SPATIAL DISTRIBUTION OF PLECOPTERA NYMPHS IN STREAMS OF A MOUNTAINOUS AREA OF CENTRAL BRAZIL

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Received March 26, 2001 – Accepted May 17, 2001 – Distributed August 31, 2002

(With 2 figures)

ABSTRACT

In this paper the spatial distribution of Plecoptera nymphs in the Almas' River basin, Pirenópolis, GO, was studied. Two Surber samples, each comprising 20 sampling units and totalling 2 m^2, were taken in each of the 13 stations, one during the rainy season (January 1994) and the second during the dry season (July 1994). In 5 of these stations, monthly samplings were made from June 1993 to July 1994; in these, temperature, velocity, discharge, electrical conductivity and pH were measured. Regional rainfall was also obtained. To ascertain the distribution of nymphs in the habitat, a separate sample was taken. Of the factors considered, the most important affecting the spatial distribution of the stonefly nymphs were altitude, stream order, and anthropic influence. Locally, the genera *Anacroneuria* and *Kempnyia* showed clumped distributions, but the data for *Gripopteryx* and *Tupiperla* were inconclusive due to low numbers.

Key words: Plecoptera, nymphs, spatial distribution, Central Brazil.

RESUMO

Distribuição espacial de ninfas de Plecoptera em córregos de uma região serrana do Brasil Central

A distribuição espacial de ninfas de Plecoptera em córregos da microbacia do Rio das Almas, Pirenópolis, GO, foi estudada. Foram feitas duas amostragens (amostrador de Surber, 20 unidades de amostra aleatórias – 2 m^2) em 13 pontos de coleta, uma na estação chuvosa (janeiro/1994) e outra na estação de seca (julho/1994). Em cinco desses pontos, as coletas foram feitas mensalmente de junho/1993 a julho/1994. Nesses pontos foram registrados também a temperatura, a velocidade, a vazão, a condutividade elétrica e o pH, além da pluviosidade para a região. Para verificar se os plecópteros possuem distribuição agregada ou não, foi realizada coleta no ponto com maior riqueza de Plecoptera, onde as subamostragens foram individualizadas e posteriormente submetidas a análises estatísticas. Os fatores mais importantes na distribuição espacial dos plecópteros foram a altitude, a classificação hidrológica e a ação antrópica. Quanto à agregação, os gêneros *Anacroneuria* e *Kempnyia* tiveram distribuição agregada. *Gripopteryx* e *Tupiperla* tiveram distribuição aleatória, porém, em razão do baixo número, o resultado deve ser considerado inconclusivo.

Palavras-chave: Plecoptera, ninfas, distribuição espacial, Brasil Central.

INTRODUCTION

The spatial distribution of Plecoptera nymphs can be influenced by several factors as chemical factors, altitude, temperature, stream size, vegetable cover, microhabitats and substratum type (Macan, 1962; Hynes, 1976; González del Tánago, 1984; Puig, 1984; Wais, 1984; Hassage & Stewart, 1991). The nymphs are found in riffles and litter accumulations in microhabitats with high water movement (Hynes, 1976; Williams & Feltmate, 1992; Froehlich & Oliveira, 1997). There are species that live in the margins of cold oligotrophic lakes in places where water movements occur (Hynes, 1976; Harper & Stewart, 1996). These insects are frequently associated with cold and clean streams (Williams & Feltmate, 1992). In the tropical area, many taxons are limited to mountainous and/or forested areas. The Plecoptera nymphs are conspicuous elements in fast, clean and cold waters with stone bottoms (Macan, 1962; Bachmann, 1995; Harper & Stewart, 1996).

In previous papers (Bispo *et al*., submitted a and b), the Plecoptera fauna of Almas' River basin, Pirenópolis, GO, was studied in terms of the faunistic composition and the temporal variation of nymphs and adults. In this paper the spatial distribution of nymphs is considered as well as some factors that could explain this distribution are discussed.

MATERIAL AND METHODS

Study area

Fig. 1 shows Almas' River basin. The sources of this river are located in the Serra (Range) dos Pireneus, Pirenópolis, Goiás State, and comprise a number of streams descending steep slopes with stony or sandy bottoms but also with some pools retaining leaf accumulations. These streams run on the western slopes of the range and are part of the Amazon basin.

The area, according to Nimer (1989), presents a semi-humid tropical climate with a summer rainy season (higher pluviosities from December to February) and a winter dry season from May to September.

Collections and taxonomic identification

Thirteen sampling stations were chosen (Fig. 1); their characteristics are presented in Table 1. Each station was sampled twice, once during the rainy season (January 1994) and once during the dry season (July 1994). Five stations (1, 4, 6, 11 and 12) were sampled monthly from June 1993 to July 1994; an additional collection was made in May 1997 in station 1 (Inferno Stream), the station with the highest taxa richness, to ascertain whether the nymphs presented a clumped distribution.

The hydrological classification follows Strahler (1957). For the degree of canopy cover and degree of anthropic influence, scales from 0 to 3, based on a subjective evaluation, were set as follows: 0-none, 1-small, 2-medium, 3-large (Table 1).

Nymphs were collected in riffles with a Surber sampler with an area of 0.1 m^2 and a 0.225 mm mesh, following Lind (1979) and Merritt & Cummins (1996). In each station, 20 random sampling units were taken, totalling 2 m^2. The collected material was fixed in 5% formalin. In the laboratory, the material was sorted out and the stonefly nymphs were identified and preserved in 80% ethyl alcohol. For the additional collection of May 1997, ten sampling units were taken, each was sorted out individually and the results were submitted to a statistical analysis.

Plecoptera nymphs were determined to genus, the possible level to nymphs in the region, mainly using the keys of Benedetto (1974) and Froehlich (1984). The nymphs of each genus were deposited in the Zoological Museum, USP.

Abiotic factors

Air and water temperatures, water velocity, discharge, electrical conductivity and pH were measured in stations 1, 4, 6, 11 and 12. Water and air temperatures were measured with an alcohol thermometer (0-50°C). Water velocity by the float method and discharge by multiplying velocity by the area of a cross-section of the stream (Lind, 1979). Electrical conductivity and pH were measured by a CORNING PS-17 and a CORNING PS-15 field meters, respectively. Regional monthly average temperatures and precipitation for Pirenópolis were obtained at the 10th Meteorological District, Ministry of Agriculture, Goiânia, GO.

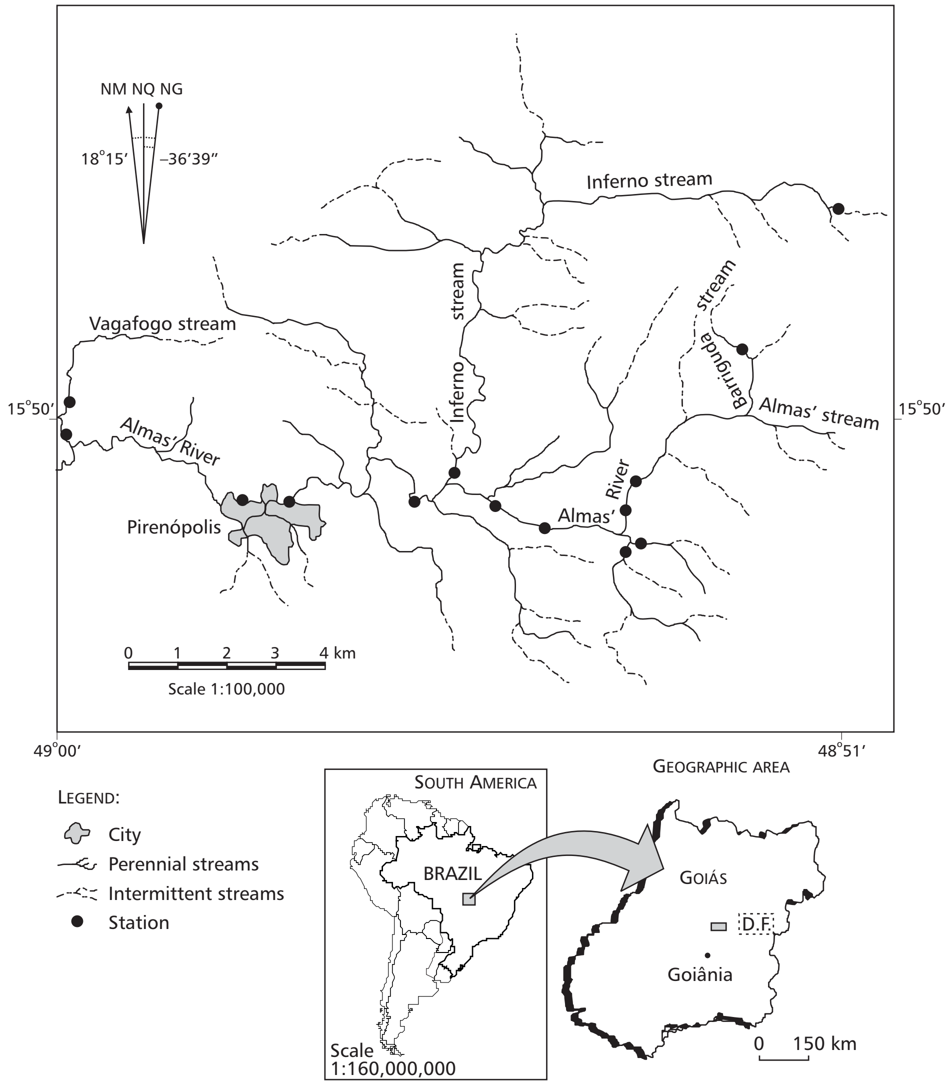

Fig. 1 — Map of the Almas' River basin, Pirenópolis Municipality, GO, showing the sampling stations.

Statistics

The paired t-test was used to verify differences between the Plecoptera fauna in the two seasons. According to Resh (1979), a clumped distribution is very common among aquatic insects. To test this, a separate sampling made up of 10 samplings units, was made in station 1, Inferno Stream, where the largest richness of stonefly nymphs was found. Dispersion (ID) was evaluated by the ratio between variance and the mean, and the statistical significance was evaluated by a χ^2 test [$\chi^2 = ID(N - 1)$] (Ludwig & Reynolds, 1988).

RESULTS AND DISCUSSION

Various authors studied the spatial distribution of benthic insects (Illies, 1964; Lillehammer & Brittain, 1987; Dominguez & Valdez, 1992; Albariño, 1997) because it provides important information on the environmental conditions and on the organisms' responses to the patchiness of the lotic habitat. The size of the water body, the interaction with the riparian vegetation and the anthropic actions are important factors when studying the spatial distribution of aquatic organisms (Bispo & Oliveira, 1998; Diniz-Filho *et al.*, 1998).

TABLE 1
Characterization of the 13 sampling stations in the Almas' River basin, Pirenópolis, GO.

	Site	Stream classification	Degree of canopy cover	Degree of anthropic influence	Altitude
Station 1	Inferno Stream	1st	3	0	1100 m
Station 2	Barriguda Stream	1st	2	1	950 m
Station 3	Almas' River, up Fráter	3rd	2	1	–
Station 4	Almas' River, Fráter	3rd	2	1	780 m
Station 5	Tributary of Almas' River, OMNI	3rd	2	1	–
Station 6	Almas' River, club	4th	1	2	750 m
Station 7	Almas' River, down club	4th	1	2	–
Station 8	Almas' River, up quarry	4th	1	2	–
Station 9	Almas' River, quarry camping	4th	1	2	–
Station 10	Almas' River, city	4th	0	3	–
Station 11	Almas' River, city	4th	0	3	730 m
Station 12	Vagafogo Stream	1st	3	0	710 m
Station 13	Vagafogo Stream	1st	3	0	–

0 – none; 1 – small; 2 – medium; 3 – large.

During the present study, 1501 nymphs were collected, 513 in the rainy season (pluviometric precipitation in January 1994: 325.3 mm) and 988 in the dry one (pluviometric precipitation in July 1994: 17.4 mm) (Tables 2 and 3). Table 2 shows the abundance in each station in the rainy and dry seasons. A significant difference was found between the densities of both seasons (Paired t-test, $p < 0.05$). Station 1 had the largest overall abundance, 372 nymphs; station 10 had the smallest, with 3 nymphs (Table 2).

Diniz-Filho *et al.* (1998), studying the spatial distribution of the Ephemeroptera, Plecoptera and Trichoptera (EPT) fauna of the Pirenópolis region, and Bispo & Oliveira (1998), studying the EPT fauna of the Goiânia Ecological Park, found differences among the communities in the rainy and the dry seasons. The temporal variation of Plecoptera nymphs from Pirenópolis region, studied by Bispo *et al*. (submitted a), showed a non-seasonal pattern. However, in the present paper there was a significant difference between the abundance of Plecoptera nymphs in the rainy (January 1994) and the dry (July 1994) seasons; these months are the extremes of the two seasons.

The hydrological classification of lotic waters is extremely important when considering the spatial distribution of macroinvertebrates. With growing stream order, interactions between abiotic and biotic factors vary, influencing the distribution of the groups (Vannote *et al*., 1980). Froehlich (1969) and Froehlich & Oliveira (1997) observed the preference of some Plecoptera species for different stream sizes. Froehlich & Oliveira (1997) suggest that in some cases the preference may be related to water velocity, as often stream size and water velocity are related (Hynes, 1970). In low order streams, the vegetable cover tends to be dense (Vannote *et al*., 1980), this occurred in the streams studied in the Perinópolis area.

TABLE 2

Total number of nymphs collected during the rainy (January 1994) and the dry (July 1994) seasons in the Almas' River basin, Pirenópolis, GO.

Stations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total**
Rainy season														
Anacroneuria	84	30	15	13	15	14	9	85	35	3	14	66	78	461
Kempnyia		15												15
Gripopteryx	23	4												27
Tupiperla	9	1												10
Total	116	50	15	13	15	14	9	85	35	3	14	66	78	513
Dry season														
Anacroneuria	174	36	75	68	95	109	49	62	77		2	61	60	868
Kempnyia	28	28												56
Gripopteryx	2	9												11
Tupiperla	52	1												53
Total	256	74	75	68	95	109	49	62	77		2	61	60	988
Grand total	372	124	90	81	110	123	58	147	112	3	16	127	138	1501

In the Pirenópolis area, *Kempnyia* and *Macrogynoplax* preferred 1st order streams and highest vegetable cover (Tables 2 and 3), only one specimen of *Kempnyia* was collected in station 4, 3rd order (Table 3). *Gripopteryx* and *Tupiperla* preferred 1st order streams, highest vegetable cover and highest altitude (Table 2).

Anacroneuria is a very diversified group, it was represented in the Pireneus Mountains by 8 morphospecies (Bispo *et al.*, submitted b) and occurred in all the collection stations (Table 2).

According to Bachmann (1995), the spatial distribution of the Plecoptera is closely linked to higher latitudes and altitudes. Hynes (1941 *apud* Macan, 1962) states that altitude influences these organisms through temperature (higher altitudes, lower temperatures); besides the direct effect of temperature on the aquatic organisms there is also the effect of an increased oxygen solubility. Temperature and oxygen solubility are negatively correlated and their combination can restrict the occurrence of some Plecoptera taxa to definite altitudes or latitudes, as is known from North America (Pennak, 1978). Corroborating Illies (1964), the present study showed that altitude was one of the main factors influencing the distribution of the stoneflies. In Brazil, the gripopterygids are characteristic of the mountainous areas of the south and southeast; in the studied area, they occurred only in stations 1 and 2 (Table 2), where altitudes are above 950 m a.s.l. (Table 1). In the other sampling stations, with lower altitudes (between 800 and 700 m a.s.l.), only Perlidae were found (Table 2), with the exception of a single *Tupiperla* nymph collected, in a separate sampling, in station 12 (710 m a.s.l.) (Table 3).

When studying the spatial distribution of aquatic macroinvertebrates, one important aspect is the anthropic influence and their responses to it (Schroeder-Araujo & Cipólli, 1986; Hellawell, 1989; Rosenberg & Resh, 1993). Among the organisms sensitive to water quality, the Plecoptera occupy an outstanding position for their vulnerability to environmental impacts. Many methods for the evaluation of water quality consider the stoneflies as good indicators of clean waters (Navas-Pereira & Henrique, 1996).

Donald (1980) and Simpson (1980) described morphological deformities in stoneflies exposed to inorganic pollution. Wielgosz *et al*. (1982) verified the absence of Plecoptera and other stenoic taxa in places with organic pollution. Considering the five stations collected along the year, a total of 3513 specimens were collected, 45% in station 1, 19% in station 4, 9% in station 6, 1% in station 11 and 26% in station 12 (Fig. 2). The physico-chemical characterization of these five stations are presented in Table 4. There was a large reduction in stonefly nymph abundance in stretches with a pronounced anthropic influence and larger stream order (Table 1 and Fig. 2). The increase of the size of the stream was coincident with the increase of the anthropic influence, being difficult to separate which of the two influenced more the decrease of the Plecoptera density. However, probably the influence of anthropic action (organic pollution) was a very important factor in the variation of the Plecoptera density among the stations (McCafferty, 1981; Wielgosz *et al.*, 1982; Rosenberg & Resh, 1993; Giller & Malmqvist, 1998). The organic enrichment due to the discharge of organic sewage in the system can decrease the dissolved oxygen concentration and the Plecoptera gills can become covered with fine particles, hindering gaseous exchanges. Both can be related to the decrease in abundance of nymphs observed where the anthropic actions are higher.

Lotic habitats are composed of many microhabitats. This environmental mosaic affects the spatial distribution of the organisms (Scarsbrook & Townsend, 1993; Allan, 1995). This heterogeneity favours the aggregation of organisms in microhabitats that offer them optimal conditions (resource availability, water velocity, substrate, etc.) for their development and survival. Besides the abiotic factors, interactions with other organisms may also affect their distribution (Hart, 1992). Hassage *et al*. (1988) verified a clumped distribution for the stonefly *Pteronarcella badia.* When submitted experimentally to the presence of a predator stonefly, *Claassenia sabulosa,* the distribution became random.

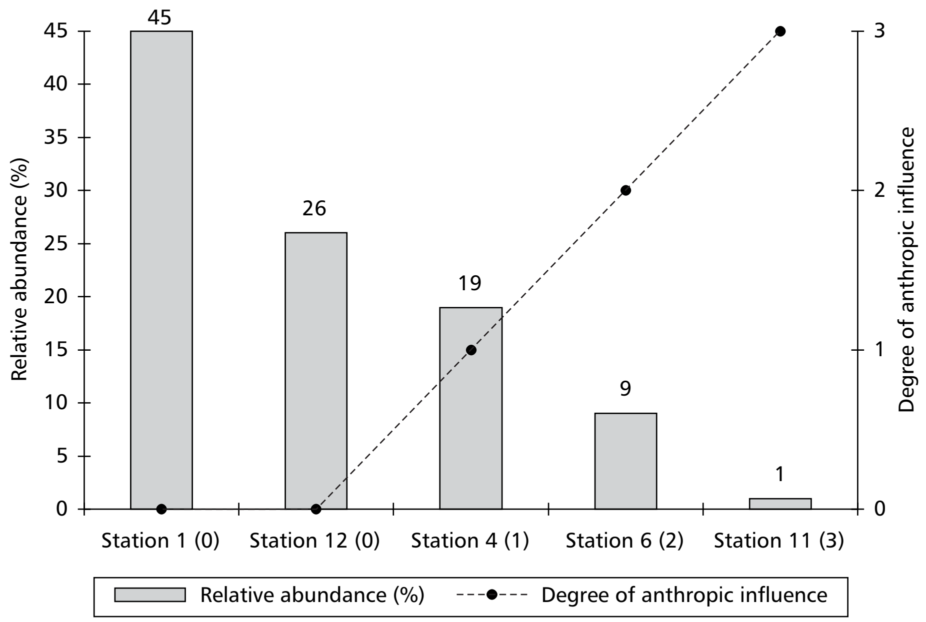

Fig. 2 — Graph of the relative abundances of nymphs collected from June 1993 to July 1994 in stations 1, 4, 6, 11 and 12, and the respective degrees of anthropic influence, parenthesis, in Almas' River basin, Pirenópolis, GO.

TABLE 3

Genera of Plecoptera nymphs recorded from June 1993 to July 1994 in stations 1, 4, 6, 11 and 12 in Almas' River basin, Pirenópolis, GO. 1: only one specimen.

Stations	**1**	**4**	**6**	**11**	**12**
Anacroneuria	X	X	X	X	X
Kempnyia	X	1			X
Macrogynoplax	X				X
Gripopteryx	X				
Tupiperla	X				1

Ferreira (1990) and Oliveira (1991) found clumped distributions for most Ephemeroptera and Trichoptera in the area of Pedregulho, SP. Regarding the temporal variation, these authors verified that in some months the pattern became random, probably due to a reduction in numbers of these insects.

Most insects in the Almas' River basin showed a clumped distribution, corroborating Resh (1979), who considers this pattern a common one in the aquatic insects. Statistical analyses showed a clumped distribution for *Anacroneuria* and *Kempnyia*. *Gripopteryx* and *Tupiperla* were randomly distributed, a common result when numbers are very low. The clumped distribution is a problem in the evaluation of the density and sampling procedures in the study of aquatic insects. In communities with highly clumped distributions, a great number of samples are necessary for reducing the sampling error. Often ecological patterns are not detected on account of the large sampling error. Compared methodological studies are necessary in tropical areas in order to establish the best cost-benefit between the sampling effort and the associated error. Resh (1979) and Merritt *et al.* (1996) discuss some of those problems in aquatic insects.

In a general manner it can be said that altitude, anthropic influence and stream order were the chief factors conditioning the spatial distribution of Plecoptera nymphs in Almas' River basin.

TABLE 4

Mean and standard deviation of the abiotic factors recorded from June 1993 to July 1994 in sampling stations 1, 4, 6, 11 and 12, and the average precipitation for the area of the Almas' River basin, Pirenópolis, GO.

Stations	**1**	**4**	**6**	**11**	**12**
Water temperature (^{o}C)	18.61 ± 1.21	19.07 ± 1.78	20.49 ± 2.10	20.42 ± 2.60	20.64 ± 1.99
Air temperature (^{o}C)	20.61 ± 1.92	21.25 ± 3.76	22.61 ± 3.21	22.00 ± 4.38	22.07 ± 2.63
Water velocity (m/s)	0.29 ± 0.08	0.48 ± 0.14	0.66 ± 0.25	0.83 ± 0.25	0.38 ± 0.13
Discharge (m^3/s)	0.04 ± 0.02	0.65 ± 0.38	0.79 ± 0.58	3.09 ± 2.39	0.26 ± 0.18
pH	7.41 ± 0.27	8.31 ± 0.18	8.42 ± 0.23	8.24 ± 0.21	7.54 ± 0.21
Electrical conductivity (µS/cm)	0-19	10-29	20-39	10-29	10-29
	January/1994	July/1994			
Precipitation for the area (mm):	325.3	17.4			

Acknowledgments — We would like to express our thanks to FUNAPE-UFG, for financial support during field work; to CAPES and to FAPESP (proc. 98/11074-3), for previous and present scholarships to the first author; and to CNPq for a research fellowship to the second (301247/96-0) and third (300833/98-9) authors.

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