



Size-related changes in diet of the slipper sole *Trinectes paulistanus* (Actinopterygii, Achiridae) juveniles in a subtropical Brazilian estuary

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Abstract. Size-related changes in the diet of the slipper sole *Trinectes paulistanus* juveniles were described based on the stomach content analysis of 105 specimens (9 – 55 mm standard length) collected in an oligohaline habitat of the Paranaguá Bay estuarine complex (southern Brazil). From multivariate analyses, an ontogenetic diet shift was detected at about 25 mm standard length. Chironomidae larvae were the most important prey for the smaller fish (≤ 25 mm), and the tanaid *Kalliapseudes schubarti*, for the larger ones (> 25 mm). Results of feeding strategy analyses revealed a trophic specialization toward a single prey and, consequently, the trophic niche was narrow within each size class. We discussed such size-related dietary patterns in light of ontogenetic changes in mouth gape size.

Key words: feeding habits, population feeding specialization, Paranaguá estuarine complex, flatfish, *Leptocheirus spinicoxa*

Resumo. Mudanças ontogenéticas na dieta de juvenis do linguado *Trinectes paulistanus* (Actinopterygii, Achiridae) em um estuário subtropical do Brasil. Variações ontogenéticas na dieta de juvenis do linguado *Trinectes paulistanus* foram descritas a partir da análise do conteúdo estomacal de 105 espécimes (9 – 55 mm comprimento padrão - CP) coletados em um habitat oligohalino do complexo estuarino da baía de Paranaguá (Sul do Brasil). Análises multivariadas detectaram uma mudança na dieta em 25 mm de CP. Larva de Chironomidae e *Kalliapseudes schubarti* dominaram as dietas dos menores (≤ 25 mm CP) e maiores peixes (> 25 mm CP), respectivamente. Os resultados de análises de estratégia alimentar revelaram especialização em uma particular presa e um consequente nicho trófico reduzido dentro de cada classe de tamanho. Discutiram-se tais padrões ontogenéticos de dieta à luz de mudanças ontogenéticas na abertura oral em *T. paulistanus*.

Palavras-chave: hábito alimentar, especialização trófica da população, complexo estuarino de Paranaguá, linguado, *Leptocheirus spinicoxa*

Introduction

The Achiridae are moderately small flatfishes which are principally marine and estuarine, although some species occur in freshwater (Munroe 2002). The slipper sole, *Trinectes paulistanus* (Miranda-Ribeiro, 1915), is a small (max 180 mm standard length - SL), marine demersal species that is widely distributed along the Eastern South American coast, from Colombia to southern Brazil (Munroe 2002). It exhibits negligible commercial importance and is commonly caught and discarded

as by-catch in crustacean trawl fisheries operating in estuaries and shallow coastal areas (Munroe 2002). *T. paulistanus* larvae and juveniles appear to occupy shallow estuarine areas (Bonecker *et al.* 2007, Michele & Uieda 2007) and adults, main channels of estuaries (Maciel 2001), bays (Azevedo *et al.* 2007), beaches (Godefroid *et al.* 2004), and inner shelf habitats (Santos 2007).

Michele & Uieda (2007) found *T. paulistanus* juveniles feeding on insects, polychaetes, isopods, and amphipods in a

southeastern Brazilian mangrove river. Despite abundant in estuaries of the subtropical Brazil (Maciel 2001), the species' biology and ecology are poorly described. Further, there is no information on ontogenetic dietary shifts, which may reduce intra-specific competition for food resources especially when various size classes occur at same general habitat (Ward-Campbell & Beamish 2005). Changes in gape size facilitate intra-specific partitioning of food as gape constraints the size of the ingested prey (Ward-Campbell & Beamish 2005).

Within size-structured fish populations, individual specialization may be a conspicuous phenomenon (Svanback & Persson 2004) and thus is necessary to be estimated for characterizing the feeding niche width precisely (Bolnick *et al.* 2003).

This study deals with the diet of *T. paulistanus* juveniles of an oligohaline habitat within the estuarine complex of Paranaguá Bay (southern Brazil). Our specific goal is to examine size-related shifts in diet composition in light of the mouth dimensions changes and individual trophic specializations.

Materials and Methods

The study took place in the upper estuary of Guaraguaçu River, a large tributary located on the

southern part of the Paranaguá Bay estuarine complex, Brazil (Fig. 1). Three continuous stations within the river's oligohaline zone were selected for sampling (Fig. 1). Sampling was monthly conducted from February-2006 to April-2006. Fish were caught by a 15 m x 2 m seine-net with a uniform mesh size of 5 mm. During each survey, one 20 m-tow was performed parallel to the river's course at each station, fishing to depth of ca. 1.5 m. Fish were stored and transported on ice to the laboratory.

In laboratory, the vertical (MV) and horizontal (MH) mouth openings (0.1 mm - using a caliper) and SL (mm) were taken of each fish before its stomach was removed and preserved in 10% formalin. Stomach fullness was estimated visually on a scale of 1 (10% full) to 10 (100% full; Sarre *et al.* 2000). Prey items from each stomach were identified to the lowest taxonomic level and quantified by: (1) percentage volume (%V - by spreading all stomach contents in counting cell chamber with uniform depth and then calculating $area\ of\ prey\ item\ j / total\ item\ area \times 100$; modified from Hellowell & Abel 1971); and (2) percentage abundance (%N) as $number\ of\ prey\ item\ j / total\ number\ of\ prey \times 100$ (Hyslop 1980). To preserve individual variation, stomach contents were not pooled in the following analyses (Ley *et al.* 1994).

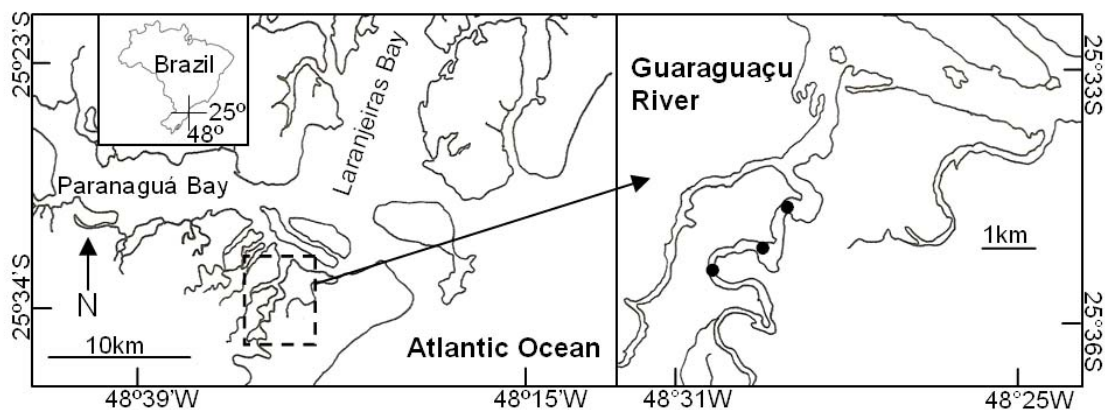


Figure 1. Map of the estuarine complex of Paranaguá Bay and its location on the southern Brazilian coast. The Guaraguaçu River Estuary and the capture stations (●) are shown in detail.

A group average hierarchical cluster analysis, using the Bray-Curtis similarity index, assessed size-related variations in diet. It based on individual stomach content data, which were described by %V values only. Due to heterogeneous size range of the diet components, %N values are less suitable in similarity analysis (Baldó & Drake 2002) and thus were not used. %V values were root-square transformed prior analysis. Analysis of similarity (ANOSIM; Clarke & Warwick 1994)

tested for differences in diet between resultant clusters (size groups) and month of captures.

To synthesize the size group diet information, the frequency of occurrence (%F - percentage of fish containing a given prey item j), the mean %V and mean %N values, and the index of relative importance $[IRI_j = (\%N_j + \%V_j) \times \%F_j]$ were computed for each prey item (Hyslop 1980).

The Costello graphical method (Costello 1990), modified by Amundsen *et al.* (1996), was

employed to look for general trends in feeding behavior of *T. paulistanus*. To identify individual specialization, the proportion similarity index was calculated following Svanback & Persson (2004):

$$PS_i = \sum_j \min(p_{ij}, q_j),$$

where p_{ij} is the proportion

volumetric of prey item j in the individual i 's diet and q_j is the volumetric contribution of j in the diet of the population as a whole. For individuals that specialize on a single diet item j , PS_i takes on the value q_j . For individuals that consume resources in direct proportion to the population as a whole, PS_i will equal 1 (Svanback & Persson 2004). The overall prevalence of individual specialization (IS) in the population can be expressed by the average PS_i value: $IS = 1/n \times \sum_i PS_i$ (Svanback & Persson

2004). Note that if all individuals have the same diets then IS will be 1, indicating no individual specialization, while values close to 0 indicate strong individual specialization (Svanback & Persson 2004).

Finally, mouth dimensions (MH and MV) were regressed against SL (either linearly or log-linearly, based on the r^2 value) (Karpouzi & Stergiou 2003). One-way ANOVA tested the association between SL and dependent variables.

Results

Caught fish ranged from 9 to 55 mm SL (mean size = 26.9 mm SL), with the best represented class being the 15-25 mm SL (Fig. 2). Of the 105 individuals caught, 88 (83.8%) contained food in the stomachs and were used in diet analysis.

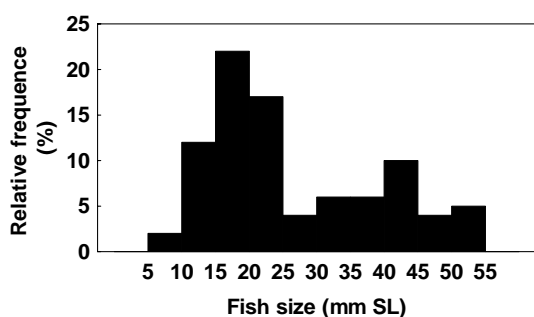


Figure 2. Size-frequency distribution of *T. paulistanus*, collected in the Guaraguaçu River Estuary. SL = Standard Length

Month of capture did not appear to have significant effect on diet compositions (ANOSIM, $R = 0.106$, $p > 0.09$).

Two size groups with similar dietary pattern were identified (Fig. 3): group 1 ($n = 38$) pooled almost all fish smaller than 26 mm SL, and group 2

($n = 50$), mainly those larger than 25 mm SL. The diet composition of the groups were significant different (ANOSIM, $R = 0.544$, $p < 0.01$) and the mean stomach fullness of both was relatively high and similar (> 6 , Table I). According to the diet indices (Table I), and the feeding strategy diagram (Fig. 4a), chironomid larva was the major prey within the group 1, followed by the tanaid *Kalliapseudes schubarti*. Some individuals specialized on the latter and also another tanaid *Sinelobus stanfordi* (Fig. 4a). The diets of the larger fish (group 2) were by far dominated by *K. schubarti*, and secondly by chironomids and polychaetes on which some fish specialized (Fig. 4b and Table I). Remaining prey items can be considered occasional.

Within each size group, the predominance of high PS_i -values (Fig. 5), the high IS -values ($IS_{\text{GROUP1}} = 0.68$, $IS_{\text{GROUP2}} = 0.76$), and a restrict point in the upper right of the diagram (Fig. 4 a, b) represent a predator population's specialization (thus a low individual specialization) as well as a population's narrow niche. MH related log-linearly ($\ln MH = \ln 1.1072SL - 3.1667$, $r^2 = 0.84$) and MV linearly ($MV = 0.0965SL - 0.0247$, $r^2 = 0.92$; Fig. 6) with SL. The slopes of the regressions were all statistically significant ($p < 0.0001$).

Discussion

Comparing our data to those of other areas reveals that benthivory appears to be common in *T. paulistanus*, despite some differences in terms of prey composition. While it feeds on polychaetes, amphipods, and aquatic insects in the Rio da Fazenda Estuary (Michele & Uieda 2007), in the Sepetiba Bay its diet is dominated by polychaetes (Guedes & Araújo 2008). The congeneric *T. maculatus* also consumes mainly benthic invertebrates, such as polychaetes and amphipods (Derrick & Kennedy 1997). In the oligohaline zone of the Guaraguaçu, *T. paulistanus* preyed heavily on chironomids and *K. schubarti*, probably due to their high availability. Chironomid larvae seem to be common in low-salinity upper estuaries (Corrêa & Uieda 2008) and *K. schubarti* is an abundant macrofauna component in the Paranaguá Bay (Lana *et al.* 1989; Lana & Guiss 1991).

Within each size group, almost all individuals fed mostly upon a dominant prey taxon (either *K. schubarti* or chironomid larvae), some specialized on specific items, and few included small proportions of other prey types occasionally. Such a strong feeding specialization of the groups resulted in narrow trophic niche widths, which differ

from those with high within- or between-phenotype component (Amundsen *et al.* 1996). Narrow trophic niche was also reported by the population from Sepetiba Bay (Guedes & Araújo 2008).

The observed size-related diet shift may be related to ontogenetic shifts in gape size that grew consistently with increasing body size in *T. paulistanus*. Ontogenetic gape increase (among other factors) allows growing predators to ingest

more elusive, larger prey successfully (Karpouzi & Stergiou 2003; Ward-Campbell & Beamish 2005). In fact, chironomid larva is a small, slow-moving prey, while *K. schubarti* is relatively larger and more elusive, despite its tubicolous life style (Lana & Guiss 1991). Similar predator-prey size relationships also were detected in other flatfish (Scharf *et al.* 2000) and other estuarine fishes (Scharf & Schlicht 2000; Contente *et al.* in press).

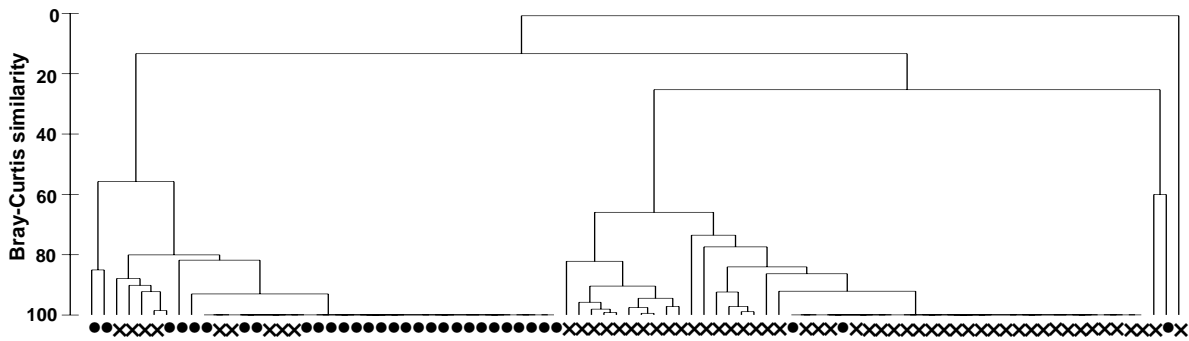


Figure 3. Hierarchical cluster analysis based on percentage by volume (%V) of the *T. paulistanus* individual diets from the Guaraguaçu River Estuary. ● = fish > 25 mm standard length; x = fish ≤ 25 mm standard length.

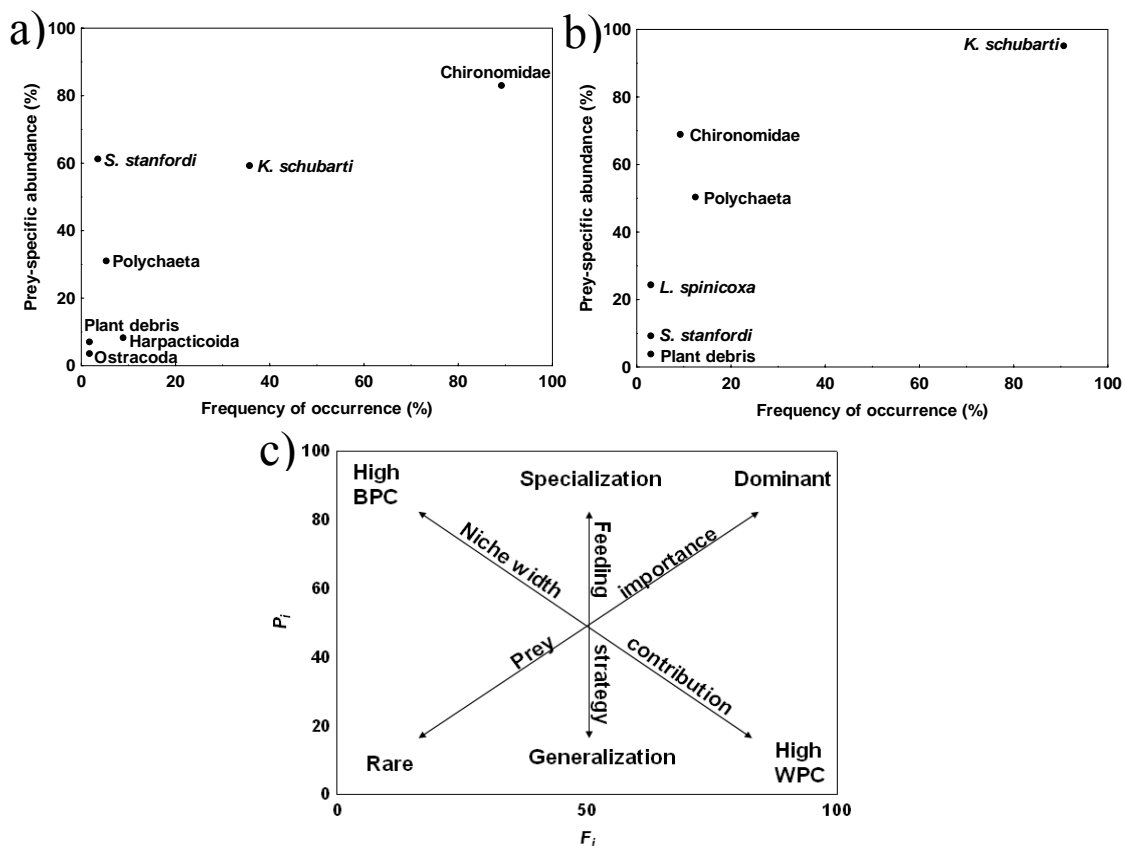
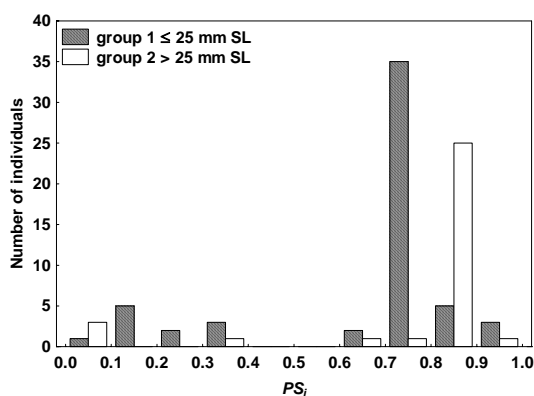
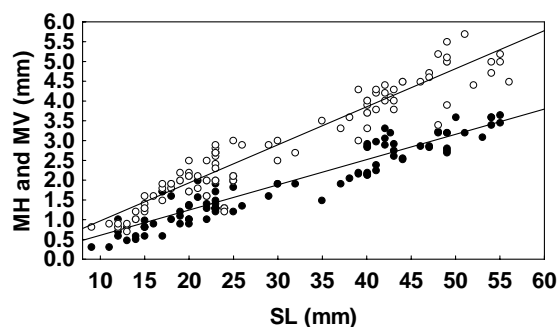


Figure 4. Relationship between prey-specific abundance (P_i) and frequency of occurrence (% F_i) of prey items in the diet of *T. paulistanus* size groups, collected in the Guaraguaçu River Estuary. [(a) ≤ 25 mm standard length group; (b) > 25 mm standard length group]. (c) explanatory diagram modified of Amundsen *et al.* (1996).

Table I. Prey items of two *T. paulistanus* size groups from the Guaraguaçu River Estuary. SL = Standard Length, %F = frequency of occurrence, %V = percentage by volume, %N = numeric abundance, and %IRI = index of relative importance. Mean stomach fullness also is given.

Prey item	≤25 mm SL group size				>25 mm SL group size			
	%F	%V	%N	%IRI	%F	%V	%N	%IRI
Insecta								
Chironomidae larva	89.29	78.75	90.17	94.46	9.38	6.98	8.57	0.91
Crustacea								
Tanaidacea								
<i>Kalliapseudes schubarti</i> Mañe-Garzon, 1969	35.71	17.53	5.94	5.25	90.63	85.88	87.15	98.36
<i>Sinelobus stanfordi</i> (Richardson, 1901)	3.57	0.74	0.52	0.03	3.13	0.15	0.71	0.02
Amphipoda								
Gammaridea								
<i>Leptocheirus spinicoxa</i> Valerio-Berardo & Wakabara, 2003					3.13	1.24	0.71	0.04
Ostracoda	1.79	0.07	0.26	< 0.01				
Copepoda								
Harpacticoida	8.93	0.53	2.33	0.16				
Polychaeta	5.36	2.18	0.78	0.10	12.50	5.67	2.86	0.67
Plant debris	1.79	0.20		< 0.01	3.13	0.08		< 0.01
Mean stomach fullness (mean ± SD)								
	6.5 ± 0.28				6.1 ± 0.27			

Considering the overlap between coexisting individuals of different sizes and such abundant prey, smaller fish may have restricted themselves to smaller prey (chironomids) due to gape limitations, while larger ones preferred more profitable, larger prey (*K. schubarti*). This narrows the feeding niche in each ontogenetic stage, which may be a potential mechanism of intra-specific partitioning of food. Such a hypothesis must be tested by future investigations taking into account prey size, prey abundance-availability, and predator's preference through size groups. Moreover, for a complete knowledge of the trophic ecology of *T. paulistanus*, future studies should focus on the description of ontogenetic patterns beyond the limits examined in this study.

**Figure 5.** Frequency distribution of proportion similarity (PS_i) index values of *T. paulistanus* from the Guaraguaçu River Estuary.**Figure 6.** Vertical (MV - ○) and horizontal (MH - ●) mouth opening relation with standard length (SL) of *T. paulistanus* from the Guaraguaçu River Estuary.

Finally, this is the first record of *Leptocheirus spinicoxa* (Corophiidae) (Table I) for the southern Brazilian coast. It has been previously only reported in the northeastern coast (Valerio-Berardo & Wakabara 2003). Due to high mobility, fish may display a higher prey detection rate than conventional samplers (Raddum & Fjellheim 2003) and this may lead to new records of taxa not detected in previous fauna surveys (Fjellheim *et al.* 2007).

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References

- Amundsen, P. A., Gabler, H. M. & Staldvik, F. J. 1996. A new approach to graphical analysis of feeding strategy from stomach contents data - modification of the Costello (1990) method. **Journal of Fish Biology**, 48(4): 607-614.
- Azevedo, M. C. C., Araújo, F. G., Cruz-Filho, A. G., Pessanha, A. L. M., Silva, M. A. & Guedes, A. P. P. 2007. Demersal fishes in a tropical bay in southeastern Brazil: Partitioning the spatial, temporal and environmental components of ecological variation. **Estuarine, Coastal and Shelf Science**, 75: 468-480.
- Baldó, F. & Drake, P. 2002. A multivariate approach to the feeding habits of small fishes in the Guadalquivir Estuary. **Journal of Fish Biology**, 61(A):21-32.
- Bolnick, D. I., Svanbäck, R., Fordyce, J. A., Yang, L. H., Davis, J. M., Hulsey, C. D. & Forister, M. L. 2003. The ecology of individuals: incidence and implications of individual specialization. **The American Naturalist**, 161(1): 1-28.
- Bonecker, A. C. T., Castro, M. S., Namiki, A. C. P., Bonecker, F. T. & Barros, F. B. A. G. 2007. Larval fish composition of a tropical estuary in northern Brazil (2°18'-2°47'S/044°20'-044°25'W) during the dry season. **Pan-American Journal of Aquatic Sciences**, 2(3): 235-241.
- Clarke, K. R. & Warwick, R. M. 1994. **Change in marine communities: An approach to statistical analysis and interpretation**. Plymouth Marine Laboratory, Plymouth, 144 p.
- Contente, R. F., Stefanoni, M. F. & Gadig, O. B. F. *In press*. Size-related shifts in dietary composition of *Centropomus parallelus* (Perciformes: Centropomidae) in an estuarine ecosystem of the southeastern coast of Brazil. **Journal of Applied Ichthyology**.
- Corrêa, M. O. D. A. & Uieda, V. S. 2008. Composition of the aquatic invertebrate fauna associated to the mangrove vegetation of a coastal river, analyzed through a manipulative experiment. **Pan-American Journal of Aquatic Sciences**, 3(1): 23-31.
- Costello, M. J. 1990. Predator feeding strategy and prey importance: a new graphical analysis. **Journal of Fish Biology**, 36: 261-263.
- Derrick, P. A. & Kennedy, V. S. 1997. Prey selection by the hogchoker, *Trinectes maculatus* (Pisces: Soleidae), along summer salinity gradients in Chesapeake Bay, USA. **Marine Biology**, 129: 699-711.
- Fjellheim, A., Tysse, A. & Bjerknes, V. 2007. Fish stomachs as a biomonitoring tool in studies of invertebrate recovery. **Water Air Soil Pollution: Focus**, 7: 293-300.
- Godefroid, R. S., Spach, H. L., Santos, C., MacLaren, G. & Schwartz Jr., R. 2004. Mudanças temporais na abundância e diversidade da fauna de peixes do infralitoral raso de uma praia, sul do Brasil. **Iheringia, Série Zoológica**, 94(1): 95-104.
- Guedes, A. P. P. & Araújo, F. G. 2008. Trophic resource partitioning among five flatfish species (Actinopterygii, Pleuronectiformes) in a tropical bay in south-eastern Brazil. **Journal of Fish Biology**, 72: 1035-1054.
- Hellawell, J. M. & Abel, R. 1971. A rapid volumetric method for the analysis of the food of fishes. **Journal of Fish Biology**, 3: 29-37.
- Hyslop, E. J. 1980. Stomach contents analysis – a review of methods and their application. **Journal of Fish Biology**, 17: 411-429.
- Karpouzi, V. S. & Stergiou, K. I. 2003. The relationships between mouth size and shape and body length for 18 species of marine fishes and their trophic implications. **Journal of Fish Biology**, 62: 1353-1365.
- Lana, P. C., Peronti, A. L. B. G., Oliveira, M.C., Freitas, C.A.F., Conti, L. M. P., Couto, E. C. G., Giles, A. G., Lopes, M. J. S., Silva, M. H. C. & Pedroso, L. H. 1989. Estrutura espacial de associações macrobênticas da Gamboa Perequê (Pontal do Sul, Paraná). **Nerítica**, 4(1/2): 119-136.
- Lana, P. C. & Guiss, C. 1991. Influence of *Spartina alterniflora* on the structure and temporal variability of macrobenthic associations in a tidal flat of Paranagua Bay (Se Brazil). **Marine Ecology Progress Series**, 73: 231-244.
- Ley, J. A., Montague, C. L. & McIvor, C. C. 1994. Food habits of mangrove fishes: A comparison along estuarine gradients in northeastern Florida Bay. **Bulletin of Marine Science**, 54(3): 881-889.
- Maciel, N. A. L. 2001. Composição, abundância e distribuição espaço-temporal da ictiofauna do complexo estuarino-lagunar de Iguape-Cananéia, São Paulo, Brasil. **PhD. Thesis**. Universidade de São Paulo, São Paulo, Brazil, 252 p.
- Michele, O. D. A. & Uieda, V. S. 2007. Diet of the ichthyofauna associated with marginal vegetation of a mangrove forest in

- southeastern Brazil. **Iheringia, Série Zoológica**, 9(4): 486-497.
- Munroe, T. A. 2002. Achiridae. Pp. 1925-1933. *In*: Carpenter, K. E. (Ed.). **The living marine resources of Western Central Atlantic. Volume 2: Bony fishes part 1. FAO Species guide for fishery purposes**. American Society of Ichthyologists and Herpetologists Special Publication No 5, Roma, 773 p.
- Raddum, G. G. & Fjellheim, A. 2003. Liming of River Audna, Southern Norway. A large scale experiment of benthic invertebrate recovery. **Ambio**, 32: 230–234.
- Santos, C. 2007. Comunidade de peixes demersais e ciclo reprodutivo de quatro espécies da família Sciaenidae na plataforma interna entre Superagui e Praia de Leste. **PhD. Thesis**. Universidade Federal do Paraná, Curitiba, Brazil, 163 p.
- Sarre, G. A., Platell, M. E. & Potter, I. C. 2000. Do the dietary compositions of *Acanthopagrus butcheri* in four estuaries and a coastal lake vary with body size and season and within and amongst these water bodies? **Journal of Fish Biology**, 56: 103-122.
- Scharf, F. S., Juanes, F. & Rountree, R. A. 2000. Predator size - prey size relationships of marine fish predators: interspecific variation and effects of ontogeny and body size on trophic-niche breadth. **Marine Ecology Progress Series**, 208: 229 – 248.
- Scharf, F. S. & Schlicht, K. 2000. Feeding habits of red drum (*Sciaenops ocellatus*) in Galveston Bay, Texas: seasonal diet variation and predator-prey size relationships. **Estuaries**, 23: 128–139
- Svanback, R. & Persson, L. 2004. Individual diet specialization, niche width and population dynamics: implications for trophic polymorphisms. **Journal of Animal Ecology**, 73: 973–982.
- Valerio-Berardo, M. T. & Wakabara, Y. 2003. *Leptocheirus spinicoxa*, a new species of Corophiidae (Amphipoda) from the northeastern Brazilian coast. **Náuplius**, 11(1): 51-56.
- Ward-Campbell, B. M. S. & Beamish, F. W. H. 2005. Ontogenetic changes in morphology and diet in the snakehead, *Channa limbata*, a predatory fish in western Thailand. **Environmental Biology of Fishes**, 72: 251-257.

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