Diel variations in macroinvertebrate drift in a mountain stream.

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ABSTRACT: Diel variations in macroinvertebrate drift in a mountain stream. The behavior of aquatic macroinvertebrates that compose diurnal and nocturnal drift was analyzed in a second order stream of the Comechingones mountains, Córdoba, Argentina. Samples were collected with drift nets of 300 microns of mesh size, placed at 1-h intervals every hour in the stream during 57 serial hours. Benthic and marginal community samples were also taken from the studied stretch. Population densities were calculated for each community and for the drift fraction. Descriptive statistics analyses were performed. Taxa were categorized according to their distribution and behavior. The categories resulted from a combination of their presence in benthos, marginal community, diurnal drift and nocturnal drift. From a total of 15 categories, 9 of them described organism behavior and the others were empty sets. For the organisms that exhibited diurnal and nocturnal drift the ratio between densities was calculated. Of 56 studied populations, 37 % were in benthos, marginal community, diurnal drift and nocturnal drift. The majority of populations increased their abundance during the dark phase at a ratio between 1:2 to 1:8. It was observed that benthic organisms presented diurnal and nocturnal drift, while riverside taxa, like some Coleoptera and Heteroptera species, presented heterogeneous behavior patterns.
Key-words: Stream, drift, benthos, macroinvertebrates, Ephemeroptera, Trichoptera.

RESUMO: As variações diárias de deriva nos macroinvertebrados em um riacho de montanha. Foi observado o comportamento dos macroinvertebrados aquáticos que compõem a deriva diurna e a deriva noturna em um riacho de segunda ordem nas montanhas de Comechingones, Córdoba, Argentina. As amostras foram coletadas com redes de deriva de 300 microns de abertura de malha, colocadas em intervalo de uma hora no riacho durante 57 horas consecutivas. Também foram coletadas amostras de bentos e de comunidades marginais. Foram calculadas as densidades da população de acordo com sua distribuição e seu comportamento. Análises estatísticas descritivas foram empregadas. Os taxas foram categorizados segundo sua distribuição e comportamento. As categorias resultaram de uma combinação entre sua presença no bentos, na comunidade marginal, na deriva diurna e deriva noturna. De um total de 15 categorías, 9 descreveram o comportamento dos organismos e as outras eram conjuntos vazios. Foi calculado o coeficiente entre as densidades dos organismos que apresentaram deriva diurna e, noturna. Das 56 populações estudadas, 37% estavam presentes no bentos, na comunidade marginal e na deriva diurna e noturna. Foi observado que a maioria das populações tiveram um aumento na sua abundância durante a fase noturna numa proporção entre 1:2 a 1:8. Também observou-se que os organismos do bentos apresentaram deriva diurna e noturna, enquanto que as taxas marginais, assim como algumas espécies de Coleoptera e Heteroptera, apresentaram padrões heterogeneos de comportamento.
Palavras-chave: Riachos, deriva, macroinvertebrados, bentos, Ephemeroptera, Trichoptera.

Introduction

In spite of the morphological and behavioral adaptations that make possible for fluvial macroinvertebrates to remain in their habitats, they are transported downstream by the flow of the current. This process of drift, which causes are still a topic of debate, is relevant for its ecological and evolutionary meaning. It has been observed that at night the drift displays hourly distribution patterns with nocturnal maximum peaks, indicating that is a chronobiological phenomenon, that obeys as much to internal clocks as to environmental factors (Allan, 1995). Since all the species do not have the same predisposition to drifting (Rader, 1997), the relative abundance of the drifting populations is not always symmetrical with its values in the benthos (Gualdoni & Corigliano, 1999).

The drift composition has been analyzed and their space-temporary distribution patterns in rivers of different order were characterized (Reisen & Prins, 1972; Obi & Conner, 1986). In this research, the drift behavior is studied in a stream of the upper river basin of the Chocancharava river (Córdoba, Argentina). Although the more studied relations are between benthos and drift, since the partition of the habitat in the lotic systems, other communities such as riparian ones or the hyporheos can contribute macroinvertebrates to the drift (Palmer, 1992). The objective of this study is to analyze and to compare the behavior in diurnal and nocturnal drift of the macroinvertebrates coming from different fluvial communities in a small order mountain stream.

Materials and methods

The study was carried out in a stretch of Las Cañitas stream, a second order course of the upper Chocancharava river drainage basin, located in Sierras de los Comechingones, Córdoba, Argentina (32° 53' S, 64° 44' W). The drift fraction samples were collected with a drift net of 300 µm mesh size, placed hourly in the stream during 57 consecutive hours, in a period between 4 and 7 December, 1987. Samples from benthos and marginal community were also taken. The benthos samples were collected with a Surber sampler (area 0.09 m^2, mesh size 300 microns). Seven representative samples of the runs and riffles microhabitats were integrated. The sample of the marginal community were obtained filtering up to 70 liters of water between the macrophytes with a manual net. Both nets were 300 microns mesh size. Parallel to obtaining the samples, the physical and chemical variables were measured with portable electrodes and the hydraulic ones, of the fluvial channel, were measured *in situ* . The photoperiodic variables were compiled from Seiler et al. (1995). In laboratory the total counts of samples were made and the organisms at the most possible finest taxonomic level were classified. For each community and for the drift fraction the population density was calculated. Descriptive statistics were performed and the ratio between diurnal and nocturnal drift was calculated from the sum of the density in photophase and scotophase respectively. Taxa were categorized depending on their drift predisposition, according to Rader (1997), and in 15 categories according to their distribution and behavior. The categories resulted from a combination of their presence in benthos, marginal community, diurnal drift and nocturnal drift (Tab. I).

Table I: Categories of the distribution of the taxa.

Category	Presence			
1	Marginal			
2	Benthos			
3	Diurnal drift			
4	Nocturnal drift			
5	Marginal	Benthos		
6	Marginal	Diurnal drift		
7	Marginal	Nocturnal drift		
8	Benthos	Diurnal drift		
9	Benthos	Nocturnal drift		
10	Nocturnal drift	Diurnal drift		
11	Benthos	Marginal	Diurnal drift	
12	Benthos	Marginal	Nocturnal drift	
13	Marginal	Diurnal drift	Nocturnal drift	
14	Benthos	Diurnal drift	Nocturnal drift	
15	Marginal	Benthos	Diurnal drift	Nocturnal drift

In order to compare the densities between photophase and scotophase, parametric (ANOVA) and nonparametric (Kruskal-Wallis) tests and analyses of groupings of Jaccard and 1 - Pearson r were performed.

Results

The hydraulic, physical and chemical features of the studied stream determine proper conditions of piedmont rhihtron with pH near the neutrality and waters of low conductivity (Tab. II). A total of 56 taxa were determined, 37 % belonged to category 15; 9 categories described the behavior of the organisms and the others were empty sets (Fig. 1).

Table II: Chemical and physical parameters of the study site during the samples taking period (4 -7 December, 1987).

Parameter	X ± SD
Velocity ($m.seg^{-1}$)	0.82 ± 0.09
Depth (m)	0.18 ± 0.1
Width (m)	7.15 ± 0.2
Conductivity at 20°C ($\mu S.cm^{-1}$)	105.3 ± 0.1
Substrate	Gravel and sand
Discharge ($m^3. seg^{-1}$)	1.04 ± 0.6
pH	7.85 ± 0.4
Thermic daily amplitude (°C)	8 (3:00 h) -30 (13:00 h)
Mean temperature (°C)	16.20 ± 6
Photophase (h)	15.2
Scotophase (h)	8.8

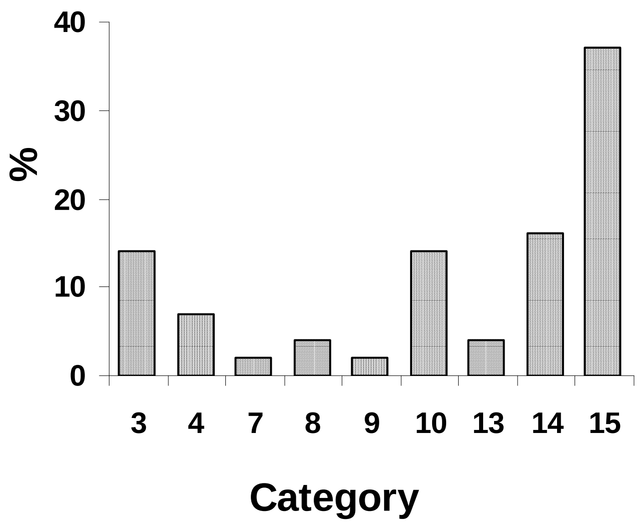

Figure 1: Percentage distribution of taxa, in the determined categories, according to its presence in diurnal drift, nocturnal drift, benthos and marginal community, in the stream Las Cañitas, Córdoba, Argentina.

The taxonomic/specific richness was greater in the nocturnal drift (52 taxa), whereas the diurnal drift was composed by 50 taxa and the marginal community and benthos by 30 and 23 taxa respectively. The results of Jaccard's coefficient, and the grouping by distance method 1-Pearson r demonstrates greater affinity between the diurnal and nocturnal drift assemblages both qualitative and quantitatively (Fig. 2 and Tab. III).

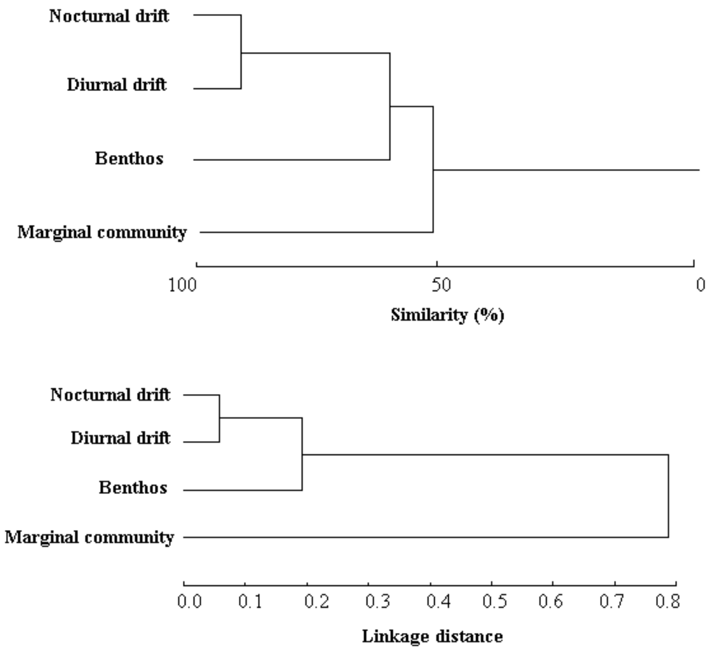

Figure 2: Dendrograms of the analyses of Jaccard similarity clustering (single linkage) and distance 1 - Pearson r (Ward linkage method) among macroinvertebrates assemblages in the stream Las Cañitas, Córdoba, Argentina.

Table III: Coefficient of correlation r , significant to p<0.05, n=57 and coefficient of determination R^2, in percentage, among macroinvertebrates assemblages in the stream Las Cañitas, Córdoba, Argentina.

	Nocturnal drift		**Diurnal drift**		**Benthos**		**Marginal community**	
	r	**R^2**	**r**	**R^2**	**r**	**R^2**	**r**	**R^2**
Nocturnal drift	1							
Diurnal drift	0.94	88	1					
Benthos	0.87	75	0.81	65	1			
Marginal community	0.45	20	0.40	16	0.45	20	1	

Most of the organisms increased in number during the dark phase in a ratio between 1:2 (caddisfly) to 1:8 (mayflies) (Fig. 3). There were significant differences (Kruskal-Wallis and ANOVA, p< 0.05) between the samples of photophase (n=30) and scothophase (n=27) for the following taxa: *Helobdella* sp., Hydracarina, *Hyalella curvispina*, Copepoda, *Baetis* sp., *Camelobaetidius penai*, *Caenis ludrica*, *Leptohyphes* sp., *Tricorythodes popayanicus*, *Farrodes* sp., *Marilia* sp., *Chimarra argentinica*, *Ochrotrichia* sp., *Hydroptila* sp., *Oxyethira* sp., *Smicridea* sp., *Heterelmis* sp., *Liodessus* sp., *Psephenops argentinensis*, *Simulium wolffhuegeli* and Chironomidae (Tab. IV). On the other hand, these taxa, with the exception of *P. argentinensis*, presented significant coefficients of correlation, among indicating similar patterns of density distribution during the 24 hours (Tab. V). In these patterns, a gradual increase starting at 20:00 h until midnight was observed and soon after the density decreased slowly and a secondary peak of smaller intensity was observed in the dawn.

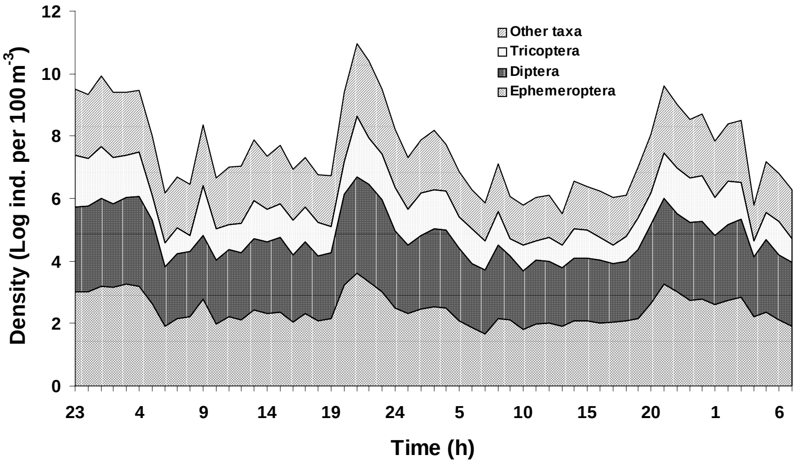

Figure 3: Drift density of the taxocenes in different hours during the studied period (4-7 December, 1987) in the stream Las Cañitas, Córdoba, Argentina.

Table IV: Statistical tests to compare the density of diurnal and nocturnal drift. K-W: Kruskal-Wallis and A: ANOVA; ns: nonsignificant, vs: very significant p<0.01 and s: significant, p<0.05. CG: category according to Tab. I and PD: predisposition to the drift according to Rader (1997): 1 greater PD and 4 smaller PD. Ratio: Diurnal drift: nocturnal drift.

Taxa	KW	A	CG	PD	Ratio	Taxa	KW	A	CG	PD	Ratio
Hydridae	ns	ns	10		1:2	*Marilia* sp	s	s	14	3	1:1
Tricladidae	ns	ns	14	2	1:1	*Chimarra argentinica*	s	vs	14	2	1:4
Gordiidae	ns	ns	14		1:4	*Ochrotrichia* sp.	s	vs	10	3	1:1
Nematoda	ns	ns	15		1:1	*Protoptila* sp.	ns	ns	8	2	1:0
Limneidae	ns	ns	4	4	-	*Hydroptila* sp.	ns	s	10	3	1:4
Planorbidae	ns	ns	14	4	1:1	*Oxyethira* sp.	s	vs	13	3	1:5
Oligochaeta	ns	ns	15	4	1:2	*Nectopsyche* sp.	ns	ns	15	2	1:0
Helobdella sp.	s	vs	15		1:2	*Helicopsyche* sp.	ns	ns	15	2	1:0
Hydracarina	s	vs	15		1:2	*Smicridea* sp.	s	vs	14	2	1:5
Hyalella curvispina	s	vs	15	1	1:5	*Laccophilus* sp.	ns	ns	8		1:0
Copepoda	s	s	15		1:1	*Berosus pallipes*	ns	ns	3		1:1
Ostracoda	ns	ns	15		1:0	*Tropisternus setiger*	ns	ns	7		1:4
Cladocera	ns	ns	14		1:1	*Enochrus (M)* sp.	ns	ns	3		1:1
Baetis sp.1	s	vs	15	1	1:9	*Heterelmis* sp.	s	vs	15	2	1:1
Baetis sp.2	s	s	4	1	-	Elmidae (l)	s	vs	15	2	1:18
Paracloeodes sp.	ns	ns	10	1	1:0	*Liodessus* sp.	s	vs	13		1:17
Baetodes sp.	ns	ns	14	1	1:0	*Helichus cordubensis*	ns	ns	14		1:4
Camelobaetidus penai	s	vs	15	1	1:2	*Psephenops argentinensis*	ns	ns	4	3	1:2
Caenis ludrica	s	vs	15	4	1:18	*Desmopachria* (N) sp.	ns	ns	3		1:0
Leptohyphes sp.	s	vs	15	4	1:4	*Derallus paranensis*	ns	ns	3		1:0
Tricorythodes popayanicus	s	vs	14	4	1:7	*Gymnocthebius* sp.	ns	ns	10		1:0
Farrodes sp.	s	vs	10	2	1:16	*Maruina* sp.	ns	ns	15	3	1:0
Zygoptera	s	vs	15	4	1:5	*Simulium wolffhuegeli* (l)	s	vs	15	1	1:3
Anisoptera	ns	ns	15	4	1:0	*Chironomidae* (l)	s	vs	15	3	1:3
Microvelia hungerfordi	ns	ns	10		1:0						
Buenoa antigone	ns	ns	4		-						
Ambrissus ochraceus	ns	ns	3		1:0						
Nerthra ranina	ns	ns	3		1:0						

Table V: Pearson correlation coefficient among the species/taxa that presented significant differences between day and night. In bold, significant correlations to p<0.05

	8	10	11	12	15	19	20	21	22	23	31	32	33	35	36	39	45	48	49	55	57
8 *Helobdella* sp.	1.00																				
10 *Hydracarina*	**0.37**	1.00																			
11 *H. curvispina*	0.22	**0.49**	1.00																		
12 *Copepoda*	**0.27**	**0.39**	**0.46**	1.00																	
15 *Baetis* sp.	**0.44**	**0.62**	**0.75**	**0.67**	1.00																
19 *C. penai*	**0.37**	**0.62**	**0.70**	**0.71**	**0.93**	1.00															
20 *C. ludrica*	**0.44**	**0.57**	**0.80**	**0.44**	**0.86**	**0.77**	1.00														
21 *Leptohyphes* sp	**0.40**	**0.66**	**0.79**	**0.66**	**0.95**	**0.93**	**0.85**	**1.00**													
22 *T. popayanicus*	**0.41**	**0.62**	**0.76**	**0.55**	**0.90**	**0.85**	**0.92**	**0.90**	**1.00**												
23 *Farrodes* sp.	0.24	**0.35**	**0.64**	**0.46**	**0.68**	**0.71**	**0.68**	**0.72**	**0.70**	1.00											
31 *Marilia* sp.	**0.29**	**0.60**	**0.45**	**0.45**	**0.57**	**0.62**	**0.48**	**0.62**	**0.63**	**0.50**	1.00										
32 *C. argentinica*	**0.28**	**0.41**	**0.80**	**0.45**	**0.70**	**0.68**	**0.77**	**0.76**	**0.71**	**0.68**	**0.49**	1.00									
33 *Ochrotrichia* sp.	**0.30**	0.21	**0.31**	**0.28**	**0.42**	**0.36**	**0.43**	**0.40**	**0.38**	**0.31**	0.24	**0.46**	1.00								
35 *Hydroptila* sp.	**0.31**	0.18	**0.27**	**0.35**	**0.37**	**0.31**	**0.29**	**0.35**	**0.31**	0.16	0.25	**0.36**	**0.27**	1.00							
36 *Oxyethira* sp.	**0.45**	0.14	**0.33**	**0.23**	**0.48**	**0.43**	**0.57**	**0.46**	**0.56**	**0.30**	**0.30**	**0.38**	0.20	**0.23**	1.00						
39 *Smicridea*	0.15	**0.34**	**0.57**	**0.56**	**0.73**	**0.68**	**0.57**	**0.73**	**0.66**	**0.68**	**0.53**	**0.60**	**0.38**	**0.26**	**0.28**	1.00					
45 *Heterelmis* sp.	**0.39**	**0.58**	**0.79**	**0.35**	**0.76**	**0.74**	**0.87**	**0.80**	**0.87**	**0.69**	**0.56**	**0.74**	**0.30**	**0.33**	**0.49**	**0.56**	1.00				
48 *Liodessus* sp	**0.59**	**0.46**	**0.51**	**0.32**	**0.62**	**0.61**	**0.69**	**0.62**	**0.66**	**0.58**	**0.31**	**0.46**	**0.28**	0.11	**0.58**	**0.35**	**0.69**	1.00			
49 *P. argentinensis*	**0.31**	0.21	-0.01	-0.04	0.16	0.16	0.18	0.11	0.15	0.07	0.00	0.00	-0.02	-0.01	0.19	0.04	0.17	**0.41**	1.00		
55 *S. wolfhfuegeli*	**0.35**	**0.65**	**0.79**	**0.56**	**0.84**	**0.83**	**0.81**	**0.90**	**0.85**	**0.61**	**0.53**	**0.69**	0.19	**0.28**	**0.50**	**0.55**	**0.76**	**0.54**	0.11	1.00	
57 *Chironomidae*	**0.41**	**0.69**	**0.72**	**0.62**	**0.89**	**0.89**	**0.80**	**0.90**	**0.89**	**0.60**	**0.64**	**0.70**	**0.38**	**0.39**	**0.42**	**0.71**	**0.81**	**0.56**	0.14	**0.82**	1.00

Discussion

The drift assemblages, both nocturnal and diurnal, presented greater species richness. Some populations with little density like *B. antigone*, *N. ranina*, *M. hungerfordi*, *A. ochraceus* (Heteroptera) and *B. pallipes*, *Enochrus (M.)* sp. (Coleoptera) observed only in downstream transport, suggests that drifts from upstream waters and that a contribution from annexed environments to the main fluvial axis exists (Elliot, 1967; Obi & Conner, 1986). The mesoinvertebrates Oligochaeta, Nematoda, Copepoda, Cladocera and Ostracoda, substantially contribute to increase the diversity and richness of the drifting assemblages. The origin of these taxa can be hiporheic, benthic or planktonic and its entrance in drift, implies important ecological consequences by its trophic and evolutionary function (Palmer, 1992). Diurnal and nocturnal differences were demonstrated, indicating a circadian rhythm in the behavior of some species. The increase is generally greater in Ephemeroptera and Trichoptera than in Diptera (Elliot, 1967; Elliott & Minshall, 1968; Allan, 1995).

In spite of differences among species and localities the nocturnal increase can be from 2 to 25 times greater (Neveu, 1974; Cowell & Carew, 1976; Cellot, 1989; Rieradevall & Prat, 1986; Sagar & Glova, 1992). In the studied stream the diurnal:nocturnal drift ratio, are in agreement with this rank. Also in the plain reach, the densities after the sunset duplicated the diurnal values (Corigliano et al., 1998). The circadian behavior has been explained by an increase of the benthic activity at dusk that determines greater predisposition to be dragged by the current.

This greater night activity of the organisms has been attributed to an avoidance behavior to the predation risk (Flecker, 1992; Forrester, 1994). Nevertheless this hypothesis still remains a debatable topic in discussion because some authors have not found correlation between the nocturnal benthic activity and the drift (Corkum, 1978; Casey, 1987).

In the stream Las Cañitas the macroinvertebrates assemblages of benthos, drift and marginal community are different as far as taxonomic richness and diversity. The drift is the one that exhibits the greater richness. Taxa of constant presence and numerical predominance present significant changes of the density during the nocturnal hours with a periodicity near the 24 hours and with beginning of the activity at sunset. The drift during scotophase showed maximum values of up to 18 times greater, than the diurnal constant drift. Drifting taxa displayed a drift pattern of bigeminus type with a major increase in density starting at 20:00h.

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