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Research Article

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Population Biology and Diet of the Pompano *Trachinotus carolinus* (Perciformes: Carangidae) in Caraguatatuba Bay, Southeastern Brazil

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Abstract

This study evaluated the spatio-temporal distribution, population biology, and diet of the pompano *Trachinotus carolinus* in Caraguatatuba Bay. Samples were taken monthly from August 2003 through October 2004, by trawling in two previously selected areas (South and North). The North area is more exposed to wave activity and is influenced by a river, functioning as a small estuary. In contrast, the South area is relatively sheltered from wave energy and influenced to a lesser degree by smaller rivers. The fish were measured for length, and the sex and reproductive stage identified. The abundance of pompano was compared between areas and among months. The diet was identified and quantified. *T. carolinus* showed a very irregular temporal distribution during the study period, with 90.5% of the individuals occurring during the summer (December to March).The population wasdominated by immature individuals. In the diet of pompano, seven items were identified (bivalve shell fragments, crustacean fragments, fish fragments, gastropoda, Mysida, nematode and *Tivela mactroides*).The bivalve fragments were also attributed to *T. mactroides,* but the whole and fragmented shells were considered separately, evidencing a very peculiar form of consumption. Fragmented bivalve shells were the most frequent item (96.7%) in the tracts. The second most frequent item was Mysida, present in 10.5% of the digestive tracts. In terms of volume, bivalve shell fragments comprised 91.9% of the ingested items, against 6.4% for Mysida. These results demonstrate that *T. carolinus* is a carnivorous species, consuming almost exclusively *T. mactroides*. The population of this species in the Caraguatatuba Bay is dominated by juveniles, and is occasionally found in higher abundance in December and March (end of spring and summer).

Keywords

Feeding; Spatio-temporal distribution; *Tivela mactroides*; Caraguatatuba bay; São Paulo

Introduction

Trachinotus carolinus (Linnaeus, 1766), popularly known as "pampo" in Brazil, "pámpano" in Spanish-speaking countries, and "pompano" in the United States [1], is distributed along western Atlantic coasts from the eastern United States (Massachusetts), the Gulf of Mexico, and isolated localities in the Caribbean, to Brazil [2]. It is absent in the clear waters of the Bahamas and similar islands [3]. It occurs in coastal waters, commonly in bays and estuaries, to depths of 70 m [4,5]. Juveniles of *T. carolinus* are abundant in the surf zone of exposed sandy beaches, where they pass part of their life cycle [6-10]. The adaptations of fish that occupy this harsh environment include tolerance to variations in temperature and salinity, turbulence, turbidity, speed of currents, and changes in substrate characteristics, among others [7]. The pompano shows temporal oscillations in abundance that are strongly correlated with the entry of juveniles into the population, mainly during the summer months [9,11,12].

Pompanos feed mainly on molluscs, crustaceans, other invertebrates, and small fish [13,14]. They are opportunistic, predating on zooplankton or on the numerous populations of molluscs or crustaceans [13,15]. They are a popular seafood, and have a high commercial value in the United States [3,11,16]. For this reason, many studies of pompano biology are of interest for aquaculture [17-20].

Despite the economic importance of the pompano, the juveniles are generally without commercial value, and form part of the bycatch of the fishery for the sea bob shrimp *Xiphopenaeus kroyeri* [21]. Therefore, knowledge of the population biology and diet of the pompano constitutes basic information to assess its potential ecological importance in a given area. The present study describes the spatio-temporal distribution, size structure, reproductive aspects, and diet of the pompano *Trachinotus carolinus* in a sheltered marine area influenced by small rivers in Caraguatatuba Bay, south eastern Brazil, where very little information on the biota is available [22]. Since this area is being subjected to increasing urban (waste and organic pollution) and industrial (harbor, oil, and gas) activities, it is the focus of public policies, such as the Ecological-Economic Zoning, which is part of the Brazilian National Coastal Management Plan. This study is an effort to produce baseline data that can be monitored in the future, as well as to understand the impact that a reduction or an increase in the abundance of this species would have on the biodiversity of the bay.

Material and Methods

Caraguatatuba Bay (23˚37' S - 45˚26' W and 23˚44' S - 45˚24' W) is about 16 km long, and contains several sandy beaches (Enseada, Flecheiras, Porto Novo, Romance, Palmeiras, Pan-Brasil, Indaiá, Centro, and Camaroeiros) (Figure 1). Two areas, each 2 × 2 km, homogeneous but different from each other, were selected for this study (Figure 1). These areas were located in order to exclude the strong influence of rivers in the region (Juqueriquerê, Lagoa, and Santo Antônio) (Figure 1). The first or south area extends from Porto Novo to Palmeiras beaches, has a gentler slope, and is more influenced by the Juqueriquerê River, with a small estuary. The North area, located between Indaiá and Centro beaches, has a steeper slope and is influenced only by smaller rivers (Lagoa and Santo Antônio).

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Monthly samples were taken from August 2003 through October 2004. Three sampling stations were selected in each area, South and North, among 200 possibilities, *i.e.*, the beach length of 2000 m was divided into 10-m intervals. The position of the station was stored in the GPS at the time of MLW (mean low water), and then the distance of 800 m was located, perpendicular to the beach, using a fishing boat (class G2M, 11 m long with a 22-HP engine). At each station, an 800-m trawl was performed, from 800 to 1600 m from MLW. This interval includes depths from 1 to 4 m. The trawling speed was 1 knot. The trawls were made with two otter trawls with 20-mm mesh, mouth aperture 1.6 m high and 6.0 m wide, and bag depth of 3.5 m.

The fish were removed from the net and immediately preserved in a 10% formalin solution in order to stop the enzyme action, preserving the digestive-tract contents [23]. The samples were identified and stored in plastic containers. After identification of species in the laboratory, all specimens were transferred to 70% ethanol.

All individuals of *T. carolinus* obtained in the samples were measured for standard length (SL), which is the distance between the anterior edge of the head and the edge of the caudal fin base (beginning of caudal fin rays) [24].

A total of 160 individuals of *T. carolinus* were sorted from the 179 obtained in the samples for the diet analysis, using a random-digits table. A ventro-sagittal abdominal incision was made from the anal aperture to the pelvic-fin insertions. The digestive tract and gonads were removed. The gonads were analyzed according to Vazzoler [25].

The length of the digestive tract (distance from the beginning of the esophagus to the end of the rectum; DTL) was measured in order to establish the DTL/SL (digestive tract length/standard length) ratio and evaluate a possible relationship to the diet of *T. carolinus* [26]. The digestive tracts were then preserved in 70% ethanol until the diet-contents analysis. Finally, the contents of each digestive tract were identified to the lowest possible taxonomic level, and when possible, the number of specimens was counted. The volume of each item was measured according to methods described by Bemvenute [27] and Petti [28].

The mean number of individuals of *T. carolinus* was calculated for the study months and areas (South and North). The sum of the areas was also computed. Two-way ANOVA was performed to test the differences in the spatial (North and South areas) and temporal (months) distributions. A histogram illustrating the relative frequency distribution of the size classes (standard length) was produced for the total population. Sex ratio was presented as the proportion of males to females. This proportion was tested for the expected ratio of 1:1 with a chi-square test.

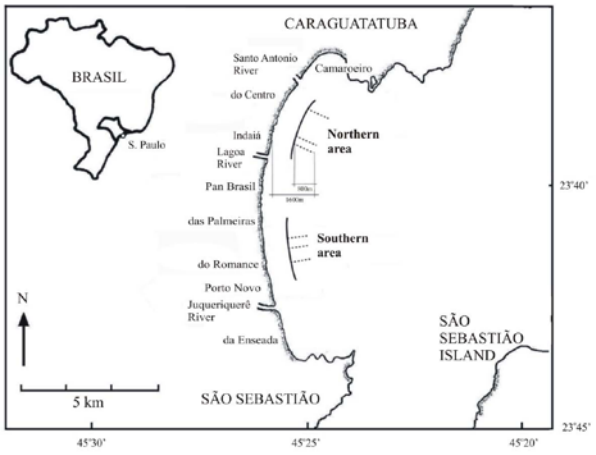

Figure 1: Caraguatatuba Bay and sampling strategy (random otter trawls; n=3; dashed lines), with monthly samples in both study areas, North and South (solid lines).

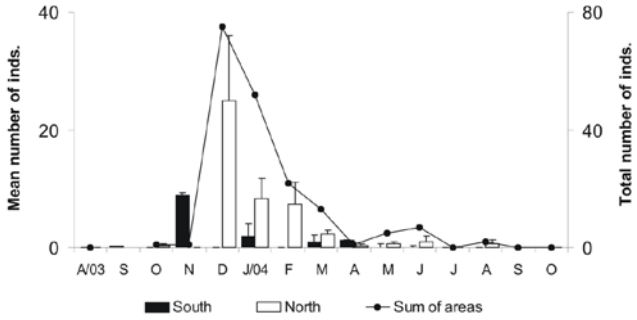

Figure 2: *Trachinotus carolinus* - Monthly mean (+ standard error) number of individuals/trawl in each of the two study areas (North and South) and monthly total number of individuals in Caraguatatuba Bay, southeastern Brazil, from August 2003 through October 2004.

The diet of *T. carolinus* was analyzed by the frequency of occurrence (F%), percent volume (V%), and alimentary importance index (AIi), which was calculated by a modification of the method used by Kawakami and Vazzoler [29], based on the frequency of occurrence (F*i*%) and on the percent volume (V*i*%) of each item.

Results

Trachinotus carolinus showed a very irregular temporal distribution during the study period (F=5.174; df=13; p<0.001) (Figure 2), with 90.5% of the individuals occurring during the summer (December to March). Abundance also differed between areas, since most individuals (77.1%) occupied the North area (F=6.673; df=1; p=0.012). Among the individuals recorded in the study area during the summer, 46.3% were collected in December and in the North area. The temporal variation in abundance varied independently of the spatial distribution (area) (F=4.163; df=13; p<0.001).The sizes of individuals of *T. Carolinus* ranged from 37 to 128mm SL, with an irregular size distribution skewed to the left, *i.e.*, with a low relative abundance of large-sized individuals (Figure 3).

The great majority of the individuals collected during spring-summer (more than 90% of the total) had immature gonads, and therefore their sex could not be identified macroscopically (Figure 4). Among the few individuals (n = 48) with developing gonads, the sex ratio was not significantly different from 1:1 (χ^2 = 1.333; df = 1; p = ns). During autumn, there was a predominance of females (7) over males (3) for individuals with developing gonads. During winter, the number of females with developing gonads (2) was too small to estimate a population trend for the period.

In the diet of *T. carolinus,* seven items were identified (Table 1). Molluscs were represented by gastropods, bivalve shell fragments, and entire shells of the clam *Tivela mactroides*. The bivalve fragments were also attributed to *T. mactroides*, but the entire and fragmented

shells were considered separately because the fragments evidenced a very peculiar form of consumption, in which the shells were strongly crushed, forming agglomerations (rigid masses of tiny fragments). A small percentage of unidentified organic matter was also recorded.

Fragmented bivalve shells were present in almost all (96.7%) of the tracts analyzed (Table 1). The second most frequent item was Mysida, present in 10.5% of the digestive tracts. In terms of volume, the fragments of bivalve shells comprised 91.9% of the ingested items, against 6.4% of Mysida (Table 1). Figure 5 illustrates the relative importance of fragments of bivalve shells in the diet of *T. carolinus* in Caraguatatuba Bay. Nematodes were present in 0.65% of the tracts analyzed.

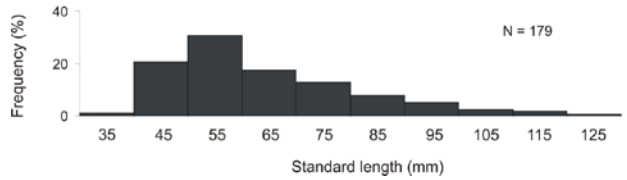

Figure 3: *Trachinotus carolinus* - Size (standard length - mm) frequency distribution of individuals in Caraguatatuba Bay, southeastern Brazil, from August 2003 through October 2004.

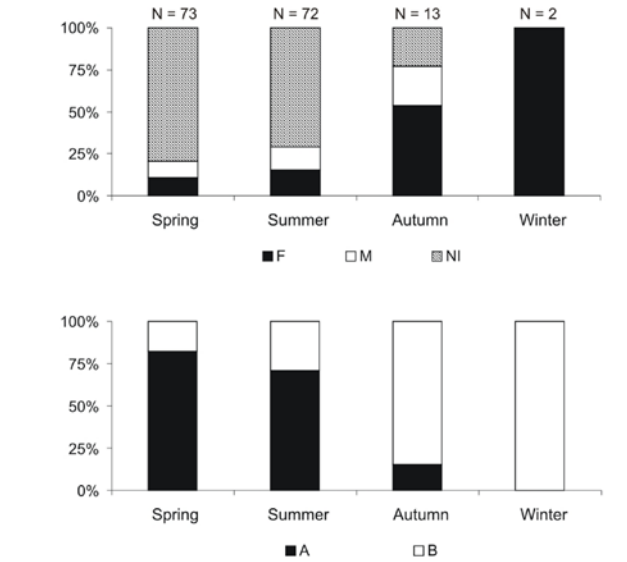

Figure 4: *Trachinotus carolinus*- Seasonal frequency of sex categories (F = female; M = male; and NI = not identified) and gonad maturation stages (A = immature; B = maturing) in Caraguatatuba Bay, southeastern Brazil, from August 2003 through October 2004.

Table 1: *Trachinotus carolinus*.Frequency of occurrence (F%), percent volume (V%), and Alimentary Importance Index (Ali%) in CaraguatatubaBay, southeastern Brazil, from August 2003 through October 2004. Total number of individuals, 160; individuals with empty digestive tract, 7; mean total length ± standard error, 64.1 ± 17.3 mm; digestive tract length and standard length ratio, DTL/SL = 0.65.

	F%	V%	Ali%
Nematoda	0.65	0.00	0.00001
Gastropoda	0.65	0.00	0.00001
Bivalve shell fragments	96.73	91.86	99.23812
Tivela mactroides	0.65	0.19	0.00137
Crustacean fragments	0.65	0.75	0.00550
Mysida	10.46	6.40	0.74747
Fish fragments	0.65	0.56	0.00412
Organic matter	1.31	0.23	0.00341

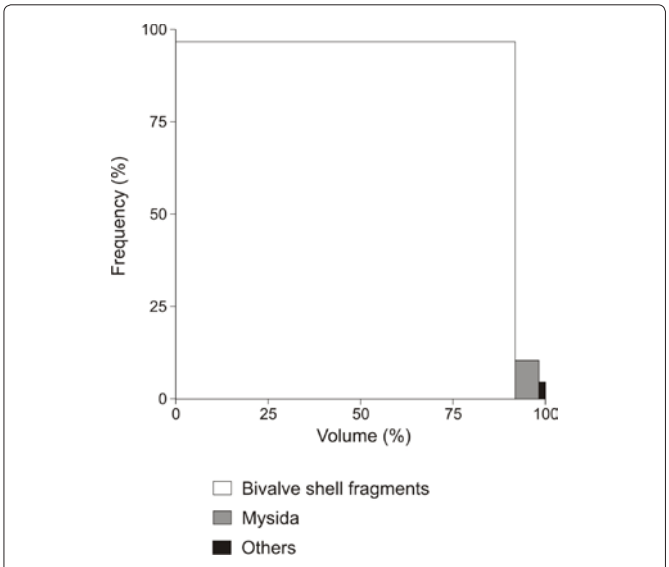

Figure 5: *Trachinotus carolinus* - Relationship between the frequency of occurrence and the percent volume of the items with highest Alimentary Importance Indexes in Caraguatatuba Bay, southeastern Brazil, from August 2003 through October 2004.

Discussion

Trachinotus carolinus occupies Caraguatatuba Bay in small numbers, with only 179 individuals captured in 15 sampling months, of a total of 63 species of fish and 21,882 individuals collected during the period. Relatively small numbers of individuals were also obtained by Cunha on the northern coast of São Paulo, during a large-scale survey in south-southeastern Brazil, between Rio Grande (state of Rio Grande do Sul, RS) and Itaipu (state of Rio de Janeiro, RJ) [9]. According to Cunha, the largest catches of this species were made in the Baixada Santista (state of São Paulo, SP) [9]. On the other hand, Matsuura and Nakatani [30] and Scorvo-Filho et al. [31] found juveniles of *T. carolinus* in some abundance off sandy beaches at Ubatuba (SP).

Both the spatial and temporal distribution of *T. carolinus* in Caraguatatuba Bay corroborated the information from the literature for the genus *Trachinotus* and for this species. The presence of young individuals in shallow waters off sandy beaches is already known for the pompano, which seems to be well adapted to this environment [13]. The samples in this study were taken from depths ranging from 1 to 4m, *i.e.*, the shallowest parts were very close to the sandy beaches of the bay and their surf zones. The entire bay, from the low-water line to its offshore limit (the imaginary line between Ponta do Arpoar to the south and Ponta do Camaroeiro to the north), is about 5km wide, and therefore has a low slope with a strong influence of waves on the seabed [32]. Most individuals (77%) were obtained in the North area of Caraguatatuba Bay, which has reflective characteristics and coarser sediment [32]. The Southarea of the bay, with dissipative characteristics, has a mud bottom and is influenced by the Juqueriquerê River. Cunha reported that the congener *Trachinotus marginatus* dominated the fauna of the surf zone, and is the most

abundant species near the community of Praia do Cassino [1]. Finucane observed that young individuals of *T. carolinus* normally occur at salinities lower than 32 [11]. The salinity in Caraguatatuba Bay, although not regularly measured, is expected to show significant variability since it is influenced by freshwater inflow from the rivers.

All the individuals collected in Caraguatatuba Bay were smaller than 128 mm SL, with a mean length of 64 ± 17 mm, indicating that, because this species may reach about 600 mm TL [9], the population in the bay is dominated by juveniles. Finucane referred to individuals measuring between 150 and 165 mm SL, obtained in Tampa Bay (Florida), as young-of-the-year [11].

With respect to the spatial distribution, juvenile individuals occupy the surf zone of sandy beaches during summer, as observed in Caraguatatuba Bay [9,11,12]. More than 90% of the fish in this study were obtained between December and March (end of spring and summer). A small number (30%) of individuals with developing gonads was observed, with the smallest maturing female measuring 71 mm SL and the smallest male 68 mm SL. No individual was identified as mature. Some authors have postulated that this species may spawn in the open sea and the juveniles later move to the sandy beaches [1,11]. Finucane provided evidence for this, in the presence of *T. marginatus* larvae in plankton samples taken between 5 and 15 miles (9.26 and 27.78 km) offshore [11]. Finucane also referred to a long spawning period in Florida, with the peak in spring (April to June), followed by other smaller peaks in summer and early autumn (July to October) [11]. About one month after the spawning, the juveniles appeared at the beaches. A similar spawning period (spring to autumn) was inferred by Cunha for *T. carolinus* on the Brazilian southeastern coast [9], and for the congener *T. marginatus* on the southern coast [1].

Trachinotus carolinus is a carnivore, according to its DTL/SL ratio (0.65) and the items found in its diet. The item most consumed in Caraguatatuba Bay was the bivalve *Tivela mactroides*. The mollusc shells were found crushed in the digestive tract, in agglomerates of tiny shell fragments. Finucane also observed that most of the food items of this species were crushed into small pieces, probably by the toothed pharyngeal plates [11]. *Tivela mactroides* is one of the most abundant macro fauna species in the Caraguatatuba Bay region; according to Denadai et al. the juveniles usually recruit in depths from 3 to 5 m, shifting in the course of their lifetime to the intertidal part of the beach [22]. The fragmented state of the shells did not allow us to measure the size of the ingested bivalves, but they were probably small, with shell lengths less than 20 mm, the size classes that predominate in the sublittoral of Caraguatatuba Bay [22]. The consumption of *T. mactroides*, which is very abundant in the region, by *T. carolinus* confirms the existence of an opportunistic habit for the genus *Trachinotus*, as previously observed by other authors [13,15]. These fish consume food items that are available, rather than showing preferences for a certain item. The second item in importance to *T. carolinus* in Caraguatatuba Bay was Mysida, and the other items had very little importance.

Bellinger and Avault [12] and Armitage and Alevison [15] described a tendency in *T. carolinus* toward less-specialized juveniles, which consume the most abundant items, while the adults select their food. Thus, Finucane observed that the diet of *T. carolinus* at sizes from 15 to 44 mm SL consisted of crustaceans (Amphipoda), larvae and adults of Diptera, and occasionally the bivalve *Donax variabilis* [11]. For fish from 50 to 110 mm SL, the diet consisted mainly of crustaceans and molluscs, and between 110 and 138 mm SL, *D. variabilis* dominated its diet. Chervinski and Zorn found that the diet of *T. ovatus* in the Mediterranean was mainly constituted of small crustaceans (Mysida, Copepoda, and Cladocera) and insects (including Diptera larvae) and commented that, in captivity, this fish might be reared with artificial food and molluscs [33]. Monteiro-Neto and Cunha [13] found that the diet of smaller individuals (20 to 70 mm TL) of the congener *T. marginatus* at Praia do Cassino (RS) was composed mainly of crustaceans (including *Emerita brasiliensis*, Copepoda, and Mysida), whereas in larger classes (70 to 150 mm TL), the polychaetes, followed by crustaceans (*E. brasiliensis*) and molluscs were the most ingested items. It was not possible to evaluate the differences in the diet between juveniles and adults for pompano in Caraguatatuba Bay, because all the individuals caught were small (37 to 128 mm SL). However, comparison with the other studies described above reveals wide variability in diet among different regions.

Other authors have found crushed mollusc shells in the digestive tract of *T. carolinus*, similarly to our observations here. Armitage and Alevizon [15] concluded that juveniles (between 10 and 65mm SL) of *T. carolinus* in Florida eat mostly *Emerita talpoida* and *Donax variabilis*, the most abundant items in the local fauna. Adults (200 to 275 mm SL) eat mainly bivalves of the genus *Tellina*, also abundant in the region, which are crushed with their pharyngeal teeth. Finucane found in a single fish (118 mm SL), 217 shell fragments from 0.4 to 2.5 mm [11]. Bellinger and Avault observed that bivalves (*Donax*) were very frequent in the stomach contents of large individuals [12]. In another observation of a species from the genus *Trachinotus* consuming molluscs, Jory noted an incident of predation of the gastropod *Strombus gigas* (20 to 45 mm shell length) by juveniles of *Trachinotus falcatus* (270 to 275 mm SL) in an aquarium tank [34]. These consistent observations suggest that the well-developed pharyngeal plates indicate a feeding specialization and shape the kind of food that these fish consume. Large and well-developed pharyngeal plates indicate an eventual specialization of the adults for durophagy, i.e., feeding on organisms with a hard surface such as molluscs and crustaceans.

Cunha reported an interesting habit of the species, which customarily feeds at the edge of the sea and often digs in the substrate in search of food [9], and is frequently seen with its caudal fin pointing out of the water [35]. Bellinger and Avault noted that *T. carolinus* is apparently adapted to digging and nosing in search of food in the sand, and in shallow waters, the juveniles have the advantage of actively surfing and thus consuming the benthic organisms when these are exposed by the waves [12].

The nematode found in the digestive tract of a single *T. carolinus* in Caraguatatuba Bay was considered to be a parasite, because of the good state of preservation of its body wall. Finucane also found nematodes parasitizing the body cavities and viscera of *T. carolinus* in Florida [11].

Considering the high proportion of the clam *T. mactroides* in the diet of the pompano, jointly with the Ecological-Economic Zoning (State Decree No. 49.215 of 7 December 2004), which prohibited the seabob fishery from trawling in the bay, a possible increase in the

numbers of these fish would prejudice the maintenance of the clam resource in the region, due to top-down regulation. However, certain environmental impacts in this area may directly and negatively affect the pompano. As reported by Santos et al. [36], *T. carolinus* showed a low metabolic rate after chronic exposure to high concentrations of naphthalene, indicating a narcotic toxicity. In Caraguatatuba Bay, the risk of contamination by chemical products from oil spills is substantial, because of its proximity to the largest Brazilian oil terminal. Complementarily, this study represents an effort to understand the biota of this area prior to the implementation of some industrial activities in Caraguatatuba Bay, such as the installation of petroleum and natural-gas pipelines, the implementation of a petroleum and natural-gas treatment facility, and the expansion of São Sebastião Port, and therefore also constitutes a baseline for future assessments of the effects of these changes on the abundance of both the pompano *T. carolinus* and the clam *T. mactroides*.

The results presented above demonstrated that the populationof *Trachinotus carolinus* in the Caraguatatuba Bay is dominated by juveniles, and is occasionally found in higher abundance in December and March (end of spring and summer). *T. carolinus* is a carnivorous species, and in this bay consumes *Tivela mactroides* almost exclusively.

Acknowledgements

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