Feeding of *Oligosarcus hepsetus* (Cuvier, 1829) (Characiformes) in the Serra do Mar State Park - Santa Virgínia Unit, São Paulo, Brazil

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Abstract

We describe the diet of *Oligosarcus hepsetus*, in the Santa Virgínia Unit of the Serra do Mar State Park. The Paraibuna and Grande rivers in the basin of the Paraíba do Sul River were sampled monthly from January to December 2004. The Alimentary Preference Degree and the frequency of occurrence indices were used to analyze the food items. The diets of *Oligosarcus hepsetus* in the two localities sampled were very similar, and reinforced the importance of the streamside forests in establishing and maintaining biotic and abiotic conditions in these environments. The species had a carnivorous diet that differed with ontogeny: smaller individuals were principally insectivorous and larger ones ichthyophagous.

Keywords: Oligosarcus hepsetus, feeding, Atlantic Forest, Brazil.

Alimentação de *Oligosarcus hepsetus* (Cuvier, 1829) (Characiformes) no Parque Estadual da Serra do Mar - Núcleo Santa Virgínia, São Paulo, Brasil

Resumo

O objetivo do trabalho foi abordar a dieta do peixe cachorro-magro, *Oligosarcus hepsetus*, no Núcleo Santa Virgínia do Parque Estadual da Serra do Mar. O rio Paraibuna e o ribeirão Grande da bacia do rio Paraíba do Sul foram amostrados mensalmente de janeiro a dezembro de 2004, sendo utilizados o Grau de Preferência Alimentar e a freqüência de ocorrência para as análises dos itens alimentares de *Oligosarcus hepsetus*. A dieta nos dois locais amostrados foi muito similar e ressaltou-se a importância das matas ribeirinhas para o fornecimento e a manutenção das condições bióticas e abióticas destes ambientes. A espécie apresentou dieta carnívora com diferenciação ontogenética, sendo que os indivíduos menores foram principalmente insetívoros e os maiores ictiófagos.

Palavras-chave: Oligosarcus hepsetus, alimentação, Floresta Atlântica, Brasil.

1. Introduction

Among the innumerable units composing the Leste basin in Brazil, the basin of the Paraíba do Sul River stands out (Braga, 2004). This isolated basin extends over an area of 57,000 km^2 including three states in southeastern Brazil: São Paulo, Minas Gerais and Rio de Janeiro (Hilsdorf et al., 2002). The region has changed over time, through the influence of human activities carried out with a lack of appropriate conservation management. This has led to the felling of gallery forests, silting, water pollution, and innumerable other environmental problems, including those stemming from the construction of a number of reservoirs for electrical energy generation and/or water storage, among these the Paraibuna-Paraitinga and Funil dams (Hilsdorf and Petrere Jr., 2002). For these reasons, the state of conservation and composition of the ichthyofauna of the reservoirs has received some attention (Araújo, 1996; Bizerril, 1999; Araújo et al., 2001; Hilsdorf and Petrere, 2002). However, the smaller affluents that descend the slopes of the Serra do Mar and Mantiqueira ranges are still little studied (Braga, 2004).

According to Villani et al. (1998), the state of São Paulo possesses the largest area of the Atlantic Forest and associated coastal ecosystems in the country, representing approximately 7% of its original plant cover. A large proportion of these remnants is located in state parks, ecological stations, and experimental stations, which cover more than 3% of the state's territory. In the Santa Virgínia Unit of the Serra do Mar State Park, some fish species (*Brycon opalinus* (Cuvier, 1819), *Neoplecostomus microps* (Steindachner, 1876) and *Phalloceros caudimaculatus* (Hensel, 1868)) were sampled in 1996; nevertheless, the fishes are the leastknown vertebrates of the Atlantic Forest (Rosa and Menezes, 1996).

Fishes with a carnivorous feeding habit increase the stability of an ecosystem, being that they act to regulate the abundance of prey species (Nikolsky, 1963; Popova, 1978). Studies of trophic ecology of carnivorous species are very useful in monitoring fishery and management programs, given that these studies furnish important information on regulatory mechanisms in populations and communities of fishes (Zavala-Camin, 1996).

Fishes of the genus *Oligosarcus* have a large buccal aperture, permitting the ingestion of whole prey in a single bite (Casatti et al., 2001). Most species of this genus feed mainly on insects, crustaceans and small fish (Lowe-McConnell, 1975). The cachorro-magro, *Oligosarcus hepsetus*, is a small to medium-sized carnivore, occurring widely in most of the freshwater ecosystems in southeastern Brazil. It mainly inhabits shallow, densely vegetated microhabitats in small streams or along the banks of larger rivers (Araújo et al., 2005).

Notable seasonal changes may occur in the diet of fishes according to the area, primarily related to changes in composition and availability of food resources, associated with reproductive pulses and physical and chemical changes in the aquatic ecosystems. Diet may also be influenced by ontogenetic effects, which are generally related to morphological differences, which lead to changes in the selection and capture of prey species (Nikolsky, 1963; Wooton, 1992). Furthermore, knowledge of the diet of fishes provides essential information for ecological research, which also furnishes additional data on the entire trophic structure of the ecosystem (Basile-Martins et al., 1983).

The objective of the present study was to describe the diet of the fish "cachorro-magro," *Oligosarcus hepsetus*, in the Santa Virgínia Unit of the Serra do Mar State Park.

2. Material and Methods

We established two collection localities within the basin of the Paraíba do Sul River: the Paraibuna and Grande rivers, both within the Santa Virgínia Unit. This Unit covers 16,000 ha in the municipalities of São Luiz do Paraitinga, Natividade da Serra, Cunha and Ubatuba, located at coordinates 23° 24' and 23° 17' S and 45° 03' W. The relief is steeply sloped, with rectilinear valleys and hogbacks with altitudes between 860 and 1,500 m . The vegetation is dense montane ombrophile forest with discontinuous patches of forest in the process of regeneration, in addition to areas of abandoned eucalyptus plantations with a sub-wood of native plants. The climate is humid, subject to the Atlantic Tropical air mass (Villani et al., 1998).

A total of 12 samples were made monthly from January to December 2004. At each sample point, individuals were collected using gill nets with mesh sizes of 1.5; 2.0; 2.5; 3.0; 3.5, and 4.0 cm, measured between adjacent knots (10 m long and 1.5 m high), and totalizing 60 m. In addition to the nets, sieves, and traps were also used. Fish effort was standardized, keeping time and the quantity of instruments employed at each point constant. The gill nets were submerged from the end of the day up to the next morning.

Afterwards, specimens were kept in plastic containers containing 10% formalin. Each container received a label describing date and sample site.

Total length of individuals were measured in cm, mass was measured in grams, repletion degree of the stomach, fat degree in the visceral cavity. Three categories, according to a previously established scale, indicated the repletion and fat degrees: 1. empty, 2. half-full, and 3. full (Braga, 1990). The frequencies of the repletion degree of the stomach and of the fat degree in the visceral cavity were used to characterize the feeding of *Oligosarcus hepsetus* per collection period.

The stomachs with degree 3 (full) were withdrawn from the visceral cavity, weighed, and kept in alcohol diluted at 70% (Zavala-Camin, 1996). Food items were identified with stereomicroscopic up to the lowest taxonomic level reached. To analyze the alimentary items found, the Alimentary Preference Degree (APD), was used following Braga (1999) in accordance with the formula: APD = Si/N, where Si is the sum of the values related to abundance of the food item (i) in the stomachs and N, the total number of the stomachs analyzed. The estimated value for the Alimentary Preference Degree (APD) for each item is indicated by:

- APD = 4: the chosen item has absolute preference;
- $3 \leq$ APD < 4: the chosen item has high preference degree;
- $2 \leq$ APD < 3: the chosen item is preferential, otherwise different items are ingested;
- $1 \leq$ APD < 2: the chosen item is secondary; and
- $0 <$ APD < 1: the chosen item is occasional.

First, a general analysis of the food items was done, and then the Alimentary Preference Degree was analyzed for the remaining items, separated into the categories of allochthonous and autochthonous.

The method of Frequency of Occurrence (Hyslop, 1980) was also used, which is the percentage between the number of stomachs with preys from a determined taxonomic group and the total number of stomachs with food. This method was used to characterize the food by locality and by total-length class of *Oligosarcus hepsetus.*

Comparisons of diets between sites (Paraibuna and Grande) were made by the non-parametric statistic, Spearman rank correlations coefficient-r_s (Fritz, 1974; Siegel, 1975). Comparisons of diets between autochthonous items and allochthonous items were made by the non-parametric statistic, Mann-Whitney U proof (Siegel, 1975). With the objective of verifying the variation of alimentary items as fish and other categories with the length of the fish, an analysis was applied using a contingency table (Vanzolini, 1993).

3. Results

A total of 162 specimens of *Oligosarcus hepsetus*, ranging in length from 8.5 to 25.0 cm, were collected. The species was more common in the Grande River than in the Paraibuna River (Figure 1).

The distributions of relative frequencies of the repletion degree of the stomach, by collection, indicated that in January through August and in December, most of the individuals collected had degree 1. At the end of winter and in spring, individuals more often had a repletion degree of 2 and 3. This tendency was obvious in the Grande River, although not in the Paraibuna River (Figure 2).

The distributions of the relative frequencies of the fat degree in the visceral cavity, by collection, showed that the highest number of individuals with degree of accumulated fat 3 occurred in October. This was the case in both the Paraibuna River and in the Grande River (Figure 3).

Analysis of the frequency of occurrence of the food items showed that Insect remains predominated, followed by Coleoptera, representing 35% of the items, and Fish at 22.5%, followed in decreasing order by Orthoptera, Oligochaeta, Hemiptera, Dermaptera, Arachnida and Macrophytes, each of which represented 2.5% of the items found. In the Paraibuna River, the most important item was also Insect remains (50%), followed by Coleoptera and Diptera, both representing approximately 40%. In the Grande River, the most important item was Insect remains (approximately 50%), followed by Coleoptera and Ephemeroptera, approximately 35% and 25%, respectively (Figure 4).

A "t" test on the r_s 0.18 indicates that the correlation is not significant ($t = 0.75$; $t_{0.05;17} = 2.11$; $p > 0.05$). Thus the diets of the fishes in both sites are quantitatively different.

The U Mann-Whitney proof applied to the ingested autochthonous items and allochthonous items, indicates that the result is significant ($U = 109 > U_{0.05;17,14} = 67$); therefore, a difference exists in the ingestion of items.

For the autochthonous items, Odonata nymphs was the most important (17.5%), followed by Scales (15%), and in descending order Macrophytes, Crustacean-Gammaridean, Dipteran pupa, *Astyanax* sp., Trychoptera and Trychopteran larva, each of which represented 2.5% of the items found. For the allochthonous items, the most important was Insect remains (50%). In second place was Coleoptera (20%), and in decreasing order Arachnida, Dermaptera, Adult Diptera, Gerridae, Odonata-Anisoptera, Oligochaeta, Orthoptera and adult Trychoptera, each representing 2.5% of the items found. In the Paraibuna River, the autochthonous item with the highest percentage was Dipteran larva (35%), followed by Odonata nymphs (25%). The most commonly occurring allochthonous item was Insect remains (50%), closely followed by Coleopteran larva (25%). In the Grande River, the most frequent autochthonous items were Odonata nymph, Scales and Nematoda, each representing 15% of the items sampled. The most frequent allochthonous item was Insect remains (50%), closely followed by Coleoptera (approximately 25%) (Figure 5).

The Alimentary Preference Degree (APD) showed that the most important item was Adult Ephemeroptera

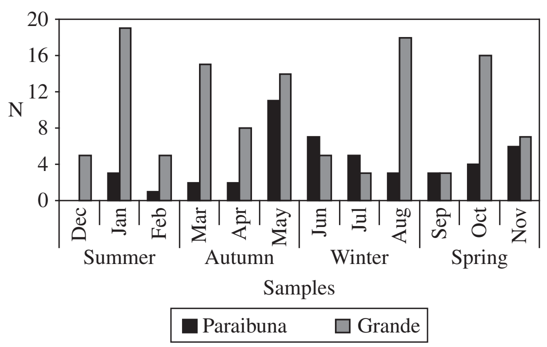

Figure 1. Numerical distribution of the individuals of *Oligosarcus hepsetus* in the collection localities.

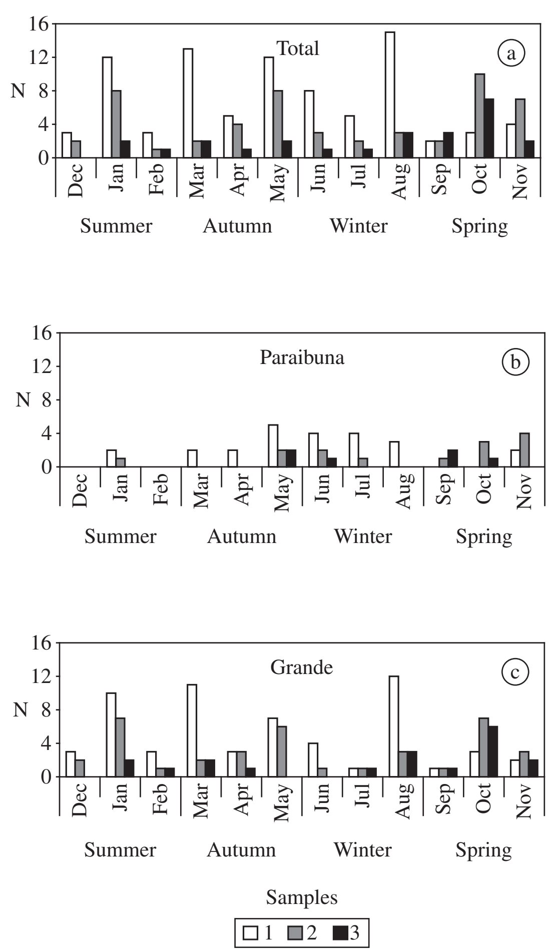

Figure 2. Numerical distribution of the repletion degree of the stomach (1. empty, 2. partly full, 3. full) of *Oligosarcus hepsetus* per collection and in each sampling locality.

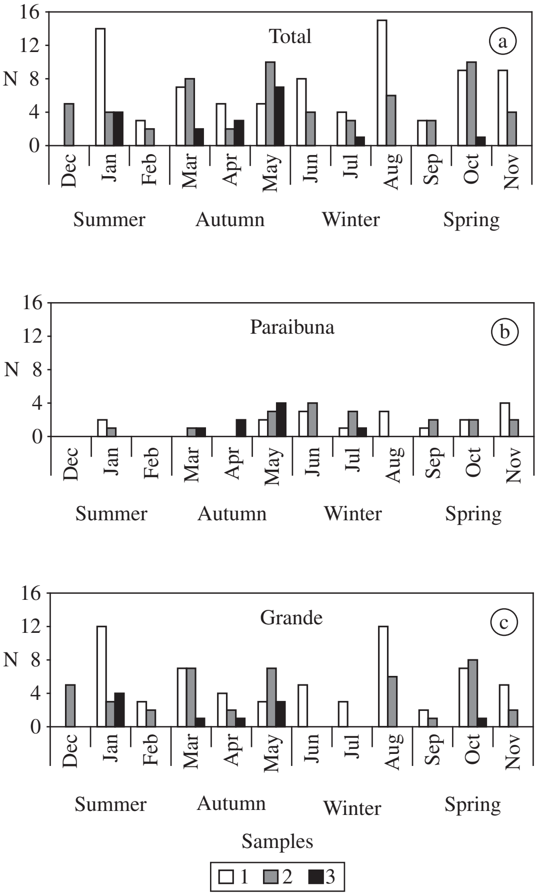

Figure 3. Numerical distribution of the fat degree in the visceral cavity (1. empty, 2. partly full, 3. full) of *Oligosarcus hepsetus* per collection and in each sampling locality.

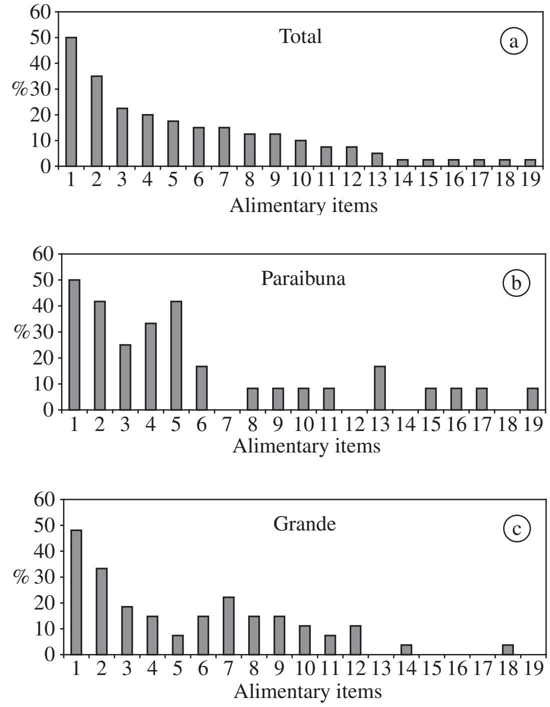

Figure 4. Frequency of occurrence of the food items of *Oligosarcus hepsetus* in the Santa Virgínia Unit, for the Paraibuna and Grande rivers, were: 1) Insect remains; 2) Coleoptera; 3) Fish; 4) Odonata; 5) Diptera; 6) Scales; 7) Ephemeroptera; 8) Trychoptera; 9) Nematoda; 10) Crustacea; 11) Vegetal remains; 12) Hymenoptera; 13) Sediments; 14) Orthoptera; 15) Oligochaeta; 16) Hemiptera; 17) Dermaptera; 18) Arachnida and 19) Macrophytes.

with a degree of 0.7 (occasional), followed by Insect remains. For the prey fish species, *Brycon opalinus* showed an APD equal to 0.5 (occasional), decreasing to *Phalloceros caudimaculatus* and *Astyanax* sp., equally the least important. All the food items analyzed for Alimentary Preference Degree were occasional (Figure 6).

When food items were grouped into categories, the most important was Insects (nymphs and pupas), with a APD of 1.6 (secondary), followed by Adult Insects with APD approximately 1.5 (secondary), decreasing to the item Sediments, with a value close to zero (occasional) (Figure 7).

In the smaller total-length classes (5 to 10 cm), the items Fish and Scales were consumed less (35%) than were other items (67%). As the total-length classes increased, consumption of Fish also increased, until in the largest total-length class (20 to 25 cm), only this item appeared in the food of *Oligosarcus hepsetus* (Figure 8).

A preference for the item fish with the length increase in *O. hepsetus* was influenced strongly in the test by the absence of others items in the total-length class (20 to 25 cm).

4. Discussion

According to Nikolsky (1963), the low feeding activity of piscivorous fishes is expected and can be explained by the better use and nutritional value of the food, which makes it necessary to feed less often. A high incidence of empty stomachs of many carnivorous-ichthyophagous species was also found by Goulding (1980), Cruz et al. (1990) and Bennemann et al. (1996). Although *Oligosarcus hepsetus* showed this characteristic, a large number of individuals had full stomachs in spring. This may have occurred because of the increased temperature and rainfall, which increase the input of insects and organic matter into the river, thus making larger amounts of food items available to the fish, as happened with *Oligosarcus jenynsii* in Lake Caconde, Rio Grande do Sul state (Hartz et al., 1996).

Another important fact was the large proportion of individuals with degree 3 of accumulated fat in the autumn, when food is scarce. Lowe-McConnell (1964),

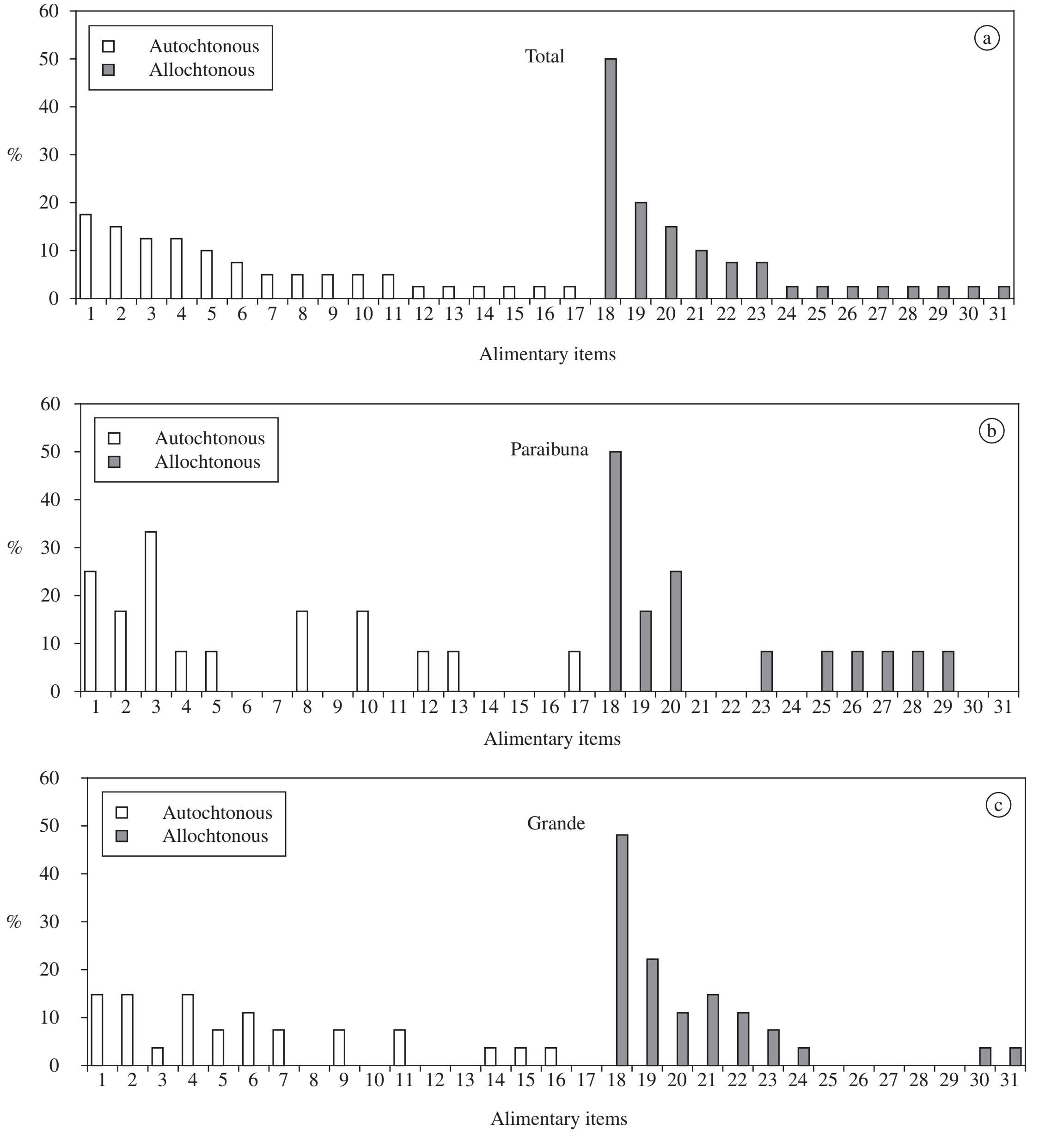

Figure 5. Frequency of occurrence of the autochthonous and allochthonous food items of *Oligosarcus hepsetus* in the Santa Virgínia Unit, for the Paraibuna and Grande rivers. (**Autochthonous items**: 1) Odonata nymphs; 2) Scales; 3) Dipteran larva; 4) Nematoda; 5) Fish; 6) *Macrobrachium potiuna*; 7) Ephemeropteran larva; 8) *Phalloceros caudimaculatus*; 9) *Brycon opalinus*; 10) Sediments; 11) Trychopteran pupa; 12) Macrophytes; 13) Crustacean-Gammaridean; 14) Dipteran pupa; 15) *Astyanax* sp.; 16) Trychoptera; 17) Trychopteran larva. **Allochthonous items:** 18) Insect remains; 19) Coleoptera; 20) Coleopteran larva; 21) Ephemeroptera; 22) Formicidae; 23) Vegetal remains; 24) Arachnida; 25) Dermaptera 26) Adult Diptera; 27) Gerridae; 28) Odonata-Anisoptera; 29) Oligochaeta; 30) Orthoptera and 31) Adult Trychoptera).

Goulding (1980) and Mérona and Mérona (2004) established that many species feed less in the dry season and consume the fat accumulated during the rainy season. Thus, *Oligosarcus hepsetus* apparently feeds more frequently in the spring and summer, storing a large fat reserve that will be used in autumn and winter as a source of energy for survival and gonad development. This behavior was observed by Bennemann et al. (1996) for *Acestrorhyncus lacustris*, which was actively reproducing in the area studied (Tibagi River, Paraná state), and for which the sequence of events of increased feeding activity, fat storage, and then breeding could be established.

The richness of food items was very similar between the two collection localities, although food items occurred more frequently in the Paraibuna than in the

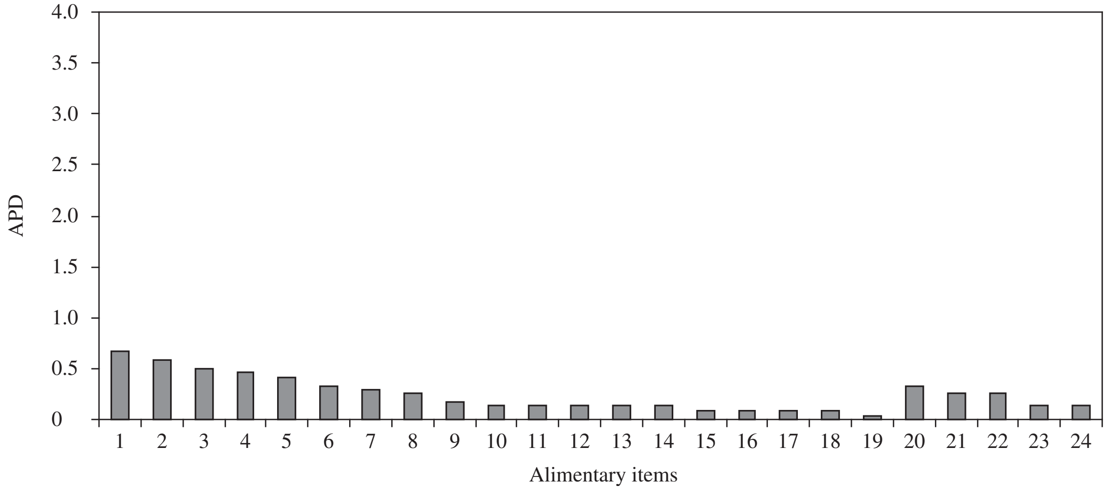

Figure 6. Alimentary Preference Degree (APD) of *Oligosarcus hepsetus* in the Santa Virgínia Unit, were: 1) Ephemeroptera; 2) Insect remains; 3) Odonata nymphs; 4) *Machrobrachium potiuna*; 5) Coleoptera; 6) Coleopteran larva; 7) Dipteran larva; 8) Trychopteran pupa; 9) Dipteran pupa; 10) Orthoptera; 11) Crustacean-Gammaridean; 12) Oligochaeta; 13) Macrophytes; 14) Nematoda; 15) Odonata-Anisoptera; 16) Vegetal remains; 17) Adult Trychoptera; 18) Adult Formicidae; 19) Sediments; 20) *Brycon opalinus*; 21) Fish remains; 22) Scales; 23) *Phalloceros caudimaculatus* and 24) *Astyanax* sp.

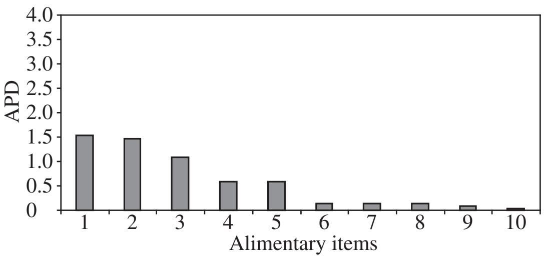

Figure 7. Alimentary Preference Degree (APD) of *Oligosarcus hepsetus* in the Santa Virgínia Unit, were: 1) Insects (nymphs and pupas); 2) Insects (adults); 3) Fish; 4) Crustacea; 5) Insect remains; 6) Oligochaeta; 7) Macrophytes; 8) Nematoda; 9) Vegetal remains; 10) Sediments.

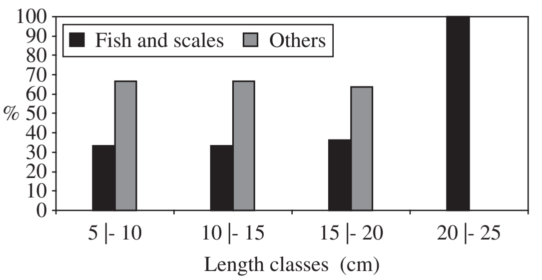

Figure 8. Frequency of occurrence of the food items consumed by *Oligosarcus hepsetus*, distributed by total-length classes.

Grande River. This difference between the two localities can be explained by the larger size and greater vegetation cover in the Paraibuna River, as well as the lower abundance of *Oligosarcus hepsetus*, which may lessen intraspecific competition. This was also observed by Alvim and Peret (2004), who concluded that the occurrence of autochthonous as much as allochthonous food items is dependent on the gallery forest, hence the importance of conserving the riverine forest to maintain the ecological balance of a river. From the point of view of the biology of the fish, the gallery forest has the following ecological functions: structural protection of the habitats, regulation of water flow and discharge, shelter and shade, maintenance of water quality, filtration of substances that arrive in the river, and providing organic matter and substrates for fixation of algae and periphyton (Barrella et al., 2001). Lowe-McConnell (1987) observed that rivers bordered by native vegetation provide a wide variety of food items, mainly insects and higher plants. These items are of great importance for the survival and ecology of freshwater tropical fishes.

The Alimentary Preference Degree for the items consumed by *Oligosarcus hepsetus* showed that the items were occasional, and when these were grouped, the first three items were secondary: Insects (nymphs and pupas); Insects (adults) and Fish. This result was confirmed by Araújo et al. (2005) in Lajes Reservoir, where *Oligosarcus hepsetus* showed a carnivorous feeding habit, feeding only on insects and fish and varying its diet according to the seasons and the zones of the reservoir.

In *Oligosarcus hepsetus* the difference in feeding during ontogeny was evident, in that smaller individuals were basically insectivorous and larger ones ichthyophagous. Hahn et al. (2000) found only fish in the stomachs of individuals of *Acestrorhyncus lacustris* over 10 cm long in the Itaipu Reservoir. Araújo et al. (2005) observed a similar situation, in which *Oligosarcus hepsetus* larger than 19 cm fed principally on fish, in contrast to smaller individuals which fed principally on insects. Similarly, Gealh and Hahn (1998) found for *Oligosarcus longirostris* in the Segredo Reservoir, that smaller individuals fed on insects, crustaceans and fish, whereas larger ones (>16 cm) were exclusively piscivorous. Araújo et al. (2005) reported that larger *Oligosarcus hepsetus* were apparently able to capture higher-quality prey, i.e., which was larger, heavier and probably richer in energy. The increase in size is related to morphological changes (size of buccal aperture and swimming speed) that may facilitate catching fish. Ontogenetic changes in feeding may also be associated with a decrease in intraspecific competition, with smaller individuals feeding preferentially on insects, and larger ones consuming mainly fish (Lowe-McConnell, 1987).

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