Aquatic insects selected as food for fishes of a tropical stream: Are there spatial and seasonal differences in their selectivity?

PINTO[1], T.L.F. & UIEDA[2], V.S.

[1,2] Departamento de Zoologia, Instituto de Biociências, CP 510, Universidade Estadual Paulista-UNESP, 18618-000 Botucatu, São Paulo, Brazil. [1]tamaralfp@yahoo.com.br; [2]vsuieda@ibb.unesp.br.

ABSTRACT: Aquatic insects selected as food for fishes of a tropical stream: Are there spatial and seasonal differences in their selectivity? The aim of this study was to examine the existence of feeding preference by insectivorous fish species through the analyses of benthic insects and fish diet. The influence of spatial factors (a "closed" area with riparian vegetation and an "open" area without riparian vegetation) and seasonal factors (dry and wet seasons) on food selectivity was also verified. Of the 14 fish species analyzed, most species were from Heptapteridae (five species) and Loricariidae (three species) families, and most individuals occurred in the dry season and in the open area. Although the insectivory was the predominant feeding habit in all analyzed situations (areas and seasons), the favorite insect groups eaten vary seasonal and spatially. In all cases of high selectivity, the selected insects were not sampled or were collected in a low density in the environment; what emphasizes the existence of a feeding preference. The fact that the majority of fish species ingested the most abundant insect group in a great amount, but with low selectivity, shows that these stream species are opportunistic.
Key-words: benthic macroinvertebrates, ichthyofauna, selectivity, diet, Brazil.

RESUMO: Insetos aquáticos selecionados como alimento por peixes de um riacho tropical: Existem diferenças espaciais e sazonais na seletividade? O presente estudo teve por objetivo verificar a existência ou não de preferência alimentar pelas espécies de peixes insetívoras de um riacho de serra, através da análise da oferta de insetos bentônicos e da dieta das espécies. A influência de fatores espaciais (uma área "fechada" com mata ciliar e uma área "aberta" sem mata ciliar) e sazonais (estação seca e chuvosa) sobre a seletividade alimentar destas espécies também foi analisada. Das treze espécies de peixes, a maioria das espécies era das famílias Heptapteridae (quatro espécies) e Loricariidae (três espécies), e a maioria dos indivíduos ocorreu na estação seca e na área aberta. Apesar da insetivoria ter predominado em todas as situações analisadas (áreas e estações), os grupos de insetos preferidos variaram sazonal e espacialmente. Em todos os casos em que as espécies apresentaram alta seletividade, os insetos selecionados não foram amostrados ou foram coletados em baixa densidade no ambiente, o que reforça a existência de uma preferência alimentar. O fato da maioria das espécies ter ingerido em grande quantidade, mas com baixa seletividade, o grupo de inseto mais abundante mostra que as espécies deste riacho são muito oportunistas.
Palavras-chave: macroinvertebrados bentônicos, ictiofauna, seletividade, dieta, Brasil.

Introduction

One factor that can influence available food sources and consequently feeding preference is the presence/absence of canopy forest. Canopy forests can have a great influence in stream structure and in aquatic fauna composition (Lima & Zakia, 2001; Barrella et al., 2001) by: controlling the water discharge, retaining the superficial and excessive draining during wet season, and keeping the water flow and volume during dry season; offering shade and keeping the temperature stable during the year; keeping the water quality through herbicides draining reduction and silting up; working as a filter in the ecotone between land and water; contributing with organic material (plant detritus), an important base of the aquatic ecosystem trophic chain; offering shelter as side roots to a great diversity of fish and invertebrate, and an important feeding site to the whole fauna (periphyton and organic material retaining). On this basis, canopy forests preservation enables the maintaining of the stream community diversity, enhancing and assuring food availability for the fish and their survival.

Differences in the feeding of fish in different seasonal and spatial scales, as in longitudinal gradients (headwater and

downstream sections), different stretches (riffles and pools; areas with dense canopy and areas with herbaceous vegetation), different microhabitats and seasons were pointed for fish communities of southeastern Brazilian streams (Uieda & Motta, 2007).

The majority of these studies have showed the predominance of insectivory and a tendency of a reduction on feeding overlap through spatial, seasonal and trophic differences (Uieda & Motta, 2007), but few consider changes in the food habit in relation to the food availability (Deus & Petrere-Junior, 2003).

This study aims to determine the existence of aquatic insects feeding preference by fish species sampled in two riffles of a tropical stream, one with dense canopy ("closed area") and other with herbaceous vegetation ("open area"). The feeding preference was evaluated by an electivity index, calculated with data from a quantitative analysis of the benthic fauna and the fish diet. The feeding preference was checked for the species that consumed aquatic insects and analyzed in relation to the changes in habitat structure that can influence the availability of food resources, such as presence/absence of riparian vegetation and seasonal changes.

Material and methods

Study area

This study was carried on Ribeirão da Quinta, a stream located in the municipality of Itatinga, São Paulo state, southeastern Brazil, which flows into Santo Inácio River, a tributary of Paranapanema River. The study site (23°06'47"S 48°29'46"W, 743 m of height) is located in a 3rd order stream and is composed by a succession of pools and riffles. The study was developed in two riffles, one with dense canopy (called closed area, located upstream) and one with herbaceous vegetation (called open area, located downstream). The riffles were shallow (10-15 cm), with strong flow (0.14-0.19 $m.s^{-1}$) and rocky substrate. Despite the fact that the two areas showed similar substrate (pebbles around 3 cm of diameter and a great amount of plant detritus), they differ on the presence of macrophytes only in the open area, covering the river bank and the river bed in a great quantity (mainly Cyperaceae).

Although a seasonal physical characterization was not done during this study, details about that can be found in Ribeiro & Uieda (2005). These authors worked in the same stream in 2001 and described for the wet season lower values of conductivity (87 ± 11.1 $mS.cm^{-1}$) and pH (7,4 ± 0.3) and higher values of temperature (21 ± 3.0 °C) and current (0.19 ± 0.07 $m.s^{-1}$), and for the dry season higher values of conductivity (131 ± 89.7 $mS.cm^{-1}$) and pH (7,9 ± 0.5) and lower values of temperature (18 ± 2.1 °C) and current (0.14 $m.s^{-1}$).

Sampling

Aquatic insect and fish samples were taken in the two areas (open and closed) and during two seasons, in November 2004 (wet season) and June 2005 (dry season). In both seasons there was a one-day break between insect and fish collecting. The collecting was done through an extension of 26 m in each area.

The insects were collected with Surber sampler (900 cm^2, 0.250 mm mesh), in a total of 10 replicates per area and season. For the ichthyofauna sampling the same capture effort was repeated (4 collectors, 2 hours per area) in both areas and seasons. Fish were sampled using a gill net (2 mm mesh) that was settled transversally to the river, forming a fence from one bank to the other. The substrate near the fence (1-2 m upstream away) was revolved manually to dislodge fish, which were then carried away into the net by the flow. This procedure was repeated upstream, covering all extension of the riffle.

Data analysis

In the laboratory the insects were identified (Lopretto & Tell, 1995; Merritt & Cummins, 1996; Fernandéz & Dominguez, 2001) and counted for the determination of abundance (absolute and relative). The fish identification was done by Dr. Francisco Langeani (Universidade Estadual Paulista – UNESP, São José do Rio Preto).

The Shannon diversity index (H') and Simpson's equitability ($E_{1/D}$) were calculated (Krebs, 1989) using the values of macroinvertebrates and fish abundance for a comparative analysis per season and area.

The fish diet was determined through stomach content analysis. The frequency of occurrence (F) and biovolume (B) methods were used. The frequency of occurrence (Hyslop, 1980) was calculated considering the number of fish having each item in relation to the total occurrences of all items. The biovolume (adapted from

Esteves & Galetti Jr., 1995) was calculated considering the occupied area of a specific item in relation to the total area occupied by all items. The occupied area was determined using a milimetric dish for the stomach analysis. The feeding habit was determined by the Alimentary Index (AI), using the formula (Kawakami & Vazzoler, 1980): AI = (F x B) / å (F x B). Food items with indices values higher than 15% were considered predominant in fish diet and were used for feeding habit determination.

Aquatic insect consumption was analyzed also through the numeric method (N), in which the percentage of the number of each insect group consumed was calculated in relation to the total number of individuals of all insect groups in the stomach content of the fish species (Hyslop, 1980). This value was associated with the frequency and biovolume values to estimate the Relative Index of Importance (RII), which defined the predominant insect group consumed (RII › 15%), using the formula (Pinkas et al., 1971): RII = (N + B) x F.

To allow comparison between species, areas and seasons, the AI and RII values were transformed in relative values (%). To the determination of feeding preference (Zavala-Camin, 1996) for any insect group it was used the electivity index formula (Ivlev, 1961): $E = (r_i - P_i) / (r_i + P_i)$, where E = electivity index; ri = percentage of each item in the stomach content (RII%); Pi = percentage of each item in the environment (relative abundance). The electivity index ranges from - 1 to + 1, being considered positive selectivity when › 0, absence of selectivity when equal to zero, negative selectivity when ‹ 0 (Zavala-Camin, 1996). In this study, high selectivity was considered for values equal or higher than 0.6.

Results

Fauna composition

Fourteen fish species were collected, representing six families and three orders (Tab. I). Most species are represented by

Table I: Species of fishes sampled in the Ribeirão da Quinta. The species acronyms will be used in the following figures and tables.

Order/Family/Especies	Acronym
Characiformes	
Characidae	
Astyanax bocknanni Veri & Castro, 2007	**Aboc**
Bryconamericus iheringii (Boulenger, 1887)	**Bihe**
Crenuchidae	
Characidium gomesi Travassos, 1956	**Cgom**
Characidium zebra Eigenmann, 1909	**Czeb**
Siluriformes	
Heptapteridae	
Cetopsorhamdia iheringi Schubart & Gomes, 1959	**Cihe**
Imparfinis borodini Maes & Cala, 1989	**Ibor**
Imparfinis mirini Haseman, 1911	**Imir**
Phenacorhamdia tenebrosa (Schubart, 1964)	**Pten**
Rhamdia quelen (Quoy & Gaimardi, 1824)	**Rque**
Trichomycteridae	
Trichomycterus brasiliensis Lütken, 1874	**Tbra**
Loricariidae	
Hisonotus sp.	**Hiso**
Hypostomus nigromaculatus (Schubarti, 1964)	**Hnig**
Rineloricaria pentamaculata Langeani & Araújo, 1994	**Rpen**
Cypriniformes	
Poeciliidae	
Phalloceros caudimaculatus (Hensel, 1868)	**Pcau**

the order Siluriformes, and from that by the family Heptapteridae. Although a great relative abundance of Phalloceros caudimaculatus was found at both seasons and areas analyzed, the seasonal and spatial analysis of fish community composition showed higher values of species richness, abundance, and diversity in the open area during the dry season (Tab. II). The relative abundance of other species also emphasized the seasonal and spatial differences in the composition (Tab. II).

Ten orders of aquatic insects were found in the Ribeirão da Quinta (Tab. III). The areas and seasons were similar in richness but different in abundance of insect groups. The aquatic insects were more abundant in the open area and during the wet season (Tab. III). Ephemeroptera was the most abundant order in all analyzed situations. The highest diversity and equitability values were also obtained for the wet season.

Fish diet

Most species sampled in the open area consumed a high percentage of aquatic insects during the wet and dry seasons (Tab. IV). This was also the only food resource consumed by eight species during the dry season. The six species sampled in both seasons did not show seasonal changes in diet and feeding habit, although their diet were more diversified in the wet season. It was also observed a higher number of species consuming terrestrial invertebrates and plants during the wet season, although in low percentage. Of the 13 species sampled in the open area, only Cetopsorhamdia iheringi did not have its diet determined because the only one individual sampled had the stomach empty.

A high percentage of aquatic insects in the stomach content was also found for most species sampled in the closed area (Tab. V). From the three species sampled at both seasons only Astyanax bocknanni showed seasonal diet variation. This species consumed the same food items in both seasons, however in different proportions. The diet of Imparfinis borodini was more diversified in the wet season (Tab. V). As found in the open area, more species consumed plants during the wet season. Aquatic insects were the only resource consumed by four species sampled in the dry season.

Table II: Absolute (N) and relative (%) abundance of the fish species sampled in the Ribeirão da Quinta, during the dry (June 2005) and wet (November 2004) seasons and in the open and closed areas.

Especies	dry-open		dry-closed		wet-open		wet-closed	
	N	%	N	%	N	%	N	%
A. bocknanni	12	15.8	8	14.5	10	18.5	4	12.9
B. iheringii	4	5.3	19	34.5	5	9.3	-	-
C. gomesi	1	1.3	-	-	-	-	-	-
C. zebra	2	2.6	-	-	5	9.3	-	-
C. iheringi	1	1.3	1	1.8	-	-	-	-
I. borodini	8	10.5	1	1.8	15	27.8	2	6.4
I. mirini	1	1.3	-	-	-	-	-	-
P. tenebrosa	2	2.6	1	1.8	-	-	-	-
R. quelen	1	1.3	-	-	-	-	-	-
T. brasiliensis	8	10.5	-	-	-	-	1	3.2
Hisonotus sp.	13	17.1	6	10.9	4	7.4	-	-
H. nigromaculatus	-	-	-	-	-	-	1	3.2
R. pentamaculata	4	5.3	6	10.9	-	-	-	-
P. caudimaculatus	19	25.0	13	23.6	15	27.8	23	74.2
Abundance	76	35.2	55	25.5	54	25.0	31	14.3
Richness	13		8		6		5	
Diversity (H´)	3.092		2.439		2.391		1.275	
Equitability (D)	0.525		0.565		0.789		0.349	

Table III: Absolute (N) and relative (%) abundance of the aquatic insects sampled in the Ribeirão da Quinta, during the dry (June 2005) and wet (November 2004) seasons and in the open and closed areas. All insects sampled are juveniles, except for Coleoptera that was represented by juveniles and adults (both aquatic).

	dry-open		**dry-closed**		**wet-open**		**wet-closed**	
Insect orders	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Coleoptera	436	11.6	143	8.9	910	11.1	555	22.4
Collembola	6	0.2	2	0.1	1	‹0.0	-	-
Diptera	210	5.6	53	3.3	1,001	12.2	193	7.8
Ephemeroptera	2,660	71.0	1,207	75.3	4,093	49.7	1,252	50.6
Hemiptera	3	0.1	6	0.4	20	0.2	34	1.4
Lepidoptera	-	-	-	-	1	‹0.0	1	‹0.0
Megaloptera	4	0.1	4	0.2	3	‹0.0	3	0.1
Odonata	12	0.3	18	1.1	3	‹0.0	4	0.2
Plecoptera	53	1.4	15	0.9	-	-	-	-
Trichoptera	363	9.7	155	9.7	2,196	26.7	433	17.5
Abundance	3,747	23.3	1,603	10.0	8,228	51.2	2,475	15.4
Richness	9		9		9		8	
Diversity (H')	1.418		1.307		1.763		1.824	
Equitability ($E_{1/D}$)	0.210		0.190		0.321		0.364	

Table IV: Alimentary Index (AI%) of all food items consumed by fish species sampled in the open area of Ribeirão da Quinta, during the wet (November 2004) and dry (June 2005) seasons. Acronyms for fish species as in Table II. N= number of fishes with stomach contents; SL= minimum and maximum standard length in mm; I= insectivore; D= detritivore; O= Omnivore. Values above 15% (boldface) were considered for the definition of the species feeding habit.

Wet season	**Aboc**	**Bihe**	**Czeb**	**Ibor**	**Hiso**	**Pcau**
N	10	5	5	15	4	15
SL	12-52	53-64	65-74	22-152	34-37	12-42
Organic matter	-	11.9	-	-	**89.0**	**35.8**
Algae	-	-	-	-	11.0	0.1
Organic matter and algae	-	-	-	-	-	**41.3**
Tecameba	‹0.0	-	-	-	-	6.4
Annelida	-	0.7	-	-	-	0.6
Crustacea	-	-	-	2.0	-	‹0.0
Acarina	‹0.0	-	-	-	-	-
Aquatic insects	**98.4**	**79.2**	**99.3**	**95.7**	**-**	**15.0**
Terrestrial invertebrates	1.2	8.1	-	0.1	-	-
Plant	0.4	0.1	0.7	0.8	-	0.8
Fishes	-	-	-	‹0.0	-	-
Feeding habit	**I**	**I**	**I**	**I**	**D**	**O**
Dry season	**Aboc**	**Bihe**	**Czeb**	**Ibor**	**Hiso**	**Pcau**
N	12	3	2	8	11	17
SL	30-60	42-60	63-64	33-80	16-31	15-27
Organic matter	-	-	-	-	**100.0**	**52.0**
Algae	‹0.0	-	-	-	-	-
Tecameba	-	-	-	-	-	‹0.0
Bryozoa	-	-	-	0.1	-	-
Annelida	-	-	-	0.1	-	-
Aquatic insects	**90.9**	**100.0**	**100.0**	**99.8**	**-**	**47.7**
Terrestrial insects	‹0.0	-	-	-	-	-
Plant	9.0	-	-	-	-	0.4
Feeding habit	**I**	**I**	**I**	**I**	**D**	**O**

Table IV: Cont.

Dry season	Cgom	Imir	Pten	Tbra	Rpen	Rque
N	1	1	2	8	4	1
SL	62	67	26-65	13-80	45-47	71
Organic matter	-	-	-	-	-	-
Algae	-	-	-	-	-	-
Tecameba	-	-	-	-	-	-
Bryozoa	-	-	-	-	-	-
Annelida	-	-	-	-	-	-
Aquatic insects	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Terrestrial insects	-	-	-	-	-	-
Plant	-	-	-	-	-	-
Feeding habit	**I**	**I**	**I**	**I**	**I**	**I**

Table V: Alimentary Index (AI%) of all food items consumed by fish species sampled in the closed area of Ribeirão da Quinta, during the wet (November 2004) and dry (June 2005) seasons. Acronyms for fish species as in Table II. N= number of fish with stomach contents; SL= minimum and maximum standard length in mm; I= insectivore; D= detritivore; O= Omnivore. Values above 15% (boldface) were considered for the definition of the species feeding habit.

Wet season	Aboc	Ibor	Pcau	Tbra	Hnig
N	3	2	23	1	1
SL	17-49	72-138	13-25	64	77
Organic matter	-	-	**36.1**	**-**	**97.0**
Algae	-	-	-	-	3.0
Tecameba	-	-	2.2	-	-
Annelida	-	7.1	-	9.7	-
Crustacea	-	0.5	‹0.0	-	-
Aquatic insects	**75.8**	**91.8**	**61.5**	**74.0**	**-**
Terrestrial invertebrates	5.9	0.2	-	-	-
Plant	**18.4**	0.2	0.2	**16.2**	-
Feeding habit	**O**	**I**	**O**	**I**	**D**

Dry season	Aboc	Ibor	Pcau	Bihe	Cihe	Pten	Rpen	Hiso
N	7	1	13	18	1	1	3	6
SL	29-62	77	15-35	37-55	70	83	69-116	30-37
Organic matter	-	-	**67.6**	**-**	-	-	-	**100.0**
Algae	-	-	**-**	**-**	-	-	-	-
Plant and organic matter	-	-	**-**	**34.7**	-	-	-	-
Tecameba	-	-	0.2	2.2	-	-	-	-
Aquatic insects	**47.3**	**100.0**	**29.7**	**62.7**	**100.0**	**100.0**	**100.0**	**-**
Terrestrial insects	**46.4**	-	-	0.4	-	-	-	-
Plant	6.3	-	2.5	-	-	-	-	-
Feeding habit	**I**	**I**	**O**	**O**	**I**	**I**	**I**	**D**

Food selectivity

For the five species sampled in the open area during the wet season, three showed high electivity index (› 0.6) only for insects not sampled in the benthos (Lepidoptera, Odonata and Plecoptera) and consumed by fishes in low percentage (Tab. VI). Only one species at this area and season (P. caudimaculatus) showed high electivity and high consume for the same insect group (Diptera), although sampled in low percentage. Besides that, the groups most abundant in this area and season, Ephemeroptera and Trichoptera, were

consumed in high percentage by fish species, although not preferred by them.

Six of the eleven fish species sampled in the dry season of the open area showed high values of electivity (Tab. VI). Of those, four species were selective to Diptera, sampled in low abundance in the benthos but consumed in high percentage by fish species. From the other two species, Bryconamericus iheringii selected insects not sampled (Lepidoptera) in the benthos and consumed in low percentage, and Characidium zebra selected insects sampled in low percentage (Plecoptera), although consumed in high percentage (Tab. VI). Ephemeroptera was the insect group most abundant and most consumed by fish species in the open area during dry season, although selected by no one species.

Table VI: Electivity Index (E) calculated for the fish species sampled in the open area of Ribeirão da Quinta, during the wet (November 2004) and dry (June 2005) seasons. For each season, it was showed the relative abundance (%) of the aquatic insects sampled in the area (only the orders of the insects consumed by the fishes). For each species, it was showed the values of the relative index of importance (RII%) of the insects in the fish diet. Acronyms for fish species as in Table II. Values in boldface were considered important in the definition of selectivity by the fishes.

Wet season		**Bihe**		**Aboc**		**Czeb**		**Pcau**		**Ibor**	
	%	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**
Coleoptera	11.1	-	-1	-	-1	1.7	-0.7	-	-1	**24.0**	0.4
Diptera	12.2	1.0	-0.8	**17.8**	0.2	3.2	-0.6	**93.4**	**0.8**	11.5	0
Ephemeroptera	**49.8**	**49.2**	0	**72.3**	0.2	**62.2**	0.1	-	-1	**46.1**	0
Hemiptera	0.2	-	-1	0.7	0.5	-	-1	-	-1	-	-1
Lepidoptera	-	0.3	**0.9**	-	-1	1.6	**1**	-	-1	1.0	**1**
Odonata	-	-	-1	-	-1	0.1	0.5	-	-1	0.8	**0.9**
Plecoptera	-	1.4	1	-	-	0.1	**1**	-	-	1.0	**1**
Trichoptera	**26.7**	**48.2**	0.3	9.2	-0.5	**31.0**	0.1	6.6	-0.6	**15.5**	-0.3

Dry season		**Bihe**		**Aboc**		**Czeb**		**Pcau**		**Ibor**	
	%	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**
Coleoptera	12.0	-	-1	3.0	-0.6	-	-1	-	-1	0.9	-0.9
Diptera	6.0	0.7	-0.8	**15.7**	0.5	-	-1	**84.5**	**0.9**	2.3	-0.4
Ephemeroptera	**71.0**	**98.2**	0.2	**80.6**	0.1	**46.5**	-0.2	13.4	-0.7	**89.1**	0.1
Lepidoptera	-	0.7	**1**	-	-	**-**	-	-	-	-	-
Plecoptera	1.0	-	-1	-	-1	**53.4**	**0.9**	-	-1	-	-1
Trichoptera	10.0	0.4	-0.9	0.6	-0.9	-	-1	2.1	-0.6	7.7	-0.1

Dry season	**Pten**		**Rque**		**Tbra**		**Rpen**		**Cgom**		**Imir**	
	RII%	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**
Coleoptera	-	-1	-	-1	-	-1	-	-1	-	-1	-	-1
Diptera	-	-1	**52.4**	**0.8**	**20.1**	**0.6**	**73.9**	**0.9**	0.4	-0.9	-	-1
Ephemeroptera	**100.0**	0.2	**47.6**	-0.2	**73.0**	0	**26.1**	-0.5	**98.3**	0.2	**100.0**	0.2
Lepidoptera	-	-	-	-	-	-	-	-	-	-	-	-
Plecoptera	-	-1	-	-1	-	-1	-	-1	-	-1	-	-1
Trichoptera	-	-1	-	-1	7.0	-0.2	-	-1	1.3	-0.8	-	-1

Most cases of high selectivity found in the wet season of the closed area were related to insect groups not sampled (Lepidoptera) or sampled in low abundance (Diptera and Hemiptera) in the benthos and consumed in low percentage, except for Trichoptera that was abundant, selected and consumed in high percentage by two fish species (Tab.VII).

For the closed area, only two fish species during the dry season did not show high selectivity for some insect group (Tab. VII). Four of the five fish species of this area and season showed

high selectivity to Diptera, a group consumed in high percentage but present in low abundance in the benthos. The other cases of high selectivity in the closed area during the dry season were related to insect groups not sampled (Lepidoptera) or sampled in low abundance (Plecoptera and Trichoptera) in the benthos.

Table VII: Electivity Index (E) calculated for the fish species sampled in the closed area of Ribeirão da Quinta, during the wet (November 2004) and dry (June 2005) seasons. For each season, it was showed the relative abundance (%) of the aquatic insects sampled in the area (only the orders of the insects consumed by the fishes). For each species, it was showed the values of the relative index of importance (RII%) of the insects in the fish diet. Acronyms for fish species as in Table II. Values in boldface were considered important in the definition of selectivity by the fishes.

Wet season		**Aboc**		**Ibor**		**Pcau**		**Tpen**	
	%	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**
Coleotera	**22.5**	**19.0**	-0.1	**36.8**	0.2	-	-1	-	-1
Diptera	7.8	1.4	-0.7	**53.6**	**0.7**	**51.0**	**0.7**	**20.0**	0.4
Ephemeroptera	**50.7**	1.8	-0.9	4.6	-0.8	1.4	-0.9	-	-1
Hemiptera	1.4	6.3	**0.6**	-	-1	-	-1	-	-1
Lepidoptera	-	-	-1	1.0	**0.9**	-	-1	-	-1
Trichoptera	**17.5**	**71.4**	**0.6**	4.1	-0.6	**47.7**	0.5	**80.0**	**0.6**

Dry season		**Aboc**		**Ibor**		**Pcau**		**Bihe**	
	%	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**
Coleoptera	9.1	-	-1	-	-1	-	-1	-	-1
Diptera	3.4	-	-1	-	-1	**76.6**	**0.9**	**30.8**	**0.8**
Ephemeroptera	**76.4**	10.7	-0.8	**100.0**	0.1	**21.8**	-0.6	**43.2**	-0.3
Hemiptera	0.4	-	-1	-	-1	-	-1	0.2	-0.3
Lepidoptera	-	-	-	-	-	-	-	9.3	**1**
Plecoptera	0.9	-	-1	-	-1	-	-1	-	-1
Trichoptera	9.8	**89.3**	**0.8**	-	-1	1.6	-0.7	**16.5**	0.3

Dry season		**Cihe**		**Pten**		**Rpen**	
	%	**RII%**	**E**	**RII%**	**E**	**RII%**	**E**
Coleoptera	9.1	**19.3**	0.4	-	-1	-	-1
Diptera	3.4	**-**	-1	**50.0**	**0.9**	**86.7**	**0.9**
Ephemeroptera	76.4	**74.7**	0	-	-1	13.3	-0.7
Hemiptera	0.4	-	-1	-	-1	-	-1
Lepidoptera	-	-	-	-	-	-	-
Plecoptera	0.9	-	-1	**50.0**	1	-	-1
Trichoptera	9.8	6.0	-0.2	-	-1	-	-1

Discussion

The South American freshwater fish fauna is considered the richest and most diversified continental ichthyofauna, dominated in diversity and biomass by Siluriformes and Characiformes (Böhlke et al., 1978; Castro, 1999). The predominance of these two groups can be found for South American streams fauna (Castro, 1999), east Basin streams (Bizerril, 1994), Amazon Basin (Lowe-McConnell, 1999) and the State of São Paulo streams (Castro & Menezes, 1998).

The seasonal and spatial changes in the ichthyofauna composition are related to changes in shelter and food availability. In this study, the major richness and abundance of the ichthyofauna observed in the open area was facilitated by the great availability of shelter and food, represented by the macrophytes recovering the stream sides and bed. The macrophytes are colonized by a rich and abundant entomofauna that utilizes them as food and shelter (Motta & Uieda, 2005), and can work not only as a shelter but also as a feeding site to many fish species, specially the ones with an insectivorous habit. In the beginning of dry season there was a reduction in the

stream volume and, consequently, a fauna concentration, representing a set of factors that must have influenced in the results concerning the seasonal changes in ichthyofauna diversity, and determined the high values of richness, abundance, and diversity during the dry season.

The composition and abundance of the aquatic insect fauna can suffer changes in relation to seasonal variations in the environment (Oliveira et al., 1997). During the wet season, the increase in precipitation, flow, and discharge can cause a removal of these organisms and, consequently, a decrease in the availability of this important food resource for the fish community (Kikuchi & Uieda, 1998). The removal of macroinvertebrates by flood was also observed by Ribeiro & Uieda (2005) studying the macroinvertebrates fauna at Ribeirão da Quinta by a manipulative experiment. Otherwise, the great environment stability in the dry season can assure a high number of insect larvae in the winter (Huamantinco & Nessimian, 1999). The opposite situation found here, with high abundance of aquatic insects during the wet season, may be related to the great amount of macrophytes in this period. This vegetation represents an increase in shelter and food availability (periphyton), probably compensating the wet season instability.

A relation between aquatic invertebrate fauna composition and riparian vegetation was emphasized by authors working in temperate (Hawkins et al., 1983; Wallace et al., 1988) and tropical streams (Angermeier & Karr, 1984; Kikuchi & Uieda, 1998). The increase in abundance or biomass of invertebrates was related to the removal of the gallery forest, what cause an increase in light incidence and, consequently, in the development of periphytic algae (Hawkins et al., 1983; Angermeier & Karr, 1984; Wallace et al., 1988).

The predominance of insectivory, the more diversified diet during the wet season, and the great importance of allochthonous material as food resource are strong patterns of the trophic organization of tropical stream fish communities (Uieda & Motta, 2007), which were also found for the community studied here. The increase of allochthonous food supply input to the tropical aquatic ecosystem during the wet season (Angermeier & Karr, 1984; Uieda & Kikuchi, 1995; Afonso et al., 2000) can explain the presence of plant material and terrestrial invertebrates in the diet of the studied fish species mainly during the wet season. This seasonal variation in the availability of allochthonous food resources to the aquatic communities was related to the effect of heavy rains and winds causing the fall of this material inside the stream (Mason & MacDonald, 1982; Angermeier & Karr, 1984).

A specific food item found in the stomach content of the fish does not mean it is the favorite food as it could have been ingested because of its availability, while the favorite food item is absent, less frequent or difficult to catch (Zavala-Camin, 1996). At Ribeirão da Quinta, in most cases that the species showed high selectivity, the selected insects were not sampled or were less frequent in the benthos (Fig. 1 and 2), showing a pattern of high selectivity for some insect groups by the studied fish community.

The occurrence of more fish species consuming less abundant insect groups during the wet season can be related to habitat characteristics. The increase in flow and discharge at the wet season may be considered as physical barriers to fish movement, reducing the efficiency of food capture.

The fact that many species of the open area have consumed a high quantity of the most abundant insect group (Ephemeroptera), though with low selectivity, shows that species are opportunistic, consuming this resource because is the most abundant, but not necessarily because it is the favorite one. When resource availability is high the species may make use of it opportunistically, becoming generalist (Deus & Petrere Jr., 2003). Moreover, most groups of insects selected by the studied fish species are less motile, living in retreats, nets and portable cases, frequently adhered to the rocks, characteristics that increased the prey availability with less foraging time. Ephemeroptera is a more motile and behaviorally responsive insect group, characteristics that results in decreased catchability and increased handling time require to consume (Scrimgeour et al., 1994). Baetidae comprises an Ephemeroptera group that is know to use chemical cues to adjust their behaviour in proportion to predator risk (McIntosh & Peckarsky, 2004). These authors verified

Figure 1: Summary of the insect selectivity analyzed for the fish species sampled in the open area of Ribeirão da Quinta, during the wet (November 2004) and dry (June 2005) seasons. Each group of fish species was related to the group of insect consumed, for which an up (representing high) and down (representing low) arrows were used to indicate the values of relative abundance of the aquatic insect sampled in the area (%), the relative index of importance of the insect in the fish diet (RII%), and the positive (high) or negative (low) electivity index (E). Acronyms for fish species as in Table II.

OPEN AREA – WET SEASON				
Fish species	**Insect Group**	**%**	**RII%**	**E**
Bihe,Aboc,Czeb,Ibor Bihe,Czeb,Ibor	Ephemeroptera Trichoptera	Ý	Ý	ß
Bihe,Czeb,Ibor Bihe,Czeb,Ibor Ibor	Plecoptera Lepidoptera Odonata	ß	ß	Ý
Pcau	Diptera	ß	Ý	Ý
OPEN AREA – DRY SEASON				
Fish species	**Insect Groups**	**%**	**RII%**	**E**
Bihe, Aboc, Czeb, Ibor,Pten, Rque, Tbra, Rpen,Cgom ,Imir	Ephemeroptera	Ý	Ý	ß
Bihe	Lepidoptera	ß	ß	Ý
Czeb Pcau, Pque, Tbra, Rpen	Plecoptera Diptera	ß	Ý	Ý

Figure 2: Summary of the insect selectivity analyzed for the fish species sampled in the closed area of Ribeirão da Quinta, during the wet (November 2004) and dry (June 2005) seasons. Each group of fish species was related to the group of insect consumed, for which an up (representing high) and down (representing low) arrows were used to indicate the values of relative abundance of the aquatic insect sampled in the area (%), the relative index of importance of the insect in the fish diet (RII%), and the positive (high) or negative (low) electivity index (E). Acronyms for fish species as in Table II.

CLOSED AREA – WET SEASON				
Fish species	**Insect group**	**%**	**RII%**	**E**
Aboc, Ibor Pcau	Coleoptera Trichoptera	Ý	Ý	ß
Aboc	Ephemeroptera	Ý	ß	ß
Aboc Ibor	Hemiptera Lepidoptera	ß	ß	Ý
Tbra	Diptera	ß	Ý	ß
Ibor, Pcau	Diptera	ß	Ý	Ý
CLOSED AREA – DRY SEASON				
Fish species	**Group**	**%**	**RII%**	**E**
Pcau, Bihe, Cihe	Ephemeroptera	Ý	Ý	ß
Aboc, Ibor	Ephemeroptera	Ý	ß	ß
Bihe	Lepidoptera	ß	ß	Ý
Cihe Bihe	Coleoptera Trichoptera	ß	Ý	ß
Aboc Pcau, Bihe, Pten, Rpen Pten	Trichoptera Diptera Lepidoptera	ß	Ý	Ý

by a laboratory experiment that Baetidae larvae are capable to adjust its movement in the water column (drift), which is risky behavior in the presence of drift-feeding predators. The fish species that consumed Ephemeroptera in high proportion in the Ribeirão da Quinta comprises Characidae and Crenuchidae species that forage in the water column and Heptapteridae species that forage in the substrate (Casatti et al., 2001), the formers representing potential predators for Ephemeroptera that use drift as dispersal movements.

The importance of the analysis of the available food resources and not only of fish diet to determine food selectivity or preference was evident in this study since the selectivity cases comprised mainly aquatic insect groups less frequent. Thus, as reinforced by Deus & Petrere Jr. (2003), lack of real assessment of food quantity available in the environment is the major constraint on the reliability of data interpretation in fish feeding study. Also, the fish feeding behaviour needs to be considered in this analysis because some species can forage not only in the benthos but also in the water column, catching insects in the drift or in the macrophytes. Thus, maybe some of the positive electivity values can not represent real selectivity for species that search for food in places other than the benthos, like Characidae and Crenuchidae species.

Acknowledgements

We are grateful to Allysson Pontes Pinheiro and Marcos Gomes Nogueira for critical comments on the manuscript; to Hamilton Antônio Rodrigues, Ludmilla de Oliveira Ribeiro and Fábio Matsu Hasue for help in the field; to Francisco Langeani for fish identification; to FAPESP for financial support. The first author received a scholarship from CNPq (PIBIC) during the current study.

References

Afonso, A.A.O., Henry, R. & Rodella, R.C.S.M. 2000. Allochthonous matter input in two different stretches of a headstream (Itatinga, São Paulo, Brazil). Braz. Arch. Biol. Technol., 43:335-343.

Angermeier, P.L. & Karr, J.R. 1984. Fish communities along environmental gradients in a system of tropical streams. In: Zaret, T.M. (ed.) Evolutionary ecology of neotropical freshwater fishes. The Hague, Netherlands. p.39-57.

Barrella, W., Petrere Júnior, M., Smith, W.S. & Montag, L.F.A. 2001. As relações entre as matas ciliares, os rios e os peixes. In: Rodrigues, R.R. & Leitão Filho, H.F. (eds.) Matas ciliares: conservação e recuperação. EDUSP, FAPESP, São Paulo. p.187-207.

Bizerril, C.R.S.F. 1994. Análise taxonômica e biogreográfica da ictiofauna de água doce do leste brasileiro. Acta Biol. Leopoldensia, 16:51-80.

Böhlke, J., Weitzman, S.H. & Menezes, N.A. 1978. Estado atual da sistemática de peixes de água doce da América do Sul. Acta Amazon., 8:657-677.

Casatti, L., Langeani, F. & Castro, R.M. 2001. Peixes de riacho do Parque Estadual Morro do Diabo, bacia do Alto Rio Paraná, SP. Biota Neotrop., 1:1-15.

Castro, R.M.C. 1999. Evolução da ictiofauna de riachos sul-americanos: padrões gerais e possíveis processo causais. In: Caramaschi, E.P., Mazzoni, R. & Peres-Neto, P.R. (eds.) Ecologia de peixes de riachos. PPGE-UFRJ, Rio de Janeiro. p.139-155. (Série Oecologia Brasiliensis, 6).

Castro, R.M.C. & Menezes, N.A. 1998. Estudo diagnóstico da diversidade de peixes do Estado de São Paulo. In: Castro, R.M.C., Joly, C.A. & Bicudo, C.E.M. (eds.) Biodiversidade do Estado de São Paulo, Brasil: síntese do conhecimento ao final do século XX. FAPESP, São Paulo. p.1-13.

Deus, C.P. & Petrere-Junior, M. 2003. Seasonal diet shifts of seven fish species in an Atlantic rainforest stream in southeastern Brazil. Braz. J. Biol., 63:579-588.

Esteves, K.E. & Galetti Jr., P.M. 1995. Food partitioning among some characids of a small brazilian foodplain lake from the Paraná River Basin. Environ. Biol. Fish., 42:375-389.

Fernandéz, H.R. & Domínguez, E. 2001. Guia para la determinación de los artrópodos bentônicos sudamericanos. Universidade Estadual de Tucumán, Argentina. 282p.

Hawkins, C.P., Murphy, M.L., Anderson, N.H. & Wilzbach, M.A. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States. Can. J. Fish. Aquat. Sci., 40:1173-1185.

Huamantinco, A.A. & Nessimian, J.L. 1999. Estrutura e distribuição espacial da co-

munidade de larvas de Trichoptera (Insecta) em um tributário de primeira ordem do Rio Paquequer, Teresópolis, RJ. Acta Limnol. Bras., 11(2):1-16.

Hyslop, E.J. 1980. Stomach contents analysis: a review of methods and their application. J. Fish. Biol., 25:1866-1870.

Ivlev, V.S. 1961. Experimental ecology of the feeding of fishes. Yale University Press, New Haven. 302p.

Kawakami, E. & Vazzoler, G. 1980. Método gráfico e estimativa de índice alimentar aplicado no estudo de alimentação de peixes. Bol. Inst. Oceanogr., 29:205-207.

Kikuchi, R.M. & Uieda, V.S. 1998. Composição da comunidade de invertebrados de um ambiente lótico tropical e sua variação espacial e temporal. In: Nessimian, J.L. & Carvalho, A.L. (eds.) Ecologia de insetos aquáticos. PPGE, UFRJ, Rio de Janeiro. p.157-173.

Krebs, J. 1989. Ecological methodology. Harper & Row, New York. 652p.

Lima, W.P. & Zakia, M.J.B. 2001. Hidrobiologia de matas ciliares. In: Rodrigues, R.R. & Leitão-Filho, H.F. (eds.) Matas ciliares: conservação e recuperação. EDUSP, FAPESP, São Paulo. p.33-44.

Lopretto, E.C. & Tell, G. 1995. Ecosistemas de aguas continentals: metodologias para su studio. Ed. Sur, Argentina. 1397p.

Lowe-McConnel, R.H. 1999. Estudos ecológicos de comunidades de peixes tropicais. EDUSP, São Paulo. 534p.

Mason, C.F. & MacDonald, S.M. 1982. The input of terrestrial invertebrates from tree canopies to a stream. Freshwater Biol., 12:305-311.

McIntosh, A.R. & Peckarsky, B.L. 2004. Are mayfly anti-predator responses to fish odour proportional to risk?. Arch. Hydrobiol., 160:145-151.

Merritt, R.W. & Cummins, K.W. 1996. An introduction to the aquatic insects of North America. 3th ed. Kendall & Hunt, Dubuque. 861p.

Motta, R.L. & Uieda, V.S. 2005. Food web structure in a tropical stream ecosystem. Austral Ecol., 30:58-73.

Oliveira, L.G., Bispo, P.C. & Sá, N.C. 1997. Ecologia de comunidades de insetos bentônicos (Ephemeroptera, Plecoptera e Trichoptera), em córregos do parque ecológico de Goiânia, Goiás, Brasil. Rev. Bras. Zool., 14:867-876.

Pinkas, L., Oliphant, M.S. & Iverson, I.L.K. 1971. Food habits of Albacore, bluefin tuna, and bonito in California waters. Fish. Bull., 152:1-105.

Ribeiro, L.O. & Uieda, V.S. 2005. Estrutura da comunidade de macroinvertebrados bentônicos de um riacho de serra em Itatinga, São Paulo, Brasil. Rev. Bras. Zool., 22:613-618.

Scrimgeour, G.J., Culp, J.M. & Cash, K.J. 1994. Anti-predator responses of mayfly larvae to conspecific and predator stimuli. J. North Am. Benthol. Soc., 13:299-309.

Uieda, V.S. & Kikuchi, R.M. 1995. Entrada de material alóctone (detritus vegetais e invertebrados terrestres) num pequeno curso de água corrente na cuesta de Botucatu, São Paulo. Acta Limnol. Bras., 7:105-114.

Uieda, V.S. & Motta, R.L. 2007. Trophic organization and food web structure of southeastern Brazilian streams: a review. Acta Limnol. Bras. (In press).

Wallace, J.B., Gurtz, M.E. & Smith-Cuffney, F. 1988. Long-term comparisons of insect abundance in disturbed and undisturbed Appalachian headwaters streams. Verh. Int. Ver. Limnol., 23:1224-1231.

Zavala-Camin, L.A. 1996. Introdução aos estudos sobre alimentação natural de peixes. EDUEM, Maringá. 129p.

Received: 28 February 2007
Accepted: 17 April 2007