ECOTRÓPICOS 23(1):37-49 2010
Sociedad Venezolana de Ecología

SEASONAL VARIATION OF MAYFLIES (INSECTA: EPHEMEROPTERA) IN TROPICAL ANDEAN HEADWATER STREAM

VARIACIÓN ESTACIONAL DE EFEMEROPTEROS (INSECTA: EPHEMEROPTERA) EN UN RÍO ALTIANDINO TROPICAL

Belkys Pérez[1] and Samuel Segnini[2]

[1] Departamento de Biología, Facultad Experimental de Ciencias y Tecnología, Universidad de Carabobo, Venezuela, and [2] Laboratorio de Ecología de Insectos, Facultad de Ciencias, Universidad de Los Andes, Venezuela.
E-mail: segninis@ula.ve

ABSTRACT

The mayfly fauna of an Andean tropical headwater stream was sampled every fifteen days during one year, and seasonal changes in density were recordered and compared to rainfall values. Even though seasonal changes of total density of genera of Ephemeroptera showed a negative correlation with rainfall values, any correlation was observed for individual genera. Two patterns were nevertheless evident: Nymphs of *Baetodes, Leptohyphes, Thraulodes, Andesiops* and *Prebaetodes* were abundant all year round, whilst nymphs of *Haplohyphes, Trichorythodes, Farrodes* and *Americabaetis* were only present occasionally and occurred in low densities.

Keywords: Andes, Aquatic insects, Ephemeroptera, neotropical stream, seasonal changes

RESUMEN

Cada quince días durante un año se recolectaron ninfas de efemerópteros en un río andino tropical de montaña y se compararon los cambios estacionales de su densidad con los de la precipitación. Aunque la variación estacional de la densidad total de los géneros de Ephemeroptera se relacionó negativamente con los cambios de precipitación, ésta asociación se perdió al analizar los cambios de densidad individualmente para cada género. Sin embargo fue evidente la existencia de dos patrones. Las ninfas de *Baetodes, Leptohyphes, Thraulodes, Andesiops* y *Prebaetodes* fueron muy abundantes todo el tiempo, mientras que las ninfas de *Haplohyphes, Trichorythodes, Farrodes* y *Americabaetis* aparecieron ocasionalmente en densidades bajas.

Palabras claves: Andes, Ephemeroptera, Insectos acuáticos, río neotropical, variación estacional

INTRODUCTION

Temporal patterns of composition and abundance of benthic macroinvertebrates can be environmentally induced by several means. Some authors argue that biotic agents are the most important factors in structuring aquatic communities (Peckarsky 1980, Power 1992, Peckarsky *et. al*. 1997, McIntosh and Peckarsky 1999, Thomson *et al*. 2002); others judge that that physical disturbance has a potentially important role in regulating the structure composition of ecological communities (Sousa, 1984; Pickett & White, 1985; Resh *et al*. 1988, Allan 2004).
A third view is held by those who argue that structure results from an alternance of the regulating effects of biotic and abiotic factors which depend on climate or environmental conditions (Palmer *et al*. 1966). The debate has stimulated research aimed at defining the conditions under which biotic and /or abiotic factors become relevant and affect the structural and functional organization of aquatic communities (Flecker and Feifarek 1994; Allan 1995; Death and Winterbourn 1995; Jacobsen *et al.* 1997; Jacobsen and Encalada 1998, Lepori, F. and N. Hjerdt 2006, Effenberger *et al*. 2006, Brown 2007).
In mountain streams, sudden changes in flow may induce major changes in current velocity that set the substrate in motion, dragging the bottom substrate and the community it hosts (Resh *et al.* 1988, McCabe & Gotelli 2000, Lytle 2001). The concomitant discharge depends on the duration, intensity and frequency of precipitation (Stanford & Ward 1983, Resh *et al*. 1988, Flecker & Feifarek 1994). Therefore, rainfall, by means of its effect on stream discharge, can be seen as the prime modifying and regulating factor of structure in mountain streams (Flecker & Feifarek 1994, Jacobsen and Encalada 1998, Rincón y Cressa 2000; Maldonado *et al.* 2001, Buss *et al*. 2004).
Considering the fact that mayflies conform one of the most important groups in the benthic macroinvertebrates community, we aimed to determine the seasonal changes in abundance and composition of mayfly nymphs and adults, and its possible relationship to seasonal variation in rainfall.

Study site

Our research was conducted at Río La Picón, a first order stream born on the northern slope of the Sierra Nevada at the Cordillera de Mérida in the Venezuelan Andes (8º 38’ N and 71º 3’ W).

Table 1. Physical and chemical variables in La Picón stream (Mar 2000 – Feb 2001).

Variable	Mean	Maximum	Minimum
Water temperature (ºC)	11,68	12,60	10,00
Stream velocity (m/seg)	0,55	1,00	0,35
Discharge (m^3/seg)	0,50	1,00	0,35
Turbidity (NTU)	0,73	2,00	0,13
pH	7,28	8,00	6,40
Conductivity (µS/cm)	47,17	60,00	45,00
Alkalinity (mg/l)	14,28	29,00	13,00
Hardness (mg/l)	26,21	28,64	23,27
Dissolved oxygen (mg/l)	8,82	12,85	7,84
Dissolved oxygen (% saturation)	78,45	111,05	71,46

This stream is relatively free of anthropogenic perturbation, since its entire course, from the spring at 3000 m a. s. l. to its confluence with Río El Oro at 2100 m a. s. l., runs through cloud forest in the Sierra Nevada National Park. The sampling locality was a reach of about 50 meters located at 2274 m a.s.l., with a slope of 12.5% and a susbstrate of rocks, gravel and sand. During the period of our observations, the waters remained clear, well oxygenated, little mineralized, with a pH near neutrality and a temperature oscillating around 12ºC (Table 1). Rainfall display a bimodal pattern (Chacón and Segnini 1996) (Figure 1). Two annual periods of high rainfall values were recorded: the first between March and June, and the last between September and November. Correspondingly, there were two periods of low rainfall, between December and February and between July and August.

METHODS

Benthic macroinvertebrates were collected and environmental variables were measured once every fifteen days between March 2000 and February 2001. Water temperature, air temperature (mercury thermometer), water conductivity (Hanna conductimeter), turbidity (Orbeco-Hellige turbidimeter), pH (Hanna potentiometer), oxygen in solution (Winkler method), hardness (complexometric method) and alkalinity (titration with H_2SO_4) were determined on each sampling date. Average stream width and average stream depth were estimated by selecting three locations 15 m apart. Stream velocity was measured at each location (floater method). These data were used to estimate average flow in m^3/sec. Rainfall records were obtained from the Instituto de Investigaciones Agropecuarias (INIA) meteorological station, located at a fish farm, ca. 1 km downstream of the study site.

Benthic macroinvertebrates were collected using a Surber sampler (960 cm^2 area and 300 µm mesh). We takes a total of six samples, which covered rapids and pools along the selected length of the stream. Faunal samples were cleared of organic and inorganic impurities, and preserved in 70% isopropilic alcohol. Insects were then identified to family level and the remaining macroinvertebrates to the class level. Numbers in each taxon were counted and fixed in Kahle's fluid (Wiggins 1998). Ephemeropteran nymphs were separated and their genera determined using the keys by Dominguez *et al*. (2001). Adults of Ephemeroptera were collected using a mixed light lamp on a white canvas screen. The screen was rigged near sunset (18:00 h approx.) and the lamp turned on for two hours (20:00 h approx.). Previous studies showed that activity of subimagos and imagos almost ceased after 20:00 h. Subimagos were

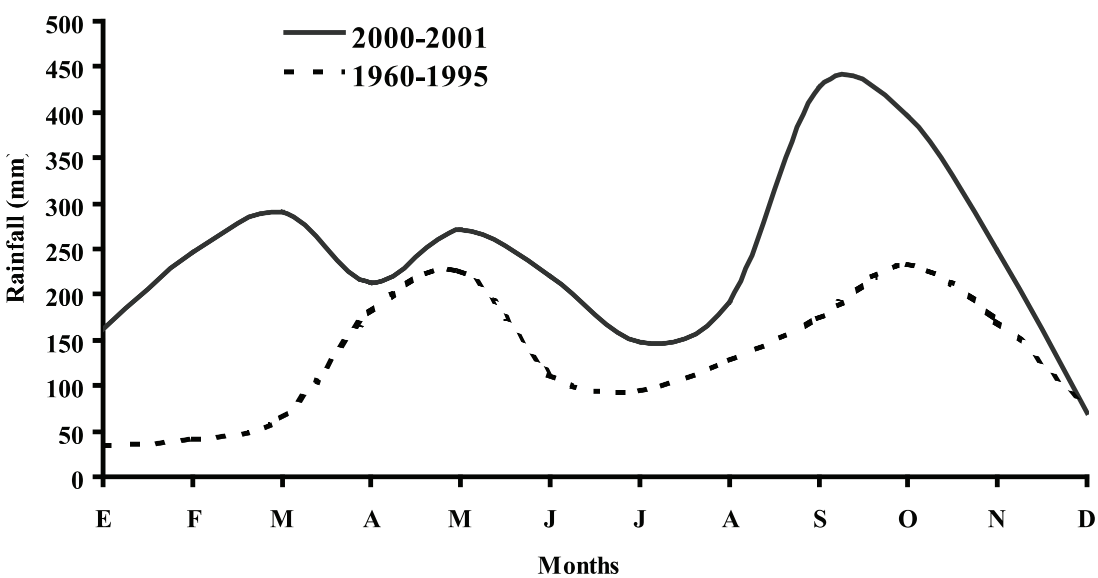

Figure 1. Rainfall for the period Jan 2000-Feb 2001 and monthly means for1960-1995.

captured and kept alive in small dark cases until their transformation into adults. Adults were preserved in 90% alcohol.

Comparison of average nymphal density between seasons were made using a Kruskal Wallis Multiple Comparisons test and his relationship with total rainfall was determined by Spearman's rank correlation coefficient (r_s).

RESULTS

Benthic macroinvertebrates from seven orders and 32 families, constituted the most abundant nearly 99% of total macroinvertebrate numbers (Table 2). The Ephemeroptera had the highest density and constituted by three families and nine genera (Figure 2).

In order to evaluate the effect of total rainfall on mayfly abundance, rainfall values were pooled for 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 days previous to each sampling date, and were related to the corresponding nymphal density. The 30 day lapse was chosen because it correlated best with changes in mayfly density (r_s = - 0.585, $p<0.05$) (Figure 3). Trends in time of these two variables, total rainfall and benthic nymphal density, show a decrease in nymph abundance during the time lapses from April through June and September through November, both of which correspond with times of heavy rainfall. Contrary to this, nymph density arose during the time lapses from July through August and December through March that are the periods with lesser rainfall (Figure 4). Kruskal Wallis Multiple Comparison test confirmed statistical significance of differences ($p<0.01$) in average nymph density during high and low rainfall seasons.

This general picture is lost when trends in density changes are examined for each of the coexisting mayfly genera. Only *Leptohyphes* (r_s =-0.53, $p<0.01$) and *Thraulodes* (r_s =-0.487) showed a negative relation, although weak, with accumulated rainfall, while *Americabaetis* related positively (r_s = +0.487, $p<0.05$). Density changes by genera did, however, show two clearly different trends. The first was characterized by the permanent presence and by the relatively high abundance of the genera *Baetodes, Leptohyphes, Thraulodes, Andesiops* and *Prebaetodes* (Figure 5). The second of these trends is apparent in the occasional, low density presence of *Haplohyphes, Trichorythodes, Farrode*s and *Americabaetis* (Figure 6).

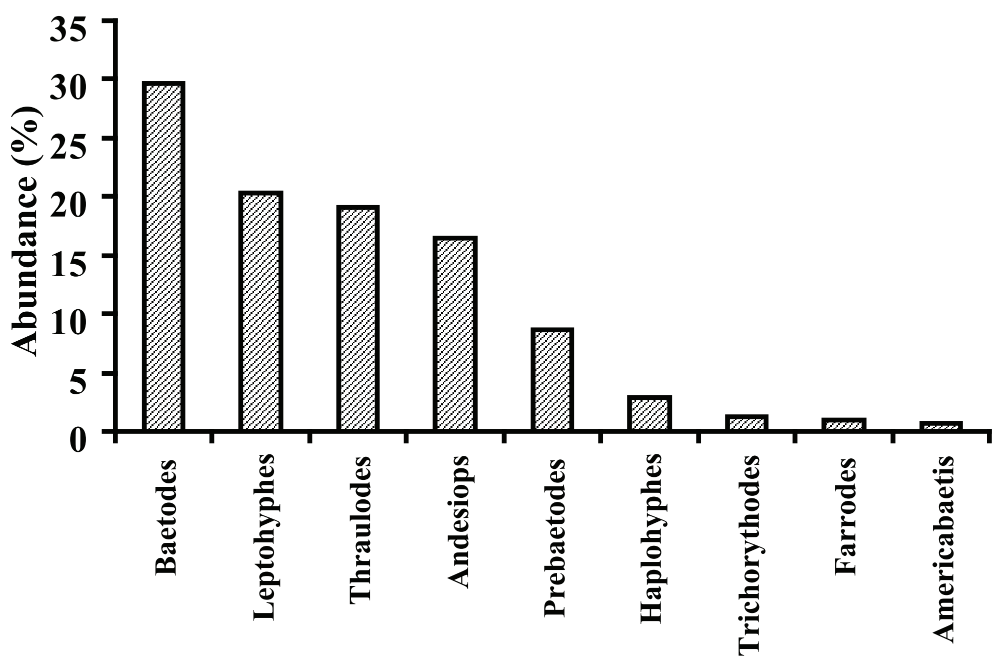

Figure 2. Abundance of mayfly nymphs genera.

Table 2. Relative Abundance of the benthic macroinvertebrates.

Class	Orden	Family	Abundance (%)
Insecta	Ephemeroptera	Baetidae	25.64
		Leptohyphidae	11.27
		Leptophlebiidae	9.20
	Diptera	Chironomidae	22.70
		Simulidae	5.30
		Tipulidae	2.94
		Athericidae	0.48
		Calamoceratidae	0.47
		Ceratopogonidae	0.32
		Empididae	0.27
		Muscidae	0.11
		Dixidae	0.09
		Dolichopodidae	0.07
		Ephydridae	0.01
	Trichoptera	Leptoceridae	1.26
		Hydropsychidae	4.97
		Hydroptilidae	0.72
		Glossosomatidae	4.71
		Hydrobiosidae	0.91
		Odontoceridae	0.58
		Polycentropodidae	0.32
	Coleoptera	Carabidae	0.01
		Elmidae A	1.35
		Staphilinidae L	0.05
		Psephenidae	0.18
		Scirtidae	0.06
		Hidraenidae	0.02
		Ptylodactilidae	0.01
	Plecoptera	Perlidae	5.29
	Lepidoptera	Noctuidae	0.02
		Pyralidae	0.01
	Odonata	Aeshnidae	0.03
Arachnida	Hydracarina		0.25
Crustacea	Isopoda		0.03
Oligochaeta			0.29
Turbellaria			0.03
Gastropoda			0.03

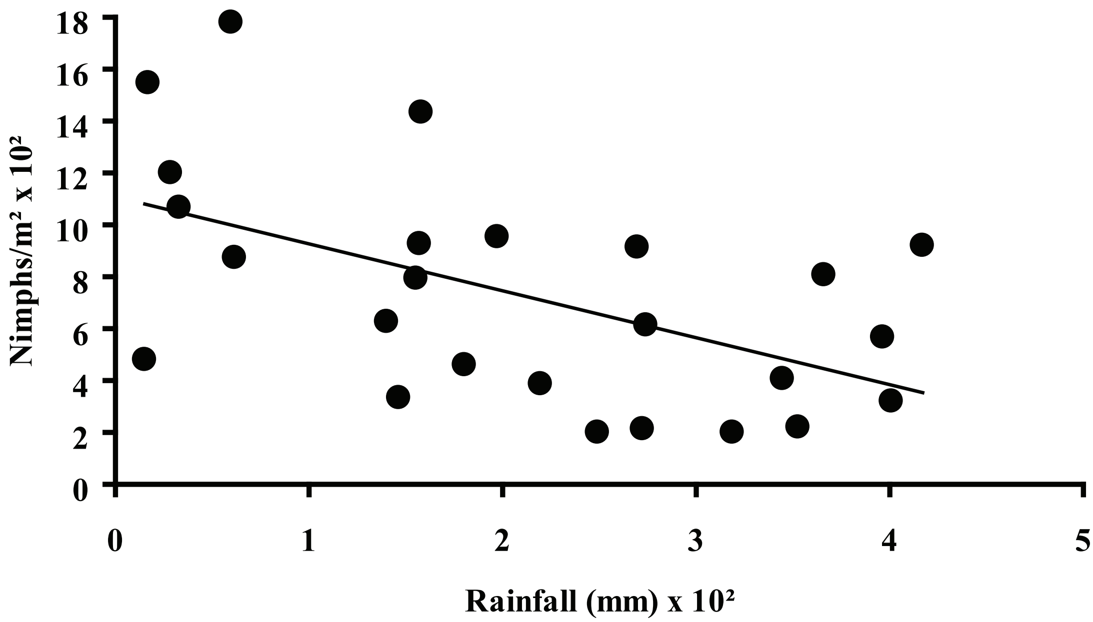

Figure 3. Correlation of mayfly nymps density and 30 days accumulated rainfall values ($r = -0.585$; $p < 0.05$).

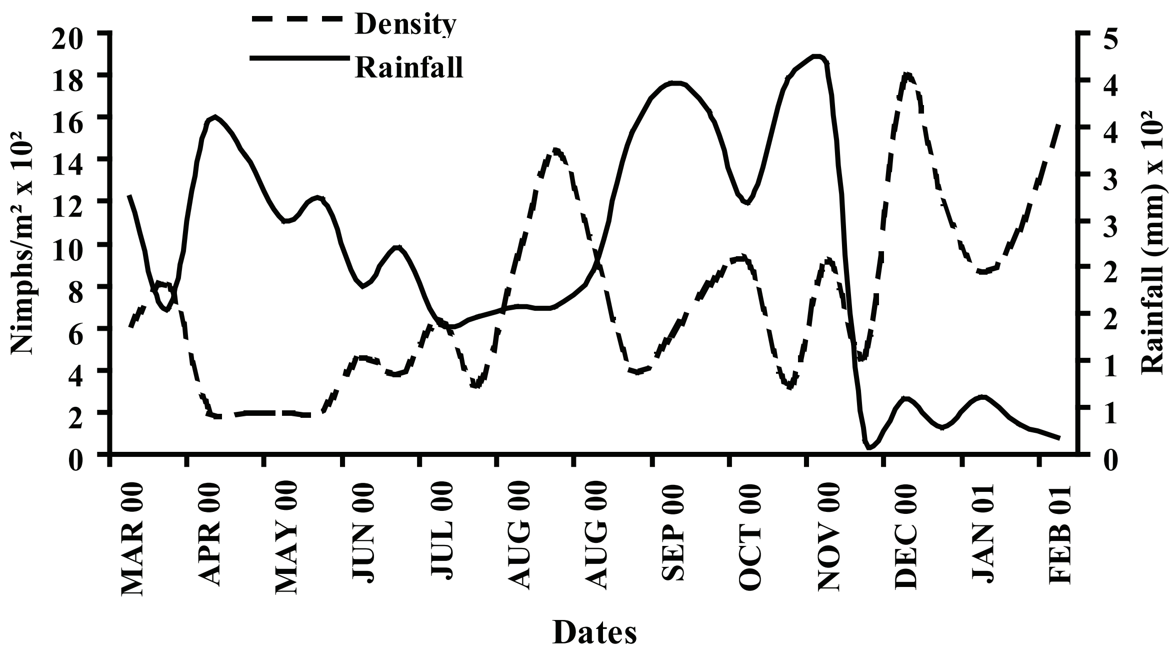

Figure 4. Mayfly nymphs density and accumulated rainfall for the previous thirty days to each sampling date.

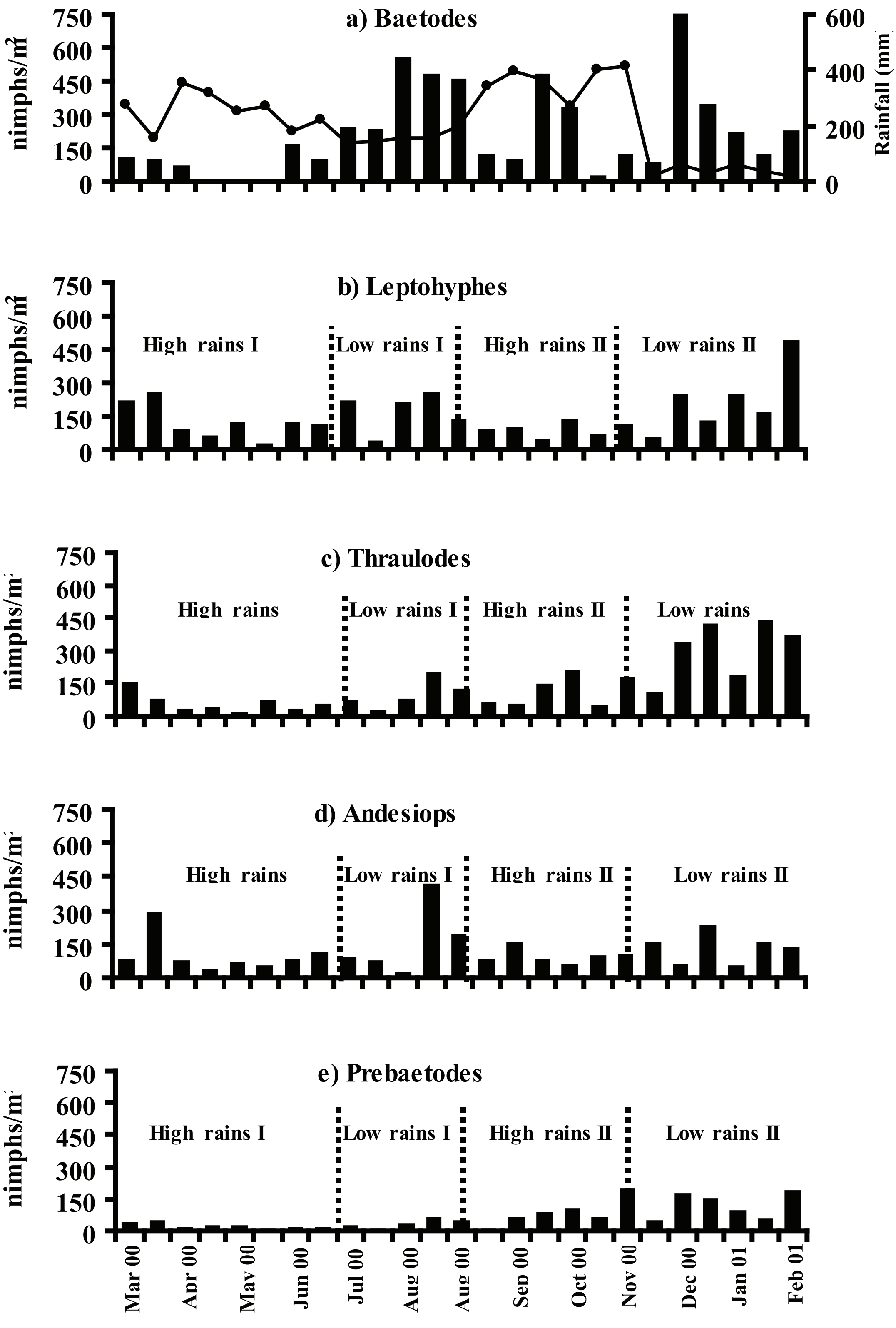

Figure 5. Seasonal variation of rainfall and density of mayflies nymphs with permanent presence.

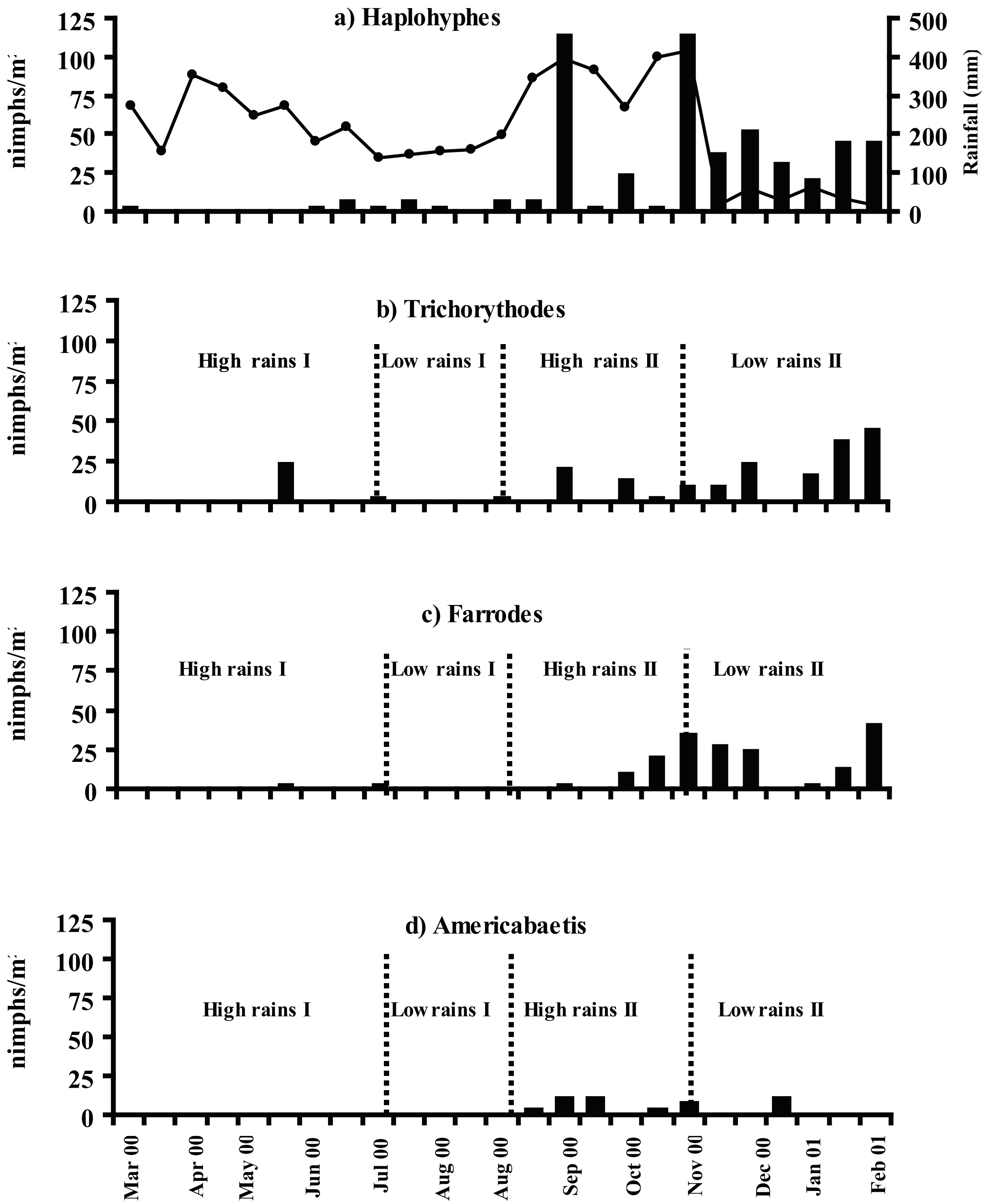

Figure 6. Seasonal variation of rainfall and density of mayflies nymphs with occasional presence.

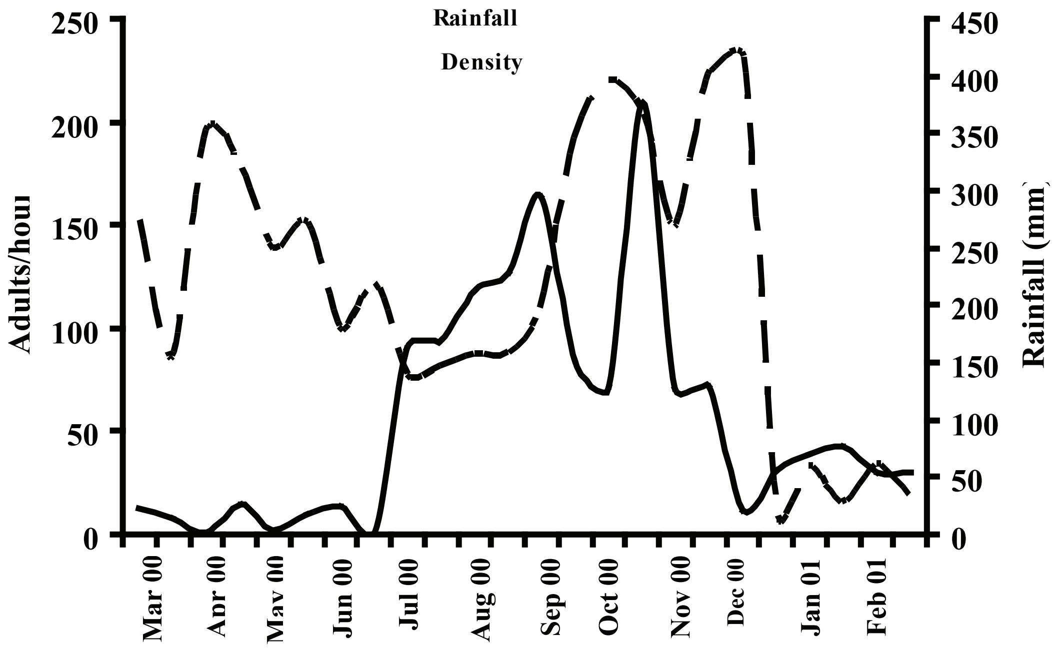

Figure 7. Mayfly adults density and accumulated rainfall 30 days previous to each sampling date.

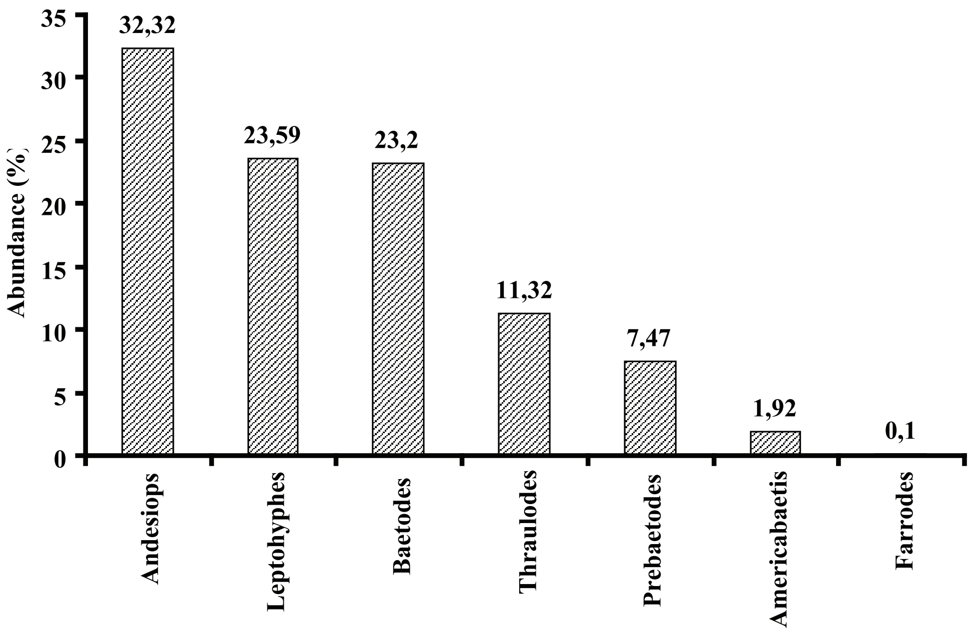

Figure 8. Abundance of mayfly adults genera.

Adult mayfly densities did not show correlation with changes in accumulated rainfall values (r_s =-0.137, p>0.05) (Figure 7). Adult density increased in the period July - September, which corresponds with a period of lower rainfall, and began to decrease in October, as the second high rainfall period began (October- November). During this period, adult densities of all genera diminished, except *Leptohyphes* and *Andesiops*, which account for the increase in total abundance observed by the end of October, increase which also interrupted the decreasing trend in density. The lesser values in adult density correspond to the period March-June of year 2000 (high rainfall) and the period between December 2000 and February 2001 (low rainfall).

The mayfly genera collected as adults were: *Baetodes, Leptohyphes, Thraulodes, Andesiops, Prebaetodes, Americabaetis,* and *Farrodes* (Figure 8). In contrast to nymphs, *Andesiops* was the genus most captured (32,3%), followed by *Leptohyphes* (23.6%), *Baetodes* (23.2%) and *Thraulodes* (11.3%). Only one individual adult *Farrodes* was collected.

DISCUSSION

The number of mayfly genera found in this research was higher than that reported by Chacón and Segnini (1996) in their study of drifting mayfly nymphs made at Río La Mucuy, near its confluence with Río La Picón, ca. 500 m. downstream from our study site.

The authors did not record the presence of *Americabaetis, Andesiops, Prebaetodes, Haplohyphes,* and *Farrodes*. Nevertheless, there was similarity in relative abundance of the genera that were common to both studies. It is likely that the genera *Americabaetis, Andesiops* and *Prebaetodes* were all included by these authors under *Baetis*, a genus now considered to be a generic complex (Dominguez *et al*. 2001).

The comparison between fluctuation of mayfly nymphal densities and seasonal change in rainfall show an association between the two variables. Similar results have been found for the whole of the benthic communities in Andean streams of Ecuador by Jacobsen and Encalada (1998), by Flecker and Feifarek (1994) in two Andean streams located in the same geographical region of this study, and by Rincon and Cressa (2000) in a stream located in North-Eastern Venezuela. Similarly, Maldonado *et al.* (2001) found rainfall to be a determining factor in the temporal fluctuation of density and composition of mayfly communities in four non-Andean streams in central Venezuela.

Being aware of the fact that the effect of rainfall on nymph abundance is not direct but occurs by means of disproportionate and sudden rises of flow (Resh *et al.* 1988, McCabe and Gotelli 2000, Lytle 2001) we expected that changes in this variable would be related to those of nymph density. However, it was not possible to confirm this association by means of simple correlation. This is likely to be in part due to the fact that flow, being measured only once, results from integrating stream velocity, depth, and width of the stream, three measurements with great natural and artificial variability.

Regarding changes in adult mayfly densities, it was noticed that even though not synchronized with rainfall changes, it was indeed affected by rainfall seasonality. In the period running from March through June, a low density of adults was observed coupled with the low density of nymphs. These months were characterized by heavy rainfalls that caused a sweeping of the river bed and a rise in ambient temperature. In the following period, running through the months of July and August, there was a rise in mayfly adults. This period was characterized by diminishing rainfall values, but which did not reach the minimum values recorded for the period of December through February. Additionally, temperature was higher, in at least 3ºC, than the temperature during period of the December through January. In accord with the previous facts, we suggest that increase in adult abundance is favored by the joint action of factors such as a diminished sweeping of the substratum of the river bed by the current due to a lesser amount of rainfall, an increase in ambient temperature, and perhaps a longer photoperiod, which is characteristic of this season.

Adult emergence was still observed during the following period (September-November), but a decreasing trend was obvious which was probably due to a substantial increase in amount of rainfall. The peak in density during the second sampling in the month of October was mainly due to a rise in emergence of the genera *Leptohyphes* and *Andesiops*. Lastly, the second period of December to February was characterized by low rainfall and low ambient temperature. Highest nymph density values observed during the year were recorded during this period, although adult densities were relatively low. These results seem contradictory, since we expected the rise in nymph density observed in Figure 5 would give rise to a concomitant increase in adult densities. A likely explanation is that adult emergence is determined by factors other than rainfall, such as temperature and photoperiod which, in conjunction with rainfall, regulate adult emergence. Evidence from other authors (Lehmkull 1979, Vannote and Sweeney 1980, Ward and Stanford 1982, Sweeney 1984, Newbold et al. 1994, Lytle 2002, Haidekker and Hering, 2008, López-Rodríguez, *et al.* 2008) show that temperature in conjunction with photoperiod control among others, life history patterns, growth, maturation, reproduction, nutrition and species distribution of aquatic insects. Low values of ambient temperature were recorded for the December-January period, especially in what regards to water temperature. According to Sweeney (1984) a decrease of at least one degree in ambient temperature could be enough to delay insect development. Photoperiod acts as a predictable environmental signal that pinpoints the beginning of seasons and daylenght, especially in temperate regions (Sweeney 1984, Lytle 2002). Shortest daylengths in our study in our site coincide with the period December-February, and shortest dayslenghts are related to delayed adult emergence as shown for insects in temperate regions (Sweeney 1984, Power *et al.* 1988, Nylin and Gotthard 1998, Lytle 2002). There is little information available in regard of effects of photoperiod on reproduction and development of tropical aquatic insects.

It is possible that during the dry season the emergency of adults is also affected by predation and competition. Favorable conditions for these biological factors to act as regulators of the population size of adults are produced by the relatively high abundance of nymphs and low water flow.

ACKNOWLEDGMENTS

We thank FONACIT and CDCHT (Projects C-943-99-01-A and C-104-00-01-EM) for partial funding of this research. Hilda Bastardo and Zaida Coché authorized our use of facilities at “Estación Truchícola La Mucuy”. The “Instituto de Investigaciones Agrícolas (INIA) provided rainfall data. Thanks are also due to Ingrit Correa and José Elex Rondón who assisted with field work, Marleny Chacón and for her aid in identifying Mayfly genera.

REFERENCES

Allan D. J. 1995. Stream ecology. Structure and function. Chapman and Hall. London.

Allan, J. D., 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. Annual Review of Ecologyand Systematics 35: 257–284.

Brown B. L. 2007. Habitat heterogeneity and disturbance influence patterns of community temporal variability in a small temperate stream. Hydrobiologia 586:93–106.

Buss, D.F., Baptista, D.F.1, Nessimian, J.L. and M. Egler. 2004. Substrate specificity, environmental degradation and disturbance structuring macroinvertebrate assemblages in neotropical streams Hydrobiologia 518: 179–188.

Chacón M. M. and Segnini S. 1996. Reconocimiento taxonómico de las náyades del Orden Ephemeroptera en la deriva de dos ríos de alta montaña en el Estado Mérida, Venezuela. Boletín de Entomología Venezolana 11:103-122.

Death R. G. and Winterbourn M. J. 1995. Diversity patterns in stream benthic invertebrate communities: the influences of habitat stability. Ecology 76:1446-1460.

Domínguez E., Hubbard M. D., Pescador M. L. and Molineri C. 2001. Capítulo I: Ephemeroptera. In: Fernández H. R. and Domínguez E. (Eds.): Guía para la determinación de los artrópodos bentónicos sudamericanos. Serie: Investigaciones de la Universidad Nacional de Tucumán. Subserie: Ciencias Exactas and Naturales. Tucuman, Argentina. p 17-54.

Effenberger, M., Sailer, G., Townsend, C.R. and C. D. Matthaei. 2006. Local disturbance history and habitat parameters influence the microdistribution of stream invertebrates. Freshwater Biology 51:312–332.

Flecker A. S. and Feifarek B. 1994. Disturbance and temporal variability of invertebrate assemblages in two Andean streams. Freshwater Biology 31:131-142.

Haidekker, A. and D. Hering. 2008. Relationship between benthic insects (Ephemeroptera, Plecoptera, Coleoptera, Trichoptera) and temperature in small and medium-sized streams in Germany: A multivariate study. Aquatic Ecology, 42:463–481

Jacobsen D., Schultz R. and Encalada A. 1997. Structure and diversity of stream invertebrate assemblages: the influence of temperature with altitude and latitude. Freshwater Biology 38:247-261.

Jacobsen D. and Encalada A. 1998. The macroinvertebrate fauna of Ecuadorian highlands streams in the wet and dry season. Archives für Hydrobiologie 142:53-70.

Lehmkuhl D. M. 1979. Environmental Disturbance and Life Histories: Principles and Examples. Journal of Fisheries Research Board Canadian 36:329-34.

Lepori, F. and N. Hjerdt. 2006. Disturbance and Aquatic Biodiversity: Reconciling Contrasting Views. BioScience 56(10):809-818.

López-Rodríguez, M.J., Tierno de Figueroa, J.M. and J. Alba-Tercedor. 2008. Life history and larval feeding of some species of Ephemeroptera and Plecoptera (Insecta) in the Sierra Nevada (Southern Iberian Peninsula). Hydrobiologia, 610(1): 277-295.

Lytle D. A. 2001. Disturbance regimes and life-history evolution. The American Naturalist 157: 525-536.

Lytle D. A. 2002. Flash floods and aquatic insect life-history evolution: evaluation of multiple models. Ecology 83: 370-385.

Maldonado V., Pérez B. and Cressa C. 2001. Seasonal variation of Ephemeroptera in four streams of Guatopo Nacional Park, Venezuela. In: Dominguez E. (Eds.) Trends in Research in Ephemeroptera and Plecoptera. Kluwe Academic / Plenum Publishers. New York.

McCabe D. J. and Gotelli N. J. 2000. Effects of disturbance frequency, intensity, and area on assemblages of stream macroinvertebrates. Oecologia 124:270-279.

McIntosh A. R. and Peckarsky B. L. 1999. Criteria determining behavioral responses to multiple predators by a stream mayfly. Oikos 85:554-564.

Newbold J. D., Sweeney B. W., and Vannote R. L. 1994. A model for seasonal synchrony in stream Mayflies. Journal of North America Benthological Society 13:3-18.

Nylin S. and Gotthard K. 1998. Plasticity in life-history traits. Annuals Review of Entomology 43: 63-83.

Palmer M. A., Allan D. J. and Butman C. A. 1996. Dispersal as a Regional Process Affecting the Local Dynamics of Marine and Stream Benthic Invertebrates. TREE 11:322-26.

Peckarsky B. L. 1980. Predator-prey interactions between stoneflies and mayflies: behavioral observations. Ecology 61. 932-943.

Peckarsky B. L., Cooper S. D. and McIntosh A. R. 1997. Extrapolating from individual behavior to populations and communities in streams. Journal of North America Benthological Society 16: 375-390.

Pickett, S. T. A. and P. S. White, 1985. The ecology of natural disturbance and patch dynamics. Academic press, San Diego, USA, 472 pp.

Power M. E., Stout R. J., Cushing C. E., Harper P. P., Hauer F. R., Matthews W. J., Moyle P. B., Statzner B. and Wais I. R. 1988. Biotic and abiotic controls in river and stream communities. Journal of North America Benthological Society 7:456-479.

Power, M. E., 1992. Habitat heterogeneity and the functional significance of fish in river food webs. Ecology 73:1675–1688.

Resh V. H., Brown A. V.; Covich A. P., Gurtz M. E., Li H. W., Minshall G. W., Reice S. R., Sheldon A. L., Wallace B.J. and Wissmar R. C. 1988. The role of disturbance in stream ecology. Journal of North America Benthological Society 7:433-455.

Rincón J. E. and Cressa C. 2000. Temporal variability of macroinvertebrate assemblages in a neotropical intermittent stream in Northwestern Venezuela. Archives fur Hydrobiologie 148:421-432.

Sousa, W. P., 1984. The role of disturbance in natural communities. Annual Review of Ecology and Systematics 15:353–391.

Stanford J.A. and Ward J.V. 1983 Insects species diversity as a function of environmental variability disturbance in stream systems. In: Barnes J.R. and Minshall G.W (eds). Application and testing of general ecological theory. NY. Plenus Publishers. p 265-278.

Sweeney B. W. 1984. Factors Influencing Life-History Patterns of Aquatic Insects. In: Resh V. H. and Rosenberg D. M. (Eds.): The Ecology of Aquatic Insects. New York:

Praeger Publishers. p 56-100.
Thomson, J. R., P. S. Lake, & B. J. Downes, 2002. The effect of hydrological disturbance on the impact of a benthic invertebrate predator. Ecology 83: 628–642.
Vannote R. L. and Sweeney B. W. 1980. Geographic analysis of thermal Equilibria: a conceptual model for evaluating the effect of natural and modified thermal regimes on aquatic insect communities. The American Naturalist 115:667-95.
Ward J. V. and Stanford J. A. 1982. Thermal responses in the evolutionary ecology of the aquatic insects. Annuals Review of Entomology 27:97-117.
Wiggins G. B. 1998. Larvae of the North American caddisfly genera (Trichoptera). 2nd Edition. University of Toronto Press. USA.

Recibido 3 de febrero de 2010
Aceptado 19 de julio de 2010