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Feeding strategy of *Menticirrhus americanus* and *Menticirrhus littoralis* (Perciformes: Sciaenidae) juveniles in a sandy beach surf zone of southern Brazil

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ABSTRACT. The diet and foraging strategy of juvenile *Menticirrhus americanus* (Linnaeus, 1758) and *Menticirrhus littoralis* (Holbrook, 1847) were studied, testing the existence of trophic overlap between these species and within different seasons (spring and summer). Individuals were sampled using a beach seine in the surf zone near Rio Grande, state of Rio Grande do Sul, Brazil. Based on Morisita's Simplified Overlap Index and Bootstrapping technique, trophic overlap between species was considered high during the spring (C*ik* = 0.97 ± 0.07) and low during the summer (C*ik* = 0.37 ± 0.14). Juveniles shared the same food resources during the spring (FO of amphipods > 0.75), with the *M. americanus* diet presenting lower prey diversity (N = 7) when compared to *M. littoralis* (N = 13). In the summer, *M. americanus* presented a more varied diet (N = 13) than during the spring, suggesting a non-specialized opportunistic diet, whereas *M. littoralis* continued to show a diversified diet (N = 14). During the summer, *M. americanus* presented a generalist-opportunist feeding strategy, whereas juvenile *M. littoralis* tended to be more specialist.

KEY WORDS. Amundsen Method; Bootstrap; diet overlap; Gulf Kingfish; Southern Kingfish.

Fish assemblages inhabiting the surf zone of sandy beaches are characterized by a high spatial and temporal variability (Wilber *et al.* 2003). However, the opportunistic feeding behavior of species (Lasiak & McLachlan 1987, Du Preez *et al.* 1990, McLachlan & Brown 2006) and the high abundance of larvae and juveniles (Robertson & Lenanton 1984, Ruple 1984, Ross *et al.* 1987, Santos & Nash 1995, Ayvazian & Hyndes 1995, Gibson *et al.* 1996) suggest that this is an important nursery and developing area for many species of coastal marine fish, which use the surf zone as refuge against predators and as an important foraging spot (Lenanton *et al.* 1982, Whitfield 1989, Busoli & Muelbert 1999, Layman 2000).

Kingfishes are characteristic of shallow coastal zones. Juvenile Gulf Kingfish *Menticirrhus littoralis* (Holbrook, 1847) are extremely abundant in the coastal marine zone of southern Brazil, where they occur throughout most of the year, whereas juvenile Southern Kingfish *Menticirrhus americanus* (Linnaeus, 1758) show a stronger association with estuarine zones (Chao *et al.* 1982, Chao *et al.* 1985, Ramos & Vieira 2001).

Information related to the trophic biology of these species is relatively scarce, and is available only for adults captured in coastal regions north of state of Rio Grande do Sul (Lunardon 1990, Lunardon *et al.* 1991, Teixeira *et al.* 1992, Haluch *et al.* 2009). Taking in consideration the co-occurrence of juveniles of both these species at the sandy beaches in municipality of Rio Grande, state of Rio Grande do Sul (RS), and the absence of trophic information on both species, the objectives of the research presented herein are to describe the diet, foraging strategy and to test trophic overlap between juveniles of these *Menticirrhus* species. In addition, we evaluate and discuss the methodology employed in the analysis of feeding strategy.

MATERIAL AND METHODS

Fishes were sampled monthly from May 2001 to May 2002 during diurnal periods along the surf zone of sandy beaches adjacent to the Patos Lagoon jetties in Rio Grande (Fig. 1). Due to the higher abundance of both species in spring 2001 (September, October and November) and summer 2001/2002 (December, January and February), only fishes captured during these seasons were chosen for analysis. The net used was a 9 m x 1.5 m beach seine (13 mm stretched mesh size in the wings and 5 mm in the center 3 m section) which was pulled at depths of less than 1.5 m. At each sampling spot, three seinings were performed, representing three samples per point. Fishes were fixed in 4% formalin for identification. Juvenile *Menticirrhus* were taken to the laboratory where they were measured (total length, in millimeters – TL mm), weighted and identified (using Johnson 1978). Stomachs were extracted, by cutting out the esophagus and pylorus, and fixed in 10% formalin buffered with sodium borate, for posterior analysis. Empty stomachs were removed from the analyses.

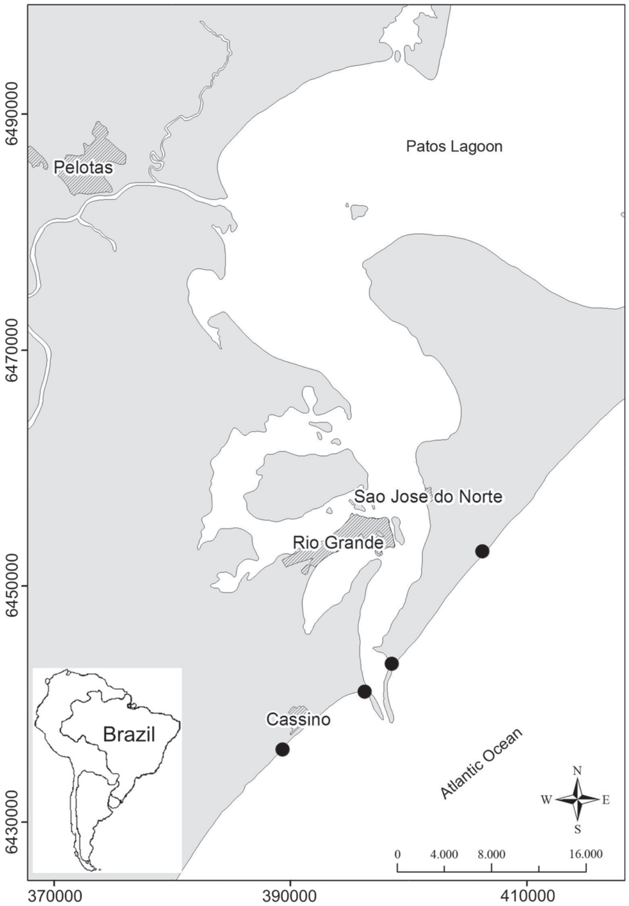


Figure 1. Map of the study area. Black circles show the sampling sites.

A total of 185 individuals of *M. americanus* (spring = 72 and summer = 113), with lengths ranging from 20-60 mm, and 424 *M. littoralis* (spring = 126 and summer = 298), with lengths between 20-140 mm, were utilized in this study.

Food items were identified to the lowest taxonomic category possible, and those in an advanced state of digestion were grouped into higher taxonomic categories, as described by Crow (1982). Prey was quantified and volumes were estimated utilizing the volumetric method proposed by Capitoli (1992). Prey volume less than 5 mm^3 was estimated employing the geometric formula method. The volumetric percentage (%V), frequency of occurrence (%FO), and frequency of occurrence adjusted to 100% (%FOAJ), were calculated for each of the identified categories, according to Hyslop (1980) and Mohan & Sankaran (1988). A prey was considered important, and utilized for description of the diet and foraging strategy, when presenting at least one of the indexes (%V or %FOAJ) greater than or equal to 100/*S*, where *S* is the number of prey per size class of the individuals utilized in the analysis.

Feeding strategy was described employing the graphic method proposed by Amundsen *et al.* (1996). This method is based on a two-dimensional representation, where: the "prey-specific abundance" (P*i*) is plotted against the frequency of occurrence (FO, expressed as a fraction instead of a percentage). The P*i* value is defined as the relative numeric proportion of a determined prey in relation to the total prey number, in stomachs which contained prey (Deus & Petrere-Júnior 2003): $P_i = (\Sigma S_i/\Sigma S_t)*100$ where, S_i is the sum of prey *i* and S_t the total number of prey in the stomachs of predators which contained only prey *i* in their stomachs. The product P*i* * FO is equal to the mean abundance of the prey.

The numeric contribution of prey was utilized for evaluation of juvenile diet similarity between and within species. In order to test trophic overlap, the Morisita Simplified Overlap Index (Krebs 1989) was utilized. The overlap coefficient (C_{ik}) varies from 0 to 1, with zero or close to zero representing entirely distinct diets, and one or close to one representing similar diets, in terms of proportion of consumed prey (Zaret & Rand 1971, Krebs 1989, Carter *et al.* 1991). The trophic overlap was considered significant when the value of C_{ik} was $\geqslant$ 0.6 (Labropoulou & Eleftheriou 1997). The standard error and 95% confidence interval ($CI = 1.96 \pm SE$), associated with the distribution of the index calculated values, were estimated based on 200 re-samples obtained by the Bootstrap statistical technique (Hall *et al.* 1990, Efron & Tibshirani 1993, Mendoza-Carranza & Vieira 2007).

Standard errors of the Bootstrap estimations were calculated utilizing the following equation:

$$Se_B = \left[\sum_{b=1}^{B} \frac{\left[\theta*\hat{(b)} - \hat{\theta}(\cdot)\right]^2}{B-1} \right]^{\frac{1}{2}} \text{ where, } \theta*(\cdot) = \sum_{b=1}^{B} \frac{\theta*\hat{(b)}}{B}, \ \theta*\hat{(b)} = \text{index}$$

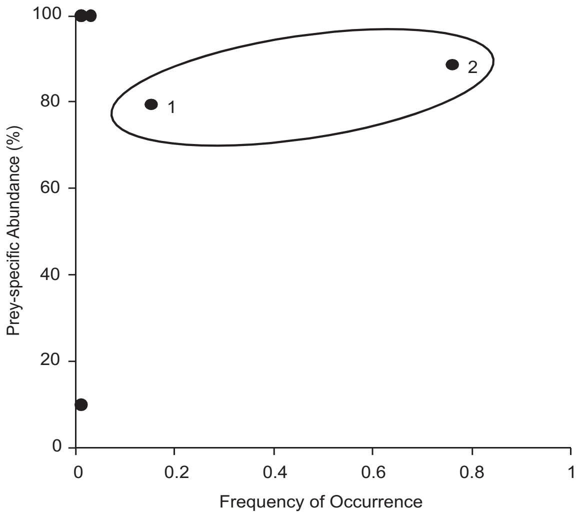
calculated by Bootstrap and *B* = number of Bootstrap samples.

RESULTS

Both species of *Menticirrhus* feed on a variety of prey items (Tab. I). Seasonal differences were observed in terms of feeding strategy by juveniles of both species. During the spring, juveniles practically shared the same food resources, with the majority of the population (FO > 0.75) foraging on the same resource: amphipods.

Menticirrhus americanus presented a diet with a low diversity of prey (N = 7), and with a high frequency of amphipods (FO = 0.76) and polychaetes (FO = 0.18, Fig. 2). *Menticirrhus littoralis* presented a higher diversity of prey (N = 13), with three prey types presenting a high frequency of occurrence (Fig. 3), where amphipods were the most frequent (FO = 0.79), followed by polychaetes (FO = 0.26) and the crustacean *Emerita brasiliensis* (Schmitt, 1935) (Hippidae), with a frequency of 0.15.

The trophic overlap index registered for juveniles of both species was high (C_{ik} = 0.97 ± 0.07), with 100% of the calcu-



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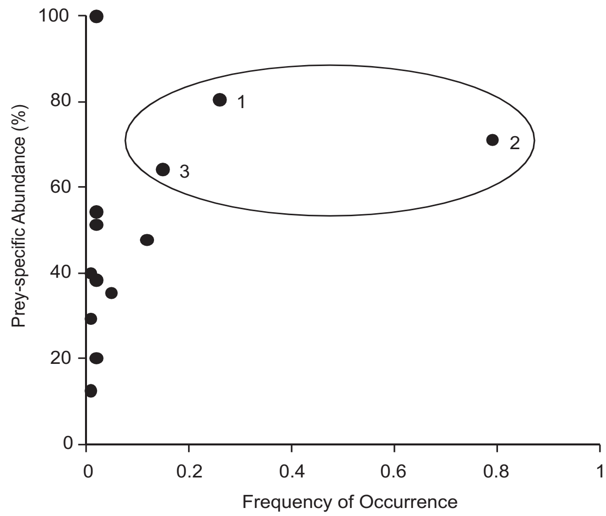

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Figures 2-3. Feeding strategy of individuals captured in the spring of 2001; (2) *M. americanus* with seven prey items and (3) *M. littoralis* with 13 prey items. The prey itens inside the circles are the most frequents. 1) Polichaets, 2) Amphipods, and 3) *E. brasiliensis*.

Table I. Frequency of occurrence (%FO) of items present in the diet of*M. americanus* and *M. littoralis* during Spring and Summer.

Prey items	*M. americanus*		*M. littoralis*	
	Spring	Summer	Spring	Summer
Polychaeta				
Unidentified Polychaetes	18.0	16.0	26.0	16.0
Mollusca				
Unidentified Gastropods	–	1.0	–	–
Bivalvia				
Donax hanleyanus	–	–	–	1.0
Siphon remains	–	2.0	2.0	5.0
Unidentified Bivalvia	–	–	2.0	2.0
Crustacea				
Unidentified Amphipods	76.0	2.0	79.0	17.0
Cumacea				
Diastylis sp.	–	10.0	–	2.0
Unidentified Isopods	–	8.0	2.0	12.0
Mysidacea				
Metamysidopsis elongata atlantica	15.0	34.0	12.0	7.0
Unidentified Tanaids	–	4.0	1.0	1.0
Unidentified Copepods	3.0	–	–	< 1.0
Anomura				
Emerita brasiliensis	1.0	22.0	15.0	65.0
Brachyura				
Pinnixa patagoniensis	–	15.0	–	19.0
Unidentified Crustacea	1.0	15.0	5.0	5.0
Pisces				
Unidentified Pisces	–	4.0	1.0	1.0
Plant Material	–	–	2.0	–
Stomach with contents	72.0	113.0	126.0	298.0

lated indexes above the 60% value (Fig. 4). These results, combined with those obtained with Amundsen's graphic method, suggest that during the spring, the feeding strategy of juvenile kingfishes varied between generalist and specialist, with both species preying on the same prey.

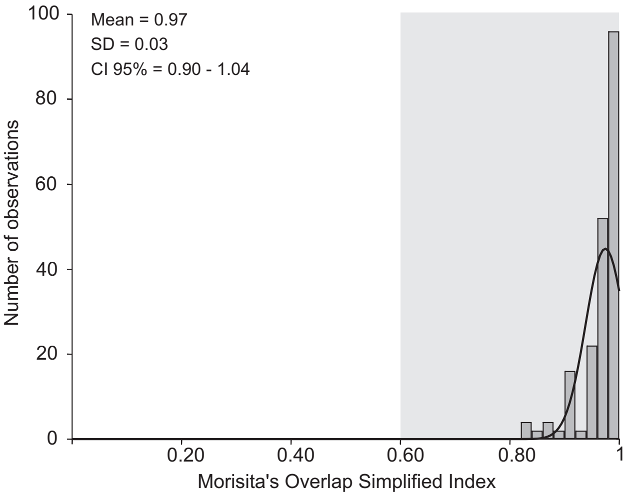


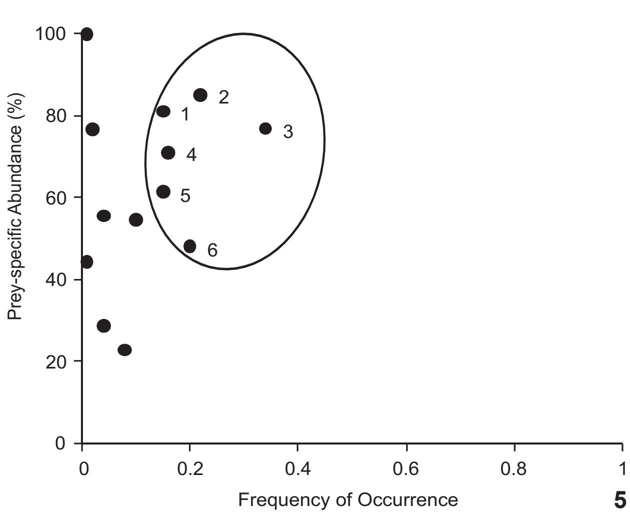
Figure 4. Results of the Bootstrap technique applied to juvenile *Menticirrhus americanus* and *M. littoralis* during the spring of 2001. The graph informs the distribution of the 200 generated indexes, with their respective means, standard deviations and 95% confidence intervals. The grey area indicates biologically significant overlap values.

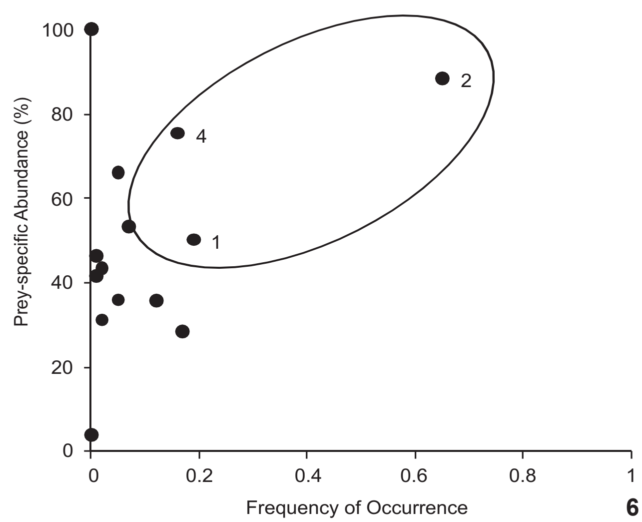
During the summer, *M. americanus* presented a more diverse diet (N = 13) than in the spring. Six types of prey were considered of high importance; however, all prey presented occurrence frequencies lower than 0.50 (Fig. 5), suggesting an opportunistic, non-specialized diet. *Menticirrhus littoralis* present a diverse diet (N = 14), of which only three types of prey were considered important, with the crustacean *E. brasiliensis* being the most frequent (FO = 0.65, Fig. 6).

During the summer, in contrast to what was observed in spring, trophic overlap between species was not considered statistically significant ($C_{ik} = 0.37 \pm 0.14$), with 100% of the calculated indexes below the 60% value (Fig. 7). For this period, juvenile *M. americanus* presented a generalist-opportunist feeding strategy, with a much more diverse diet, whereas juvenile *M. littoralis* presented a more specialized diet, foraging mainly on *E. brasiliensis*.

DISCUSSION

It is important to consider that the ecological interpretation of trophic overlap is highly dependent on the variable utilized for calculating the selected indexes, which could be frequency of occurrence, numerical abundance, prey weight or prey volume (Wallace 1981, Hall *et al*. 1990). This is due to the fact that the frequency of occurrence and numerical abundance are both influenced by small food items, which may occur in high quantities but with a relatively low contribution to the biomass ingested by the predator. Furthermore, frequency of occurrence is not commonly employed in the trophic overlap index calculations, due to the fact that it is not a proportional





Figures 5-6. Feeding strategy of individuals captured in the summer of 2001/2002; (5) *Menticirrhus americanus* with 13 prey items and (6) *M. littoralis* with 14 prey items. The prey itens inside the circles are the most frequents. 1) *P. patagoniensis*, Pinnotheridae, 2) *E. brasiliensis*, 3) *Metamysidopsis* spp. (Crustacea: Mysidacea), 4) Polichaets, 5) Crustacean remains and 6) Amphipods.

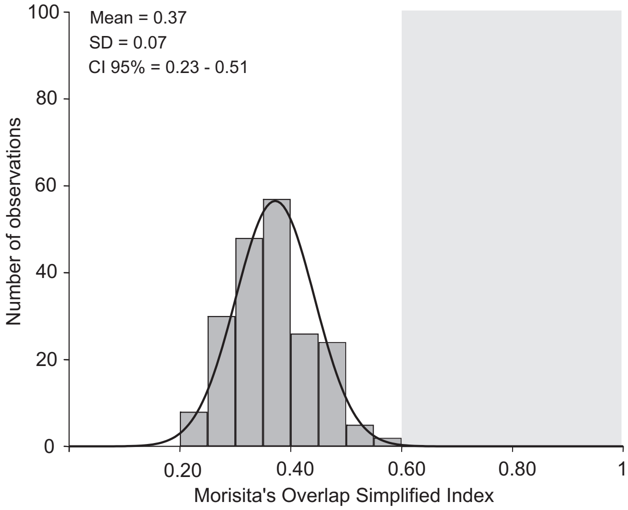


Figure 7. Results of the Bootstrap technique applied to juvenile *Menticirrhus americanus* and *M. littoralis* during the summer of 2001/2002. The graph informs the distribution of the 200 generated indexes, with their respective means, standard deviations and 95% confidence intervals. The grey area indicates biologically significant overlap values.

measurement of the diet (Krebs 1989). On the other hand, the use of volume instead of numerical abundance tends to increase the importance of the larger prey encountered in the diet (Labropoulou & Eleftheriou 1997). In this sense, according to Krebs (1989), there is no consensus on which measurement is better for diet analyses. However, the calculation of P*i*, defined by Amundsen *et al.* (1996) as the proportion of a determined prey relative to the total amount of prey, while considering only the stomachs where such prey occurred, is independent of volume, weight, or numerical quantification.

The use of volume as a measure of relative importance in stomach content analysis of juvenile *Menticirrhus* permitted grouping semi-digested or fragmented items in categories of measurable volume, which would be impossible if the numerical method is employed. Also, according to Costello (1990) and Amundsen *et al.* (1996), graphic combinations of both frequency of occurrence and some representation of relative importance of prey, generate a higher-quality ecological interpretation of diets.

This work adopted a value of 0.60 as biologically significant for the Morisita Trophic Overlap Index, despite the fact that the choice of this value is not well discussed in literature. Ross (1986) employed a 0.40 value as the cutoff point for indicating the presence of substantial separation of resources between species, while Zaret & Rand (1971), Mathur (1977) and McPherson (1981) suggested the use of 0.60 and 0.70. These authors did not, however, discuss the biological meaning of such values. Meanwhile, Wallace (1981), Langton (1982) and Labropoulou & Eleftheriou (1997), who based their discussions on the above-cited works, adopted 0.60 as the biologically significant trophic overlap value, not presenting any ecological argument as to why such value was chosen. Elliott (1994) and Marshall & Elliott (1997) comment on the necessity of employing statistical techniques for determining patterns and preventing false conclusions in regards to biological data analyses. In this manner, it can be concluded that the selection of a biologically significant trophic overlap value is apparently a statistical option, rather than an ecological one.

Until not long ago, little attention was given to the statistical properties of trophic overlap measurements, and overlap indexes were calculated without statistical significance (Petraitis 1979, Ricklefs & Lau 1980, Maurer 1982, Smith & Zaret 1982, Mueller & Altenberg 1985). Dixon (2001) commented that it is easy to calculate such indexes but difficult to estimate their precision. In order to resolve these issues, the Bootstrap method is an important tool for verifying the statistical significance for the calculated trophic overlap value, adding a confidence interval to the obtained results. Bootstrapping is an intensive computational technique, with the basic principle of treating the data set as the entire population. It removes a large number of samples from this set, where all observations present equal probability of being selected (Tirasin & Jørgensen 1999). Initiating with a database matrix, the technique recombines original and reposition data, calculating the overlap index for each generated Bootstrap sample (Mueller & Altenberg 1985, Krebs 1989). Due to the current computational advances, this technique has been extremely utilized for verification of statistical significance for the calculated trophic overlap value.

The graphic methods for the interpretation of diet data results are characterized mainly by the straightforward visual comparison of data (Costello 1990). In this sense, the largest advantage of the method proposed by Amundsen *et al.* (1996) in relation to the most commonly used graphic methods is that, besides presenting a general description of the species' diet, it shows the type of feeding strategy regarding a determined prey. Therefore, the use of distributions generated by the Bootstrap technique, associated with the graphic method proposed by Amundsen, was an essential tool for testing trophic niche similarity between the studied species (Mendoza-Carranza & Vieira 2007).

With this in mind, the results obtained in this work confirm conclusions of Gerking (1994), who states that the terms specialist, generalist and opportunist should not be considered as a system for classifying foraging activities, but rather be employed in a temporal manner for describing a particular situation in space or time, as well as to describe a different life cycle stage of a particular species.

The surf zone is an important nursery and developmental area for many species of coastal marine fish and juvenile kingfish are characteristic of such zones in southern Brazil (Ramos & Vieira 2001). Kingfish use the surf zone especially during spring and summer (LIMA & VIEIRA 2009). The variation of the size range between the two *Menticirrhus* species during the summer may also have been directly responsible for the marked difference in the species' feeding strategies during this period.

Based on the results obtained in this paper, it can be concluded that during the spring, feeding strategies of both *Menticirrhus* species were generalist-opportunistic, with a large part of individuals preying on a wide variety of prey items with an average low frequency of occurrence (FO < 0.40) per prey. On the other hand, during summer it is possible that there is a higher prey availability in the surf zone, as well as a different size segregation between both species, with the larger individuals of *Menticirrhus littoralis* apparently preying directly on larger *E. brasiliensis*, while the smaller *M. americanus* apparently forage on smaller *E. brasiliensis*. Added to these facts is a temporary increase in availability of other prey.

Juveniles of both species presented high trophic overlap during the spring, foraging in an opportunistic manner on the most abundant prey, and during the summer tended towards a more diversified diet, reducing trophic overlap. According to HALL *et al.* (1990), individuals from the same sample (*i.e.*: seine net, in this case) tend to present similar stomach contents, considering that prey items, which consist mostly of benthic invertebrates, present a patched distribution. Therefore, it is expected that fish which present higher degrees of opportunism take advantage of the momentary elevated abundance of benthic invertebrates, even though they can be classified as specialists due to the high quantity of a specific prey. However, only a comparison of diets through time would allow characterization of species as specialists, which feed exclusively on a group of prey most of the time, or as generalist-opportunists, which feed intensely on the most abundant prey in the environment presenting shifts in the stomach contents as prey assemblages change over time.

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