Life strategies in an elmid (Insecta: Coleoptera: Elmidae) community from a first order stream in the Atlantic Forest, southeastern Brazil.

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ABSTRACT: Life strategies in an elmid (Insecta: Coleoptera) community from a first order stream in the Atlantic Forest, southeastern Brazil. **The elmid fauna of a first order section of a stream at the Tijuca Forest, Rio de Janeiro, RJ, Brazil, was studied. Quantitative samples of the litter from pools, litter from riffles, sand, and stones, were taken in each of the four seasons. Based on the biomasses of the most abundant species, two life cycle patterns were recorded. *Heterelmis* sp. had its young larvae predominating in summer and later instars appearing in winter. On the other hand, *Phanocerus clavicornis* Sharp, 1882 presented the later instars appearing in summer and young ones in winter.**
Key-words**: Aquatic insects; Coleoptera; Elmidae; *Heterelmis*; *Phanocerus*.**

RESUMO: Estratégia de vida de uma comunidade de Elmidae (Insecta: Coleoptera) em um rio de primeira ordem da Floresta de Mata Atlântica, sudeste do Brasil. **A fauna de Elmidae de uma seção de primeira ordem de um riacho na Floresta da Tijuca, RJ, Brasil, foi estudada. Amostras quantitativas foram retiradas do folhiço retido em áreas de correnteza, folhiço depositado em áreas de remanso, sedimento e pedras, em cada uma das estações do ano. Com base nos dados de freqüência e biomassa das espécies mais abundantes, dois padrões de ciclos de vida foram detectados. As larvas mais jovens de *Heterelmis* sp. predominaram no verão e ínstares posteriores apareceram no inverno. De modo contrário, *Phanocerus clavicornis* Sharp, 1882 apresentou larvas mais jovens predominando no inverno e ínstares posteriores no verão.**
Palavras-chave: **Insetos Aquáticos; Coleoptera; Elmidae; *Heterelmis*; *Phanocerus*.**

Introduction

Elmids are common inhabitants of lotic environments, although some occasionally are collected in lakes and ponds. Although they are very important members of the benthic community, their knowledge is still very scarce. Few observations of elmid oviposition have been reported (Lesage & Harper, 1977; White, 1978), but probably most of them glue their eggs singly or in small clusters to the undersides of submerged stones, wood, or plant stems (Brown, 1987). The incubation period is rather short (5-15 days), and varies according to the temperature. The larval period (6-36 months) and number of instars (5-8) also vary according to the temperature, as well as with body size and the amount of available food (Brown, 1987).

Pupation takes place under stones on the sides of the streams, in riffle sections, and hatching follows after 11 or 12 days. The adults rest for a short period and then fly a little. In the Elminae, the adults fly to the water and then usually loose this flying ability, apparently as a result of the atrophy of the flight muscles. On the other side, the adults of Larainae are able to fly during all their lifetime. (White & Jennings, 1973; White, 1978; Seagle, 1980).

Both adults and larvae feed upon algae, moss, and other plant matter in the water, including roots of higher plants (Leech & Chandler, 1968). According to the trophic functional categorization, these beetles are classified as shredders and collectors (Wallace & Anderson, 1996).

Although very abundant in Atlantic forest streams, there are few studies about the taxonomy of these beetles and much less is known about their biologies and life cycles. The aim of this study is to record the life cycle strategies of the elmid species found in an Atlantic forest stream, Rio da Fazenda, at the Tijuca Forest, Rio de Janeiro, RJ, Brazil.

Study area

The Parque Nacional da Tijuca (Tijuca National Park) is entirely located inside the urban perimeter of the city of Rio de Janeiro, between S22°55'-S23°00' and W43°11'-W43°19', with a forested area of approximately 32km². The local vegetation is represented by tropical rain forests commonly named Atlantic Forest, although it had been to a great extent cut down for the establishment of coffee plantations during the eighteenth and nineteenth centuries. Although several exotic species have been employed in the reforestation of the area (Mattos et al., 1976), the secondary forest is still typical of the Atlantic Forest found along the Brazilian coast.

The Rio da Fazenda, also known as Humaitá, is a small stony stream that, in the studied site (first order), is located at 400 m of altitude, being on average 2m wide and 20cm deep. In the studied site the river has a modest slope (around 6°) and the distinction between riffle and pool areas is not very clear. In the sampling period the stream was almost entirely covered by the riparian vegetation, with very little incidence of direct sunlight.

The sampling site was represented by a small section of 20m in length, delimited by marks on the ground. Therefore, all samples were always taken from the same area, minimizing the differences that might be found along the stream.

Material and methods

In the sampling site five quantitative samples from each of the following substrates found in the area were taken in each season: litter from pools, litter from riffles, sand, and stones. Therefore, a total of 80 samples were taken each season. The sampling period extended from August 1994 to August 1995. In this work the material came from August and November 1994, and February and May 1995. All samples were taken with the aid of a Surber sampler (900cm² area, 350μm mesh size).

The material was fixed and preserved in 80% ethanol. Plant matter present in the samples of riffle litter and litter deposited in pools were removed and stored dry, according to the methodology described by Nessimian (1985).

The collected material was sorted and counted under a stereoscopic microscope Zeiss SV6 (80X). For identification, the larvae were prepared in permanent slides according to Oldroyd (1958).

In order to identify the adults, their genital structures had to be dissected out and stored in microvials with glycerin, according to Brown (1972a). Part of the material was sent to Dr. Paul J. Spangler (Department of Entomology, National Museum of Natural History, Smithsonian Institution) to confirm the identifications.

Only one morphospecies was found in each genus, both for larvae and adults. Therefore, apparently these two life forms represent the same species, although this can only be assured by raising the larvae.

The individuals of each species and morphospecies were separated into size class. It was inferred by their head widths and total lengths. The length of the larvae was measured from the apex of the head to the tip of the abdomen, with the aid of an eyepiece micrometer scale. The size class was used because the duration of larva stages and number of instars are variable to each species. Until now, there weren't any study about it.

At each sampling, temperature, pH, dissolved oxygen, electric conductivity, and stream flow, were recorded. The pH and electric conductivity values were recorded with the aid of portable meters. The amount of dissolved oxygen was measured by the method of Winkler (Brower & Zarr, 1977). Current flow was estimated by the float method in a stream section with known depth and width. Pluviosity and temperature data were provided by the Instituto Nacional de Meteorologia (National Institute of Meteorology), and taken from the Estação Meteorológica do Alto da Boa Vista (Alto da Boa Vista Meteorological Station). Detailed analyses of the temperature data were made using the methodology described by Baskerville & Emin (1969), apud Ward (1992), that is calculated by summing daily mean temperatures of the months for each season. The total amount of rainfall in each season was estimated by summing all month records in that period.

Results

Environmental Variables

The air temperature data, pluviosity, and physical and physico-chemical parameters of the water are shown in Tab. I. The air temperature varied from 18°C in winter and spring, to 25°C in summer. Degree Days was the highest in summer (92.3°C) and the lowest in winter (81.2°C). The highest water temperature was recorded in summer (20°C) and the lowest in winter and spring (18°C). The values of dissolved oxygen varied from 4.18 mg/l in the autumn to 8.08 mg/l in the winter. The pH values extended from 4.6 to 6.4. The electric conductivity was 46.1mScm^{-1} in the autumn and 67.4mS.cm^{-1} in the spring.

May presented the highest pluviosity, while February showed the lowest one. The rains were more intense in the spring and less in the summer. The highest stream flow was recorded in November and the lowest in May.

Structure and Community Composition

Table I: Environmental variables at the Rio da Fazenda, Floresta da Tijuca, Rio de Janeiro, RJ, measured during the study period.

Parameters	August	November	February	May
Air temperature	18°C	18°C	25°C	20°C
Water temperature	18°C	18°C	24°C	18°C
Degree day	73.9°C	81.2°C	92.3°C	81.6°C
Plusiosity	697.6mm	505.5mm	465.8mm	546.5mm
Oxygen Dissolved	8.08 mg/l	6.15 mg/l	6.64 mg/l	4.18 mg/l
pH	4.6	6.0	6.3	6.4
Electric conductivity	50.2 mS.cm^{-1}	67.4 mS.cm^{-1}	---	46.1 mS.cm^{-1}

A total of 1,542 elmids were collected. We found seven species belonging to seven genera: ***Austrolimmius laevigatus*** (Grouvelle, 1888), ***Cylloepus*** sp., ***Gonielmis*** sp., ***Heterelmis*** sp., ***Macrelmis*** sp., ***Neoelmis*** sp., and ***Phanocerus clavicornis*** Sharp, 1882.

Austrolimnius laevigatus

Only 15 adult specimens were collected, representing 1.0% of the elmids found. This species occurred in stones (86.7%) and sediment (13.3%), in all seasons, being predominant in summer.

Cylloepus sp.

Only 14 adult specimens were collected, representing 0.9% of the elmids found. This species occurred in the riffle litter (50.0%), stones (28.6%), and sediment (21.4%). They were found in all seasons, being predominant in autumn.

Gonielmis sp.

Only eight larval specimens were collected, representing 0.5% of the elmids found. ***Gonielmis*** larvae were found mainly in stones (62. 5%) and litter deposited in pools (37.5%). The genus has been associated with submerged wood and roots in sandy streams. They were tolerant to moderate organic enrichment, turbidity and siltation, but sensitive to paper mill effluent (Brown, 1972a).

Heterelmis sp.

A total of 565 specimens were collected, representing 36.6% of the elmids found, with 461 larvae and 104 adults. This ***Heterelmis*** species was found mainly in the riffle litter (386 individuals or 67.8%), but also on stones (92 or 12.7%) and sediment (15 or 3.0%). ***Heterelmis*** is usually found in tropical areas with submerged wood, litter or under stones in streams with riffle litter. Some species can be easily found at the surface of some streams in the dry period (Brown, 1972b). Adults and larvae were recorded in the same substrates and in all seasons. Larvae occurred mainly in winter and in spring, while adults especially in winter and in autumn. In summer, the frequency peak and the largest number of young larvae coincided. In winter, the biomass peak coincided with highest number of adults (Fig. 1).

Macrelmis sp.

A total of 103 specimens were collected, representing 6.7% of the elmids found. Six were adults and 97 larvae. This species was found mainly in riffle litter (53.4%), but also on stones (27.2%), litter deposited in pools (10.7%) and sediment (8.7%). Larvae occurred mainly in the riffle litter and on stones, and adults, by their turn, mainly on stones. Larvae were found especially in spring and in summer, while adults were recorded mainly in summer. According to Brown (1972a), ***Macrelmis*** is found under stones and is associated with clear water streams. Both frequency and biomass peaks occurred in summer, although few specimens have been sampled (Fig. 1).

Neoelmis sp.

A total of 132 specimens were collected, representing 8.6% of the elmids found, 116 being larvae and 16 adults. Larvae and adults were found mainly in the riffle litter (56.1%), but also on stones (30.3%), sediment (8.3%), and litter deposited in pools (5.3%). Larvae and adults occurred in the same types of substrate, but the former were found mainly in spring while the latter were recorded especially in winter. According to Brown (1972a), ***Neoelmis*** species are found under stones or cobble and were associated with clear streams. The frequency and biomass peaks took place in the spring, together with the beginning of the rainy season. Mature larvae occurred in spring, coinciding with the highest stream flow, when possibly the adults emerge and oviposition takes place. The young larvae are predominant in autumn (Fig.1).

Phanocerus clavicornis

A total of 678 specimens were collected, representing 44.0% of the elmids found, being 587 larvae and 91 adults. Both larvae and adults of ***P. clavicornis*** were found mainly in riffle litter (79.1%) in all the seasons, followed by stones (11.4%), litter deposited in pools (8.0%), and sediment (1.6%). This distribution is a feature of the specimens of ***P. clavicornis***, which are associated with fast stream flow and abundant organic matter (Steedman & Anderson, 1985; Spangler & Santiago-Fragoso, 1992). Usually adults and larvae occurred together, except in summer, when no adults were recorded. Larvae were found in all seasons, mainly in winter and summer, and the adults especially in winter. The biomass peak was observed in summer, with high numbers of mature larvae, probably due to a decrease in the stream flow. The highest frequency occurred in winter, when a great number of young larvae were found (Fig. 1).

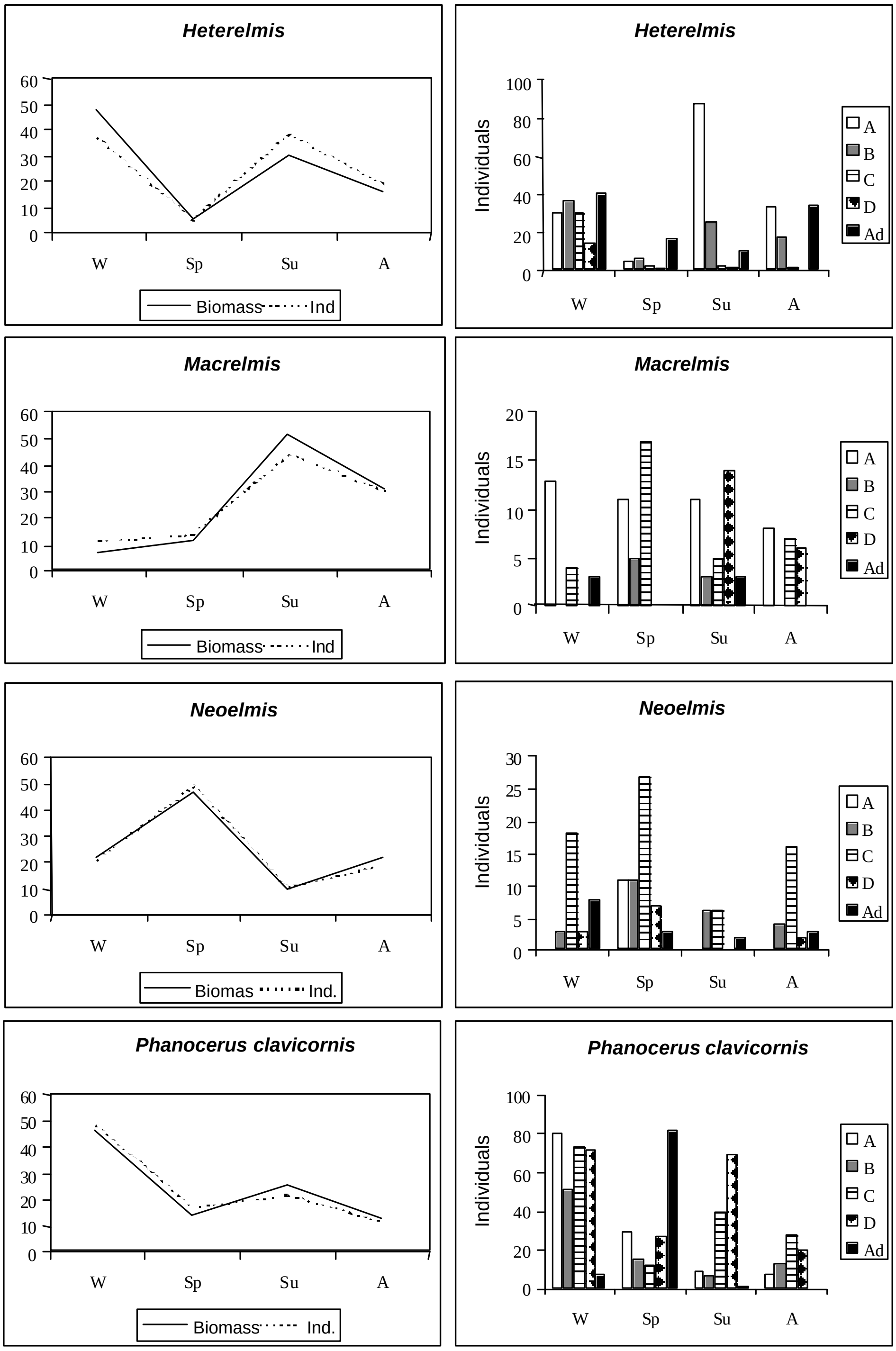

Figure 1: Frequency (---) and biomass (—) percentages (left column) and instars distribution (right column) of Elmidae taxa in four season of the year (August 1994 – May 1995) at a rithral section of Rio da Fazenda, Floresta da Tijuca, Rio de Janeiro, RJ. A-D. measure of the head. A. 0-0.1mm, B. 0.1-0.2mm, C. 0.2-0.3mm, D. 0.3-0.4mm, Ad. Adults. W. winter, Sp. spring, Su. summer, A. autumn.

Discussion

Environmental variables

Water temperature generally changes temporally (both daily and seasonally) and among places, due to climate, altitude, extent of the riparian vegetation in the stream, and underground waters (Allan, 1995 apud Kikuchi & Uieda, 1998). Some authors have pointed out that temperature does not seen to represent a major factor in the structure and distribution of aquatic organisms in the tropics (Wolf et al., 1988). However, according to Ward (1992), the aquatic insects may respond both to the sum of the thermal units (*i.e.*, degree days) as well as to the absolute temperatures. The accumulated temperature acts upon the aquatic insects growth. In the study area, the accumulated temperature values were clearly highest in the summer and lowest in the winter. According to Brown (1987), temperature was the major factor acting upon elmid development, with a faster growth rate at higher temperatures. However, other factors such as oxygen concentration and water level variation can influence the growth rate (White & Jennings, 1973; White, 1978).

The values of dissolved oxygen and stream depth are probably correlated with precipitation. The highest pluviosity was recorded in autumn and the lowest in the summer, therefore not presenting an unimodal pattern of precipitation.

According to extensive studies carried out in tropical streams, leaves compose most of the organic matter present in the headwaters. The organic matter coming in the margins, mainly leaves, represents the main energetic source in streams (Anderson & Sedell, 1979 apud Short et al., 1980). Leaves are carried downstream and held by rocks and woody material present in the riffles. In the Fazenda stream a higher proportion of riffle litter was recorded (81.6%), than litter deposited from pools (75.15%), this latter with a great amount of wood. The accumulated wood provided a good retention capacity, providing refuges and food for invertebrates, as well as more stability to the habitat (Wohl et al., 1995). Spring samples presented a great proportion of leaves. According to Huamantinco (1998), in a study performed in a first order stream, in Teresópolis, Rio de Janeiro State, this fact occurred due to leaves and organic matter accumulated in the river margins during winter. At the beginning of the rainy period this material is carried into the aquatic system.

Life Strategies

We can distinguish two elmid groups based on their opposite life strategies. The first group is represented mainly by *Heterelmis* sp., which presented the adult emergence period in winter, and probably oviposition in summer. According to Wolf et al. (1998), the months with higher rainfall coincide with the highest number of emerging insects, as occurred with *Heterelmis* sp. In the second group, represented by *Phanocerus clavicornis*, the oviposition took place probably in winter and emergence period in summer. Huamantinco & Nessimian (2000), studying the Trichoptera community in a stream at the Teresópolis Municipality, Rio de Janeiro State, observed the prevalence of young larvae in autumn and winter, which was explained by the presence of available food, as recorded for *Phanocerus clavicornis*. As mentioned above, winter was the season that presented the highest stability. The rains were less intense, current flow was the lowest and there was more food available. The summer presented the highest temperature and the lowest water level. These environmental conditions were probably influencing the life strategies of these groups.

The two elmids species previously mentioned had a behavior similar to that recorded by White (1978) and Phillips (1997a, 1997b). The last instar larvae waited for the water level to lower in order to pupate, which resulted in the synchronized emergence of adults. This emergence was associated with the higher temperature, beginning of the rainy season, and with the input of organic matter into the stream.

According to Tavares & Williams (1990), which studied three elmid species, *Promoresia elegans* (LeConte, 1852), *Optioservus fastiditus* (LeConte, 1850), and *Stenelmis bicarinata*

LeConte, 1852, in a North American stream, under the same environmental conditions different species can present different life cycles, as recorded in the present study.

Some factors usually control the elmid life cycle, however the two most important ones are water temperature and water level variation (White & Jennings, 1973; White, 1978; Seagle, 1980; Brown, 1987).

Aquatic insects employ four dispersion modes, according to Ward (1992): 1) downstream drift, 2) upstream migration inside the water; 3) upward vertical migration from the hyporheic zone, and 4) aerial migration by flying adults. Aerial colonization may occur from ovipositing terrestrial adults or from immigration by aquatic adults capable of flying. The presence of only adults of *Austrolimnius laevigatus* and *Cylloepus* sp. can be explained by the fourth mechanism described above. These two elmids probably are able of flying, which would allow them to fly up and downstream searching for places suited for ovipositing or for living. Seagle (1980), which studied the flight period of the Dryopoidea in a North American stream, observed a similar mechanism. Another factor that might explain the presence of only adults, would be not sampling the specific type of substrate in which the larvae live.

Drifting is a widely used means of transport among stream insects (Hynes, 1970 apud Brown, 1987; Newman & Funk, 1984). Perez (1863 apud Brown, 1987) was the first to report elmid larval drift and suggested its mechanism, although he regarded it simply as a device for escaping poor environmental conditions, such as waters with low dissolved oxygen. However, according to Sheldon (1984), larval drift is a major strategy to find substrates with higher amounts of food. A possible drift example would be the presence of only larvae of *Gonielmis* sp. in the studied section.

Acknowledgements

We are grateful to Prof. Dr. Paul J. Spangler and Prof. Dr. Harley P. Brown for confirming the identification of the material. Also to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, Brasil) and to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brasil), for the financial support.

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Received: **22 October 2002**
Accepded: **25 March 2003**