus brasiliensis* (Steindachner, 1875) (Pisces, Ostraciidae). Mem Inst Oswaldo Cruz. 1992;87:207-212. Doi: http://dx.doi.org/10.1590/S0074-02761992000500039

Robert MDC, Michels-Souza MA, Chaves PDT. Biology of *Paralonchurus brasiliensis* (Steindachner) (Teleostei, Sciaenidae) in Paraná coast, Brazil. Rev Bras Zool. 2007;24(1):191-198. Doi: http://dx.doi.org/10.1590/S0101-81752007000100024

Sedrez MC, Branco JO, Júnior FF, Monteiro HS, Barbieri E. Ictiofauna acompanhante na pesca artesanal do camarão sete-barbas (*Xiphopenaeus kroyeri*) no litoral sul do Brasil. Neotrop Biota. 2013;13(1):165. Doi: https://doi.org/10.1590/S1676-06032013000100019

Simoons SM, Castilho AL, Fransozo A, Negreiros-Fransozo ML, Da Costa RC. Distribution related to temperature and salinity of the shrimps *Acetes americanus* and *Peisos petrunkevitchi* (Crustacea: Sergestoidea) in the south-eastern Brazilian littoral zone. J Mar Biol Assoc UK. 2013;93(03):753-759. Doi: https://doi.org/10.1017/S0025315412000902

Soares LSH, Vazzoler AEA. Diel changes in food and feeding activity of sciaenid fishes from the South-western Atlantic, Brazil. Rev Bras Biol. 2001;61(2):197-216. Doi: https://doi.org/10.1590/S0034-71082001000200004

Soares-Gomes A, Figueiredo AG. O ambiente marinho. In: Pereira RC, Soares-Gomes A, editors. Biologia Marinha. Rio de Janeiro: Interciência; 2002. p. 1-33.

Sokal RR, Rohlf FJ. Biometry: the principles of statistics in biological research. New York: Freeman; 1995. 887p.

Souza UP, Costa RCD, Martins IA, Fransozo A. Associações entre as biomassas de peixes Sciaenidae (Teleostei: Perciformes) e de camarões Penaeoidea (Decapoda: Dendrobranchiata) no litoral norte do Estado de São Paulo. Biota Neot. 2008;8(1):83-92. Doi: https://doi.org/10.1590/S1676-06032008000100011

Teixeira JLA, Gurgel HCB. Métodos de análise do conteúdo estomacal em peixes e suas aplicações. Arqu Apadec. 2002;6(1):20-25.

Turra A, Santos FB, Bessa E, Fernandez WS, Bernadochi LC, Denadai MR. Population biology and diet of the southern kingcroaker *Menticirrhus americanus* (Linnaeus, 1758) (Perciformes: Sciaenidae) in Caraguatatuba Bay, southeastern Brazil. Braz J Oceanog. 2012;60(3):343-352. Doi: http://dx.doi.org/10.1590/S1679-87592012000300007

van Denderen PD, van Kooten T, Rijnsdorp AD. When does fishing lead to more fish? Community consequences of bottom trawl fisheries in demersal food webs. Proc R Soc Lond B Biol Sci. 2013;280(1769):20131883. Doi: https://doi.org/10.1098/rspb.2013.1883

Vazzoler G. Distribuição da fauna de peixes demersais e ecologia dos Sciaenidae da plataforma continental brasileira, entre as latitudes 29°21'S (Torres) e 33°41'S (Chuí). Bol Inst Oceanogr. 1975;24:85-169. Doi: http://dx.doi.org/10.1590/S0373-55241975000100006

Wakabara Y, Tararam AS, Flynn MN. Importance of the macrofauna for the feeding of young fish species from infralittoral of Arrozal: Cananeia lagoon estuarine region (25°02'S-47°56'W) - Brazil. Bol Inst Ocean. 1993;41(1-2):39-52. Doi: http://dx.doi.org/10.1590/S0373-55241993000100004

Wear RG, Haddon M. Natural diet of the crab *Ovalipes catharus* (Crustacea, Portunidae) around central and northern New Zealand. Mar Ecol Prog Ser. 1987;35:39-49. Doi: http://dx.doi.org/10.1590/S1516-89132011000100012

Wellenreuther M, Connell SD. Response of predators to prey abundance: separating the effects of prey density and patch size. J Exp Mar Biol Ecol. 2002;273(1):61-71. Doi: https://doi.org/10.1016/S0022-0981(02)00145-4

Mário Cesar Sedrez, Germano Henrique Costa Barrilli, Evelise Nunes Fragoso-Moura, João Pedro Barreiros, Joaquim Olinto Branco, José Roberto Verani

Williams MJ. Methods for analysis of natural diet in portunid crabs (Crustacea: Decapoda: Portunidae). J Exp Mar Biol Ecol. 1981;52(1):103-113. Doi: https://doi.org/10.1016/0022-0981(81)90174-X

Wootton RJ. Ecology of teleost fishes. London: Chapman & Hall; 1990. 404 p.

Zavala-Camin LA. Introdução aos estudos sobre alimentação natural em peixes. Maringá: Eduem-Nupelia; 1996. 129p.