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Feeding ecology of *Phalloceros anisophallos* (Osteichthyes: Cyprinodontiformes) from Andorinha Stream, Ilha Grande, Brazil

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In the present work, we determined the relative importance of allochthonous and autochthonous food items as well as seasonal and ontogenetic variation in the feeding habits of *Phalloceros anisophallos* from córrego Andorinha, Ilha Grande. Quantitative analysis, based on alimentary index (IA_i) and food volume (Vo), revealed that *P. anisophallos* fed on detritus, autochthonous algae (diatoms, unicellular and filamentous Chlorophyceae algae), autochthonous animals (aquatic insect larvae: Trichoptera, Chironomidae and other Diptera) and allochthonous animals (terrestrial insects: Hymenoptera). Ontogenetic variations were recorded for the consumption of each food category. Adults used a larger amount of algae and detritus, and juveniles used a higher amount of animal items. Significant differences in intestinal coefficient between adult and juvenile individuals corroborated the ontogenetic differences in feeding behavior. IA_i values of each consumed food category did not vary between the rainy and dry seasons, but mean detritus Vo differed between seasons and was significantly (Anova, $p<0.01$) greater during the dry season.

No presente trabalho determinamos a importância relativa dos itens de origem alóctone e autóctone, bem como as variações sazonais e ontogenéticas do hábito alimentar de *Phalloceros anisophallos* do córrego Andorinha, Ilha Grande. Análises quantitativas baseadas no índice alimentar (IA_i) e no volume (Vo) de cada item alimentar revelaram que *P. anisophallos* se alimentou de detrito, algas (diatomáceas, unicelulares e clorofíceas filamentosas), animais autóctones (larvas de insetos aquáticos: Trichoptera, Chironomidae e outros Diptera) e animais alóctones (insetos terrestres: Hymenoptera). Foram registradas variações ontogenéticas para o consumo de cada categoria alimentar. Os adultos consumiram maiores quantidades de algas e detrito enquanto os jovens consumiram maiores quantidades de itens animais. As diferenças significativas do coeficiente intestinal de adultos e jovens corroboraram as diferenças ontogenéticas do hábito alimentar. Os valores de IA_i de cada categoria alimentar consumida não variou entre as estações chuvosa e seca, mas os valores médios do volume de detrito consumido variou entre as estações e foi significativamente (Anova, $p<0.01$) superior na estação seca.

Key words: Poeciliidae, Atlantic Rain Forest, Coastal stream, Ontogeny, Seasonality.

Introduction

In upstream areas, with high canopy density, trees shade the water surface and reduce primary production, and food webs are dependent on allochthonous matter. In such cases, fish feed mainly on allochthonous matter such as terrestrial insects and seeds (Welcomme, 1985; Luiz *et al.*, 1998). These conditions are found in Mata Atlântica streams, where rivers normally drain closed-canopy forests and where allochthonous production seems to support aquatic life (Moulton & Magalhães, 2003).

Fish feeding habits vary in a cyclic manner according to seasonal rhythms of physical variables, such as rainfall, photoperiod and temperature (Zavala-Camin, 1996), and biological variables, such as competition and vegetation. Nonetheless, in tropical areas, rainfall and vegetation are among the main variables affecting biological traits of fish species (Munro, 1990; Wootton, 1990). Considering the large number of Mata Atlântica streams draining the Brazilian coast and their importance for conservation priorities as sources of endemic species (Mazzoni *et al.*, 2000; Mazzoni *et al.*, 2009), information concerning the feeding biology of this fish fauna is important but very scarce (Sabino & Castro, 1990; Castro & Casatti, 1997; Aranha & Caramaschi, 1999; Mazzoni & Iglesias-Rios, 2002; Mazzoni & Rezende, 2003).

Phalloceros Eigenmann, 1907 comprises small poeciliin fishes broadly distributed throughout the southern rivers of South America (Lucinda, 2003), one of the eight areas of endemism for poeciliines on the American continent (Lucinda & Reis, 2005). The *Phalloceros* species have been hardly studied with regard to ecology, anatomy, embryology, and many others biological aspects; nonetheless, from the perspective of systematics, it has been poorly studied since Lucinda (2008) revised the genus and identified twenty-one new species, previously classified as *Phalloceros caudimaculatus*. *Phalloceros anisophallos* Lucinda 2008 is

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one of these species and was described with material collected from the drainages of rio Parati, rio Barra Grande (= córrego Andorinha – Ilha Grande), rio São Roque, rio Taquari and rio Itinguçu, all of them from the small coastal drainages of the state of Rio de Janeiro.

In the present work, we analyzed the relative importance of allochthonous and autochthonous material as well as seasonal and ontogenetic variation on the feeding habits of *Phalloceros anisophallos* from córrego Andorinha, Ilha Grande, a tropical rain forest island from Mata Atlântica.

Material and Methods

Ilha Grande (23º 05'- 23º 15'S and 44º 06'- 44º 23'W) is one of the biggest islands along the Rio de Janeiro coast, where its Atlantic Rainforest shows different levels of regeneration following century-old anthropogenic disturbances. Some remnants of primary forest can still be found in the most inaccessible areas (Bittencourt & Rocha, 2002), mainly at headwaters. It is characterized by marked rainy and dry seasons with annual precipitation of about 2200 mm (Estação Meteorológica da Central Nuclear de Angra dos Reis – NUCLEN) and maximum and minimum water temperature of 25.7ºC in February and 19.6ºC in July (Oliveira & Neto, 1996).

Several streams drain both the eastern and western slopes of Ilha Grande and, because of their high inclination, as well as their geological landscape, these streams are very poor in freshwater fish diversity and densities (Rezende & Mazzoni, 2006). Among the most abundant species, *Phalloceros anisophallos* has the widest distribution along the córrego Andorinha.

The study area comprised a stretch of about 80 m long in córrego Andorinha, at approximately 100 m asl (above sea level). It has a poor marginal vegetation and abundant canopy (~90%). Stream flow is fast, the stretch shows prevailing riffles and runs with rocky and gravel substrata as well as pools with accumulated sand and debris.

Samples were taken monthly between November 1999 and October 2000 using only hand nets and sieves with mesh size from 0.2 to 0.5 cm. At each sampling occasion, between 15 and 20 specimens of *P. anisophallos* were collected. Specimens were kept in ice for transportation and processed in the laboratory, and the following data were obtained: (i) standard length (L_S, cm), (ii) total weight (W_T, gr), (iii) stomach weight (W_S, mg x 10) and (iv) intestine length (L_I, cm). Stomachs were fixed for three days in 5% formalin and then stored in 70ºGL alcohol.

Stomach contents were examined under stereoscopic and light microscopes according to the frequency of occurrence (Fo) and volumetric (Vo) methods (Hyslop, 1980). Food items were identified according to the corresponding literature (Chu, 1949; Bicudo & Bicudo, 1970; Merritt & Cummins, 1984). Depending on the analysis, objective food items were classified according to: (1) three food categories – (i) animal = aquatic or terrestrial insects - adult and larvae, (ii) plant/algae = seeds, leaves, algae and (iii) detritus = decomposing material or (2) food item origin – (i) allochthonous and (ii) autochthonous. The volume of each food category/origin was estimated using a Sedgewick-Rafter counting camera (SRcc).

The relative importance of each food item category was established according to the alimentary index (IA_i). IA_i consisted of the correlation between Fo and Vo data as proposed by Kawakami & Vazzoler (1980) and adapted by Hahn *et al.* (1997) and was applied according to the following model: $IA_i = (F_i * V_i) / (\Sigma F_i * V_i) * 100$, where i = 1, 2, ….n food items; F_i = frequency of occurrence and Vo = volume of a given food item; IA_i values varied as follows: $0 \leq IA_i \leq 100$.

Intestinal coefficient (I_C) was estimated according to: $I_C = L_I / L_S$, where L_I = intestine length and L_S = standard length (Barbieri *et al*., 1994), and was applied as complementary information for feeding habit classification and its ontogenetic variation. Ontogenetic variations of feeding habits were based on the IA_i and Vo values of each food category (detritus, animal and plant/algae) of adult and juvenile specimens. Ontogenetic variations in I_C were based on mean I_C values of juvenile and adult fish. Specimens were classified as juveniles or adults according to data for 1st maturation (L_{S50} = 2.0 cm), and thus, adults were those individuals with $L_S \geq 2.0$ cm and juveniles were individuals with $L_S < 2.0$ cm. Seasonal (rainy and dry seasons) variation in feeding habits was determined according to Vo and the relative importance (IA_i) of allochthonous and autochthonous items.

Differences in consumption based on mean Vo of detritus, plant/algal and animal food items eaten by juveniles and adults and the seasonal (rainy *vs.* dry) variations in mean Vo of detritus, autochthonous plant/algae and animal and allochthonous animal were tested by Anova ($\alpha = 0.01$). The I_C values were submitted to a t-test to verify differences between juveniles and adults. All statistical tests were carried out using STATISTICA 7.0 software (StatSoft, 1996).

Results

One hundred and seven individuals were analyzed, including 46 juveniles and 61 adults, where 51 were from the dry season and 56 from the rainy season. Voucher specimens were placed in the fish collection of Museu Nacional do Rio de Janeiro (MNRJ 28725) and Universidade Federal do Tocantins (UNT 6772 - paratype specimen).

Considering the whole sample, of both juvenile and adult individuals, quantitative analyses indicated that *P. anisophallos* fed on detritus, autochthonous algae (diatoms and unicellular and filamentous Chlorophyceae algae), autochthonous animals (aquatic insect larvae: Trichoptera, Chironomidae and other Diptera) and allochthonous animals (terrestrial insects: Hymenoptera). Detritus was the most important item (IA_i = 57.79), followed by autochthonous algae (IA_i = 32.11). Mean I_C was 3.8 ($\pm$ 1.8).

Juvenile and adult specimens differed in the use of detritus, algae and animal items. Adults used a greater amount of algal items and detritus (ΣIA_i = 92), but juveniles used a greater amount of animal items (IAi = 83) (Fig. 1). Significant differences in Vo for each food category were recorded (Anova; F_{adults} = 38.2; $F_{juveniles}$ = 4.2; $p<0.01$), which corroborated the above mentioned IA_i results (Figs. 1).

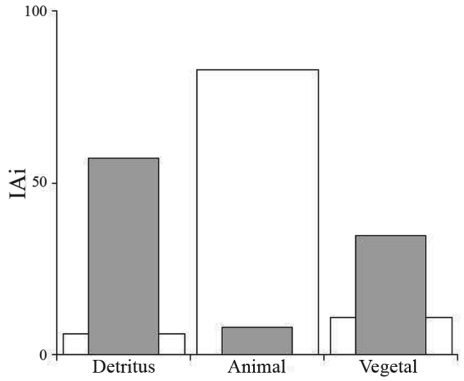

Fig. 1. Comparison between juvenile (white) and adult (grey) alimentary index (IA_i) of each food category consumed by *Phalloceros anisophallos* from córrego Andorinha (Ilha Grande, Rio de Janeiro).

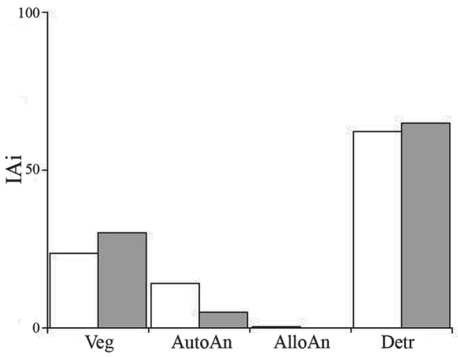

Fig. 2. Comparison of alimentary index (IA_i) of each food category consumed by *Phalloceros anisophallos* from córrego Andorinha (Ilha Grande, Rio de Janeiro) during the rainy (white bars) and dry (grey bars) seasons. Alg = autochthonous algae, AutoAn = autochthonous animal, AlloAn = allochthonous animal and Detr = detritus.

Intestinal coefficient (I_C) differed significantly between L_S groups (t-test; $t = 5.33$; $p < 0.01$); mean values were 4.9 ± 1.7 and 2.9 ± 1.2 for adult and juvenile individuals, respectively.

The relative importance (IA_i - Fig. 2) of each food category consumed by *P. anisophallos* did not vary between the rainy and dry seasons. Temporal variation of mean volume of autochthonous algae, allochthonous animal and detritus was tested by ANOVA; a *post hoc* test (Tukey) showed significant differences ($F_{juveniles} = 5.6$; $p<0.01$) only for the detritus consumption, where the dry season showed the higher incidence of this food category.

Discussion

Phalloceros anisophallos from córrego Andorinha displayed an omnivorous diet based mainly on autochthonous resources from the sediment (insect larvae, algae and detritus). Small participation of allochthonous items (terrestrial insects) was also recorded. Mean value of intestinal coefficient (I_C) was 3.8, corroborating the omnivorous classification and was in agreement with the I_C range proposed by Barbieri *et al.* (1994). We found differences in feeding habits and I_C range related to ontogenetic development. Juvenile specimens (size greater than that of 1st maturation) showed high occurrence of aquatic insects and larvae and lower I_C values, whereas adults showed higher occurrence of algae and I_C values. Based on these differences and according to Barbieri *et al*. (1994), we classified adult and juvenile specimens as detritivorous/algivorous and insectivorous, respectively.

A number of studies concerning Poeciliidae feeding habits have pointed out that algae and periphyton appear to be the main food resource among these species, where little or no ingestion of animal items have been recorded (*e.g.,* Costa, 1987; Aranha & Caramaschi, 1999). Costa (1987) reported that 100% of the diet of a stream-dwelling population of *P. caudimaculatus* was based on algae, and Teixeira (1989) found only large amounts of plant/algal items in stomach content of another population from a coastal stream in Rio Grande do Sul. Nonetheless, Aranha & Caramaschi (1999), studying a population of *P. caudimaculatus* from a coastal stream in Rio de Janeiro, reported that animals (larvae and insects) were found in 99% of the stomachs analyzed. Nonetheless, Sabino & Castro (1990) classified *P. caudimaculatus* as omnivorous tending toward herbivorous. We must be aware, however, that the several populations then called *P. caudimaculatus* were latter split in twenty two species by Lucinda (2008).

The results presented in this study provide strong evidence that animal items as well as detritus are important food resources for *P. anisophallos* from córrego Andorinha. Given the structural landscape of the study site, where a closed canopy is the main local characteristic, we suppose that the absence of sunlight which facilitates primary production is the main reason for the low incidence of plant/algal items in the species' diet.

It has been repeatedly mentioned that animal items such as aquatic larvae and aquatic and/or terrestrial insects, both of autochthonous and/or allochthonous origin, are important elements in stream food webs and are an important food source for stream-dwelling fishes (Lowe-McConnell, 1987), but strong differences in the nature of feeding habits of the same species living under different environmental conditions have also been reported (Esteves & Aranha, 1999).

In fact, very different results were found in the literature concerning the feeding habits of *Phalloceros* species from Mata Atlântica streams in southern Brazil. In many cases, species were classified as omnivorous (*e.g.*, Sabino & Castro, 1990; Castro & Casatti, 1997; Deus & Petrere-Junior, 2003), whereas in others they were classified as herbivorous (*e.g.*, Costa, 1987; Teixeira, 1989; Casatti, 2002). This feeding flexibility could be attributed to the use of different feeding tactics, such as picking items off the surface, backbiting and capturing food near the bottom (Sazima, 1986).

In the present work, we found that the importance of autochthonous items superimposed that of the allochthonous ones. We were unable to find clear evidence of seasonal changes in food consumption, probably due to the constant availability of food and also because of the large feeding spectrum shown by the species studied. The ontogenetic variation in feeding habits of *Phalloceros anisophallos* from córrego Andorinha

should be one of the explanations for these results by reducing the consumption of only one kind of food category.

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