SEASONAL VARIATION OF EPHEMEROPTERA IN FOUR STREAMS OF GUATOPO NATIONAL PARK, VENEZUELA

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ABSTRACT

The composition, seasonal variation and diversity of the mayfly fauna in four streams (two watersheds) of the Guatopo National Park were studied biweekly for one year (February 1996-February 1997). The density of the Ephemeroptera has a distinctive cycle with maximum abundance at the middle of the dry season and minimum during the rainy season. The abundance of this community is significantly different among rivers belonging to different watersheds. The Leptophlebiidae (*Thraulodes* sp.) was always the most abundant family, in all rivers, followed by the Leptohyphiidae. However, the latter showed a higher diversity than the former. Principal Component Analysis of the data indicated that the community structure of the mayfly fauna is more similar among rivers belonging to the same watershed regardless of differences in morphometric variables of the streams.

INTRODUCTION

Seasonal variations as well as distributional patterns in aquatic insects have been associated with different causes. Historically, since seasonal variation in tropical systems was smaller than in temperate ones, they were considered climatically stable (Klopfer, 1959). Thus, it follows that the fauna should also exhibit smaller fluctuations. However, as more research in tropical areas is being conducted, they indicate that aquatic insects exhibit seasonal fluctuations similar to temperate ones (Flecker and Feifarek, 1994; Flowers and Pringle, 1995; Cressa, 1998; Jacobsen and Encalada, 1998).

On the other hand, distributional patterns of insects were explained using three different approaches. First of all, the classification of rivers was based on empirical relationships between the riverine fauna and environmental factors. The environmental factors more frequently used were substrate composition (Wright *et al.*, 1984), hydrological conditions (Stanford and Ward, 1983; Resh *et al.*, 1988; Corkum, 1989; 1992). However, the prediction power was poor since models were area-specific (Hawkes, 1975; Corkum, 1989). Secondly, distributional patterns

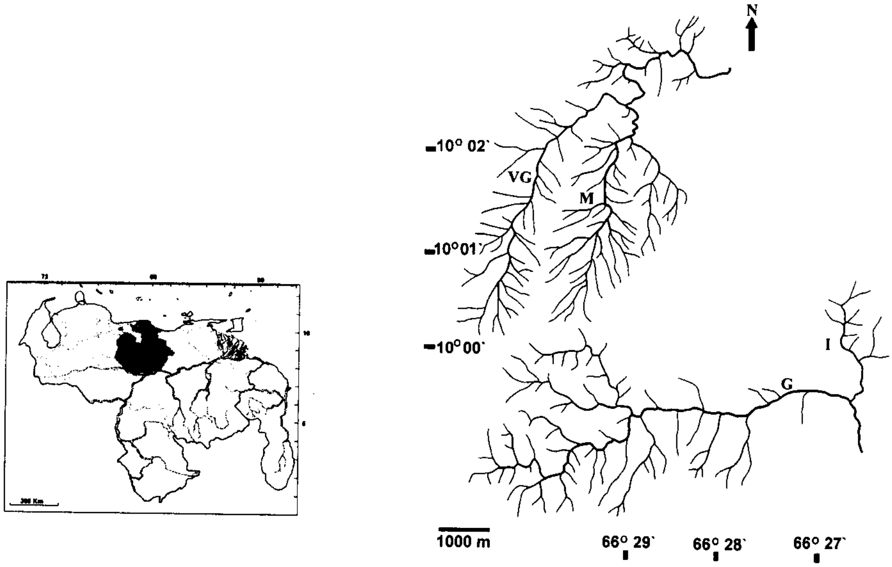

Fig. 1. Venezuela map including two watersheds studied.

were sought applying the continuum concept (Vannote *et al.*, 1980) which stated that longitudinal changes in physical variables along a river were associated with changes in biological process (production) and community composition of vertebrates (fishes) as well as invertebrates (feeding groups). In this case also several modifications were needed in order to apply the model to different biomes for the rest of the world (Wiggins and Mackay, 1978; Minshall *et al.*, 1985; Winterbourn *et al.*, 1981; Cressa, 1994). Finally, the biome dependency hypothesis originally expressed by Ross (1963) indicated that caddisflies were associated with the biome through which the river flowed. Corkum (1989; 1990) expanded on this idea and suggested that similar assemblages of macroinvertebrates were likely to be found within drainage basins.

In this study, we present data from one year's sampling of the mayfly community of four streams located in Guatopo National Park, Venezuela. We studied the seasonal fluctuations of mayflies as well as their distributional patterns in these two watersheds and evaluated the importance of the hydrological variables on their assemblages.

Study Area

This study was conducted on four streams of Guatopo National Park, Venezuela (9° 57' – 10° 5' N and 66° 24' – 66° 30' W, Fig. 1) where the rivers are unperturbed and in pristine state. The National Park lies on the Cordillera del Interior of Cenozoic origin (Tertiary period); its geological characterization is metamorphic-sedimentary (shale) and metamorphic-igneous rocks. The region has narrow valleys, abrupt and pronounced slopes, and narrow areas for deposition of material and terraces formed as by-products of climatic changes during the Quaternary. Due to the extension of the Park (122,464 Ha) there is a difference in altitude (200-1,430 m) easily recognized in the vegetation that changes from humid to a dry tropical forest as the altitude dismishes.

The rivers studied belong to two different watersheds (Fig. 1), Quebrada Martinera (M) and Quebrada Vuelta Grande (VG) are the headwaters of the river Taguaza which flows into the Caribbean Sea. The other streams, Quebrada Ingenio (I) and Quebrada Guatopo (G), are part of the Orituco basin of the Orinoco river system.

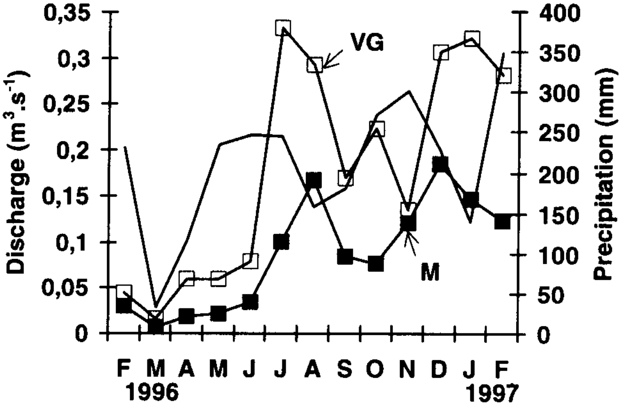

Fig. 2. Discharge and precipitation in Vuelta Grande – Martinera watershed.

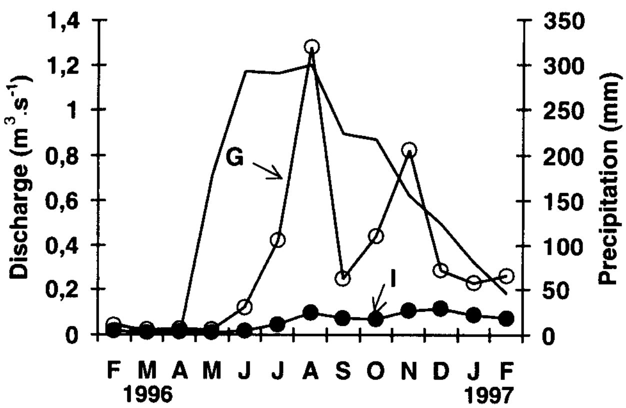

Fig. 3. Discharge and precipitation in Guatopo – Ingenio watershed.

The weather data were obtained from the Ministerio del Ambiente y los Recursos Naturales Renovables from stations located near the sampling sites (Agua Blanca for VG-M and Guatopo for G-I). Mean annual rainfall based on 37 records (1960-1997) is 2611.4 mm and 2166.4 mm for VG-M and G-I respectively. However, during the sampling period VG-M had more rainfall that this average (2737.9 mm) while for G-I it was lower (1925.5). In general, precipitation is bimodal; the first rainy season begins in April and continues until July. The second period starts in August and lasts until December. VG-M follows this pattern more closely (Fig. 2) since the bimodality was present during the sampling period.

Discharge annual variation resembles the rainfall pattern (Figs. 2 and 3) as previously recorded by Cressa and Senior (1987) for the G-I watershed. The highest discharge is for G (Table 1) followed by VG. Interestingly, even though VG and I are streams of the same order (3rd) the latter presented the lower discharge (Table 1).

Table 1. Morphometric characteristics of four streams in Guatopo National Park

River	Vuelta Grande	Martinera	Guatopo	Ingenio
Order	3rd	4th	5th	3rd
Altitude (masl)	396	300	620	620
Length (km)	6	5	7.75	3
Watershed area (km^2)	6.08	6.24	11.83	1.786
Mean Depth (m)				
Annual	0.17	0.12	0.15	0.12
Dry	0.15	0.10	0.11	0.10
Wet	0.19	0.15	0.21	0.14
Mean Width (m)				
Annual	3.02	3.14	3.89	1.87
Dry	3.14	2.90	2.93	1.22
Wet	2.86	7.85	5.25	2.22
Bank Full (m)	9.2	10.3	8.4	6.4
Mean Velocity (m/s)				
Annual	0.53	0.35	0.57	0.38
Dry	0.42	0.31	0.40	0.33
Wet	0.70	0.41	0.82	0.44
Mean Discharge (m^3s)				
Annual	0.16	0.08	0.30	0.05
Dry	0.11	0.05	0.10	0.03
Wet	0.24	0.11	0.6	0.08

The river channel in Qda. Ingenio and Martinera is completely covered by the riparian vegetation with canopies interlocking over the stream while in Vuelta Grande and Guatopo canopies do not cover the entire river bed. The streams substrates were mainly cobble (5-10 cm) and gravel in both watersheds. In Martinera and Ingenio the rock bottom was clearly visible in several stretches of the river. The riparian vegetation was by far dominated by the Leguminosae which were the most abundant and diverse component, followed by the Euphorbiaceae, Rubiaceae and Moraceae. The main representatives of the riparian vegetation in Martinera were *Bauhinia multinervia, Acacia glomerosa, Guazuma tomentosa, Ficus* sp., *Inga* sp. *and Erythrina poeppigiana.* In Guatopo *Hura crepitans, Brownea leucantha, Simira longifolia, Zanthoxylum monophyllum,* and *Jacaranda* sp. were the more representative species.

MATERIALS AND METHODS

The macroinvertebrates were collected biweekly from February 1996 to February 1997, with a Surber net (0.1296 m^2, 0.286 mesh size) using a stratified design to cover all the habitats of the highly heterogeneous substrate as well as to obtain a good representation of the early instars. Organisms were separated from the sediment in the field and preserved with ethanol (70%) for counting and identification at the laboratory. The identification of the specimens were determined, as far as possible to morphospecies, using available literature (Roldan, 1988; Domínguez *et al.*, 1992; Merritt and Cummins, 1996). Some mayflies were directly identified by Dr. E. Domínguez, Universidad de Tucumán, Argentina.

At the same time that macroinvertebrates were collected, the following variables were recorded: velocity (Ott meter), depth, width, temperature, pH and conductivity as well as water samples for chemical analysis. These data will be presented in another paper.

Table 2. Mean density (no.m^{-2}), number of morphospecies, Fisher's alpha diversity of the log series (μ) and Shannon (H') index in four streams in Guatopo National Park. All variables are giving as and annual mean as well as for the dry and wet season.

River	Vuelta Grande	Martinera	Guatopo	Ingenio
Mean Density (no/m^2)	12.814	14.618	13.048	16.590
Annual	13.382	17.048	19.435	22.787
Dry	12.056	11.083	4.533	8.317
Wet				
Number of morphospecies				
Annual	11	13	11	10
Dry	11	11	11	10
Wet	11	10	10	10
a diversity index				
Annual	1.791	2.167	1.691	1.506
Dry	1.944	1.824	1.784	1.634
Wet	2.119	2.006	2.511	2.017
Shannon Index (H')				
Annual	0.624	0.548	0.588	0.614
Dry	0.583	0.532	0.542	0.574
Wet	0.661	0.541	0.774	0.687

RESULTS

The maximum number of morphospecies was 13 (Table 2) which could be considered low when compared with the thirty-seven found by Flowers and Pringle (1995) in the Río Sábalo-Esquina in Costa Rica. The highest number of morphospecies as well as the highest density was found in the Leptophlebiidae followed by the Leptohyphidae. The same family was also the most important in R. Sábalo (Flowers and Pringle, 1995).

The mean annual density of mayflies was similar between watersheds (Table 2). However, a statistically significant difference (Two-way Anova, $p < 0.05$) was found between seasons, with maximum and minimum abundance during the dry (March, Fig. 4) and wet season (August), respectively. The watersheds did not behave similarly since in G-I this difference was an order of magnitude while for VG-M the variation was much smaller (Table 2). Similar results in the magnitude of the seasonal variation on density was reported by Flecker and Feifarek (1994) for Río las Marías, Venezuela.

This seasonal variation in density, indicates changes in mayfly composition since some morphospecies appear only during one of the seasons (dry or wet). Thus, in Martinera, *Leptohyphes* 3, *Camelobaetidius* sp. and *Hydrosmilodon* sp. were present only during the dry season as was *Camelobaetidius* sp. in Guatopo.

On the other hand, *Thraulodes* sp. was the most abundant morphospecies. Its highest density was in Qda. Martinera during the dry season (66 %) while the lowest was found in Qda. Ingenio during the wet season (21 %).

Diversity is also shown in Table 2, calculated as Fisher's alpha of the log series and Shannon's index. The alpha values give a better representation of the morphospecies variation than Shannon's. This was expected since Fisher's alpha of the log series is independent of the sample size and does not give excessive weight to the most common species in a sample (Wolda, 1981; 1983a; 1983b). However, peaks in diversity, for both indexes, relatively coincide with peaks in number of species and less so with density (Fig. 4). Similar results were found by Wolda (1983b) for tropical cockroaches which do not have abrupt changes in density, similar to the results for aquatic insects presented here.

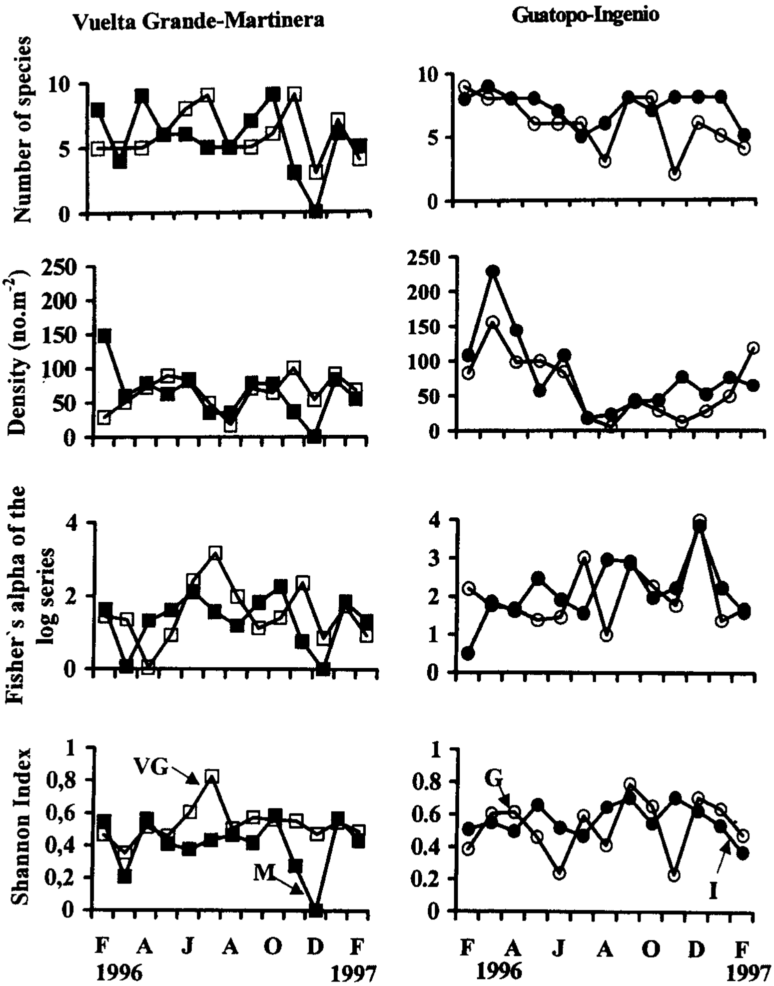

Fig. 4. Monthly changes in number of species, density, Fisher's alpha of the log series and Shannon index for two watersheds.

Since the seasonal variation in mayflies abundance was so pronounced, the data were analyzed using Principal Component Analysis (PCA) in order to associate changes in the community with seasons and rivers. The first axis of the PCA was able to separate the streams, and the species more representative were *Terpides* sp. (94%), *Euthyplocia* sp. (86%) and *Haplohyphes* sp. (63%). The second axis of the PCA was able to separate the dry and wet season for all streams (Fig. 5) and the species with greater weight were *Thraulodes* sp. (69%), *Leptohyphes* 1 (56%) and *Baetodes* sp. (55%). The PCA also indicates that the difference during seasons in VG was not as great as in the other rivers.

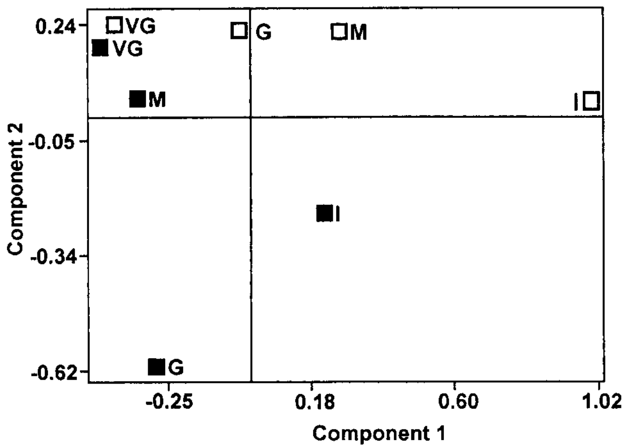

Fig. 5. Principal Component Analysis. White square: dry season and black square: wet season (VG: Vuelta Grande, M: Martinera, G: Guatopo and I: Ingenio).

Furthermore, during the wet season sites belonging to the same watershed were more similar because they shared the same faunal composition. During the dry season the association between streams belonging to the same watershed was not as clear as during the wet season because Guatopo and Martinera are closer. This similarity could be explained by the physical characteristics of both streams during this season, since their width, depth, velocity and discharge were similar (Table 1).

During the dry season the changes on community composition and density were greater for Ingenio (Table 2, Fig. 5) than for the other rivers. Ingenio had mainly the less abundant species (*Terpides* sp. and *Euthyplocia* sp.) as is indicated by axis 1. On the other hand, Guatopo was characterized by the more common species (*Thraulodes* sp. and *Leptohyphes* 1) as is clearly indicated by the axis 2 (Fig. 5). Therefore, these patterns are more similar among rivers draining similar watersheds than between rivers from different watersheds, as expected according to the biome theory of Ross (1963) and Corkum (1989).

DISCUSSION

This study indicates the importance of seasons in determining the mayfly community composition in the four streams studied. The seasonal variation can produce alterations in environmental variables which in turn can regulate the mayfly community composition (discharge, substrate, mean width), as was demonstrated by Dudgeon (1993) for a river in Hong Kong, Flecker and Feirarek (1994) for Andean Venezuelan rivers and Jacobsen and Encalada (1998) for Andean Ecuatorian rivers.

The low number of morphospecies found in these streams is surprising, and even though there are few studies on tropical streams from which to draw meaningful comparisons, the data that exist indicate higher numbers (Stout and Vandermeer, 1975; Pearson *et al.*, 1986; Flowers and Pringle, 1995). Only the recent paper by Jacobsen and Encalada (1998) reported lower numbers (7) for rivers of Ecuador. In our case, there are three reasons that could explain this difference. First, that sample size was not adequate; however, even though there is always the possibility that a greater sample size could capture the rarer species, we feel that sample size was appropriate since it follows the suggestion of Vinson and Hawkins (1996). Second, that fluctuations of the composition of the mayfly fauna are greater than a year sampling and thus were not observed. This also could not be disregarded completely, particularly in view of the data presented by Flowers and Pringle (1995) where only thirteen taxa were found only one of the three years that lasted the study. However, in our case this is also unlikely since sampling in one of the rivers (Qda. Guatopo) has been going on since 1983. Even though this sampling has not been continuous, we feel that our collections should indicate the actual morphospecies present in the stream. Finally, we feel that taxonomic separation could be our major problem due to the high number of undescribed nymphal stages. However, care was taken to separate species as morphospecies, although the small size of organisms could easily have caused some species to be overlooked and thus the diversity could be underestimated. Accounting for this factor even if we double our numbers of morphospecies, they are still low and could really mean that this is characteristic of the area.

In any case, these results emphasize both the need for more studies in tropical systems in order to characterize these systems appropriately and the importance that long-term studies have in evaluating diversity in lotic systems (Flowers and Pringle, 1995). This is even more important if a great variation in composition and abundance is present, as was in this case.

The seasonal patterns shown by the mayflies fauna are similar to the studies of Hynes (1975) in Ghana, Dudgeon (1993) in Hong Kong, Flecker and Feifarek (1994) in Venezuela and Jacobsen and Escalada (1998) in Ecuador. In this study as well as in those mentioned above, the density of the aquatic fauna is dependent on the hydrological conditions in the environment. In our case the hydrological regime is different in the four rivers studied. Martinera and Ingenio being smaller in size are more subject to changes in morphometry during high floods and the variation in density should reflect this higher washing out of the fauna during the wet season. Flecker and Feifarek (1994) reported similar results for two rivers of Venezuela, where they found that magnitude of changes of the density of the macroinvertebrates was lower in the stream with the less pronounced changes in the hydrological regime. Flooding them must be one of the major causes of mortality in tropical streams and given that rain is also a pseudo-random event it should not be surprising that short life cycles and a fast recolonization rate are common events in tropical systems.

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REFERENCES

Corkum L. A. 1989. Patterns of benthic invertebrate assemblages in rivers of northwestern North America. Freshw. Biol. 21: 191-205.

Corkum L. D. 1990. Intrabiome distributional patterns of lotic macroinvertebrate assemblages. Can. J. Fish. Aquat. Sci. 47: 2147-2157.

Corkum L. D. 1992. Spatial distributional patterns of macroinvertebrates along rivers within and among biomes. Hydrobiologia. 239: 101-114.

Cressa C. 1994. Structural changes of the macroinvertebrate community in a tropical river. Verh. Int. Ver. Limnol. 25:1853-1855.

Cressa C. 1998. Community composition and structure of macroinvertebrates of the river Camurí Grande, Venezuela. Verh. Int. Ver. Limnol. 26: 1008-1011.

Cressa C. and C. Senior. 1987. Aspects of the chemistry and hydrology of the Orituco river, Venezuela. Acta Cientif. Venez. 38: 99-105.

Domínguez, E., M. D. Hubbard and W. L. Peters. 1992. Clave para ninfas y adultos de las familias y generos de Ephemeroptera (Insecta) Sudamericanos. Biología Acuática. (16): 1-24.

Dudgeon, D. 1993. The effects of spate-induced, predation and enviromental complexity on macroinvertebrates in a tropical stream. Freshw. Biol. 30: 189-197.
Flecker A. S. and B. Feifarek. 1994. Disturbance and the temporal variability of invertebrate assemblages in two Andean streams. Freshw. Biol. 31: 131-142.
Flowers, R. W. and Pringle C. M. 1995. Yearly fluctuations in the mayfly community of a tropical stream draining lowland pasture in Costa Rica, pp. 131-150. In: L. D. Corkum and J. J. H. Ciborowski (eds.). Current Directions in Research on Ephemeroptera. Canadian Scholar's Press Inc.
Hawkes, H. A. 1975. River zonation and classiffication. In: B. A. Whitton (ed.). River Ecology. Blackwell Scientific Press, Oxford.
Hynes, J. D. 1975. Annual cycles of macro-invertebrates in a river in southern Ghana. Freshw. Biol. 5: 71-83.
Jacobsen, D. and A. Encalada. 1998. The macroinvertebrate fauna of Ecuadorian highland streams in the wet and dry season. Arch. Hydrobiol. 142: 53-70.
Klopfer, P. H. 1959. Environmental determinants of faunal diversity. Amer. Natural. 93: 337-342.
Merritt, R. W. and C. W. Cummins. 1996. An introduction to the aquatic insects of North America. Third Edition. Kendall/Hurt Publishing. USA.
Minshall, G. W., K. W. Cummins, R. C. Petersen, C. E. Cushing, D. A. Bruns, J. R. Sedell and R. L. Vannote. 1985. Developments in stream ecosystem theory. Can. J. Fish. Aquat. Sci. 42: 1045-1055.
Pearson, R. G., L. J. Benson and R. E. W. Smith. 1986. Diversity and abundance of the fauna in Yuccabine Creek, a tropical rainforest stream. In: P. Deckker and W. D. Williams (eds.). Limnology in Australia. 329-342. Melbourne: CSIRO and Dordrecht: Dr. W. Junk Publishers.
Resh, V. H., A. V. Brown, A. P. Covich, M. E. Gurtz, H. W. Li, G. W. Minshall, S. R. Reice, A. L. Sheldon, J. B. Wallace and R. C. Wissmar. 1988. The role of disturbance in stream ecology. J. N. Amer. Benthol. Soc. 7: 433-455.
Roldán, G. 1988. Guía para el estudio de macroinvertebrados acuáticos del Departamento de Antioquia. Fondo para la protección del ambiente. Universidad de Antioquia. Colombia.
Ross H. H. 1963. Stream communities and terrestrial biomes. Arch. Hydrobiol. 59: 235-242.
Stanford, J. A. and J. V. Ward. 1983. Insect species divertsity as a function of enviromental variability and disturbance in stream systems, p. 265-78. In: J. R. Barnes and G. W. Minshall (eds.): Stream Ecology: Application and Testing of General Ecology Theory: 265-278. Plenum Press, New York.
Stout, J. and J. Vandermeer. 1975. Comparison of species richness for stream-inhabiting insects in tropical and mid-latitude streams. Amer. Natural. 109: 263-280.
Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell. and C. E. Cushing. 1980. The rivers continuum concept. Can. J. Fish. Aqua. Sci. 37: 130-137.
Vinson, M. R. and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. J. N. Amer. Benthol. Soc. 15: 392-399.
Wiggins, G. B. and R. J. Mackay. 1978. Some relationships between systematics and trophic ecology in nearctic aquatic insects, with special reference to Trichoptera. University of Toronto Press. Toronto.
Winterbourn, M. J., J. S. Rounick and B. Cowie. 1981. Are New Zeland stream ecosystems really different? New Zeland J. of Marine Freshw. Res. 16: 271-281.
Wolda, H. 1981. Similarity Indices, Sample Size and Diversity. Oecologia. 50: 296-302.
Wolda, H. 1983a. 'Long term' stability of tropical insect populations. Res. Pop. Ecol. Suppl. 3: 112-126.
Wolda, H. 1983b. Diversity, diversity indices and tropical cockroaches. Oecologia. 58: 290-298.
Wright, J. F., P. D. Hiley, D. A. Cooling and A. C. Cameron. 1984. The invertebrate fauna of a small chalk stream in Berkshire, England, and the effect of intermittent flow. Arch. Hydrobiol. 99: 176-199.