ABUNDANCE AND ALTITUDINAL DISTRIBUTION OF EPHEMEROPTERA IN AN ANDEAN-PATAGONEAN RIVER SYSTEM (ARGENTINA)

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ABSTRACT

The distribution patterns of the Ephemeroptera found in a river system of the Patagonian Cordillera (Chubut, Argentina) were analyzed. The system extends along a 1000 m altitudinal gradient and exhibits a marked perturbation in its middle reach owing to the organic sewage discharged by the city of Esquel. Eight ephemeropteran species were identified. Species distributions were determined by altitude, stream order, water temperature, conductivity, total alkalinity, and biochemical oxygen demand. *Metamonius* sp and *Meridialaris chiloeensis* proved to be stenothermic, *M. laminata* characterized the reaches of higher stream order, while *Baetis* sp. and *M. chiloeensis* were the species most affected by organic sewage.

INTRODUCTION

The nymphs of ephemeropterans are one of the most important insect groups within the macrobenthic communities of lotic environments. Most mayfly nymphs consume epilithic algae and fine particulate organic matter (Merritt and Cummins, 1978; Ward, 1992), and also form part of the diet of fishes of temperate zones (Allan, 1995). Thus they are considered one of the chief links within the riverine food web. Ephemeropterans are also among the dominant organisms involved in drift and because of their marked sensitivity to organic pollution, they are widely used as water quality indicators (Rosenberg and Resh, 1993; Allan, 1995).

Investigations of the distribution patterns of ephemeropterans along altitudinal gradients are scarce in Argentina, and have only been carried out in the subtropical zone (Domínguez and Ballesteros Valdez, 1992). Most of the studies on the riverine species of the group in Argentina refer to taxonomic and biogeographical aspects. A few qualitative surveys have dealt

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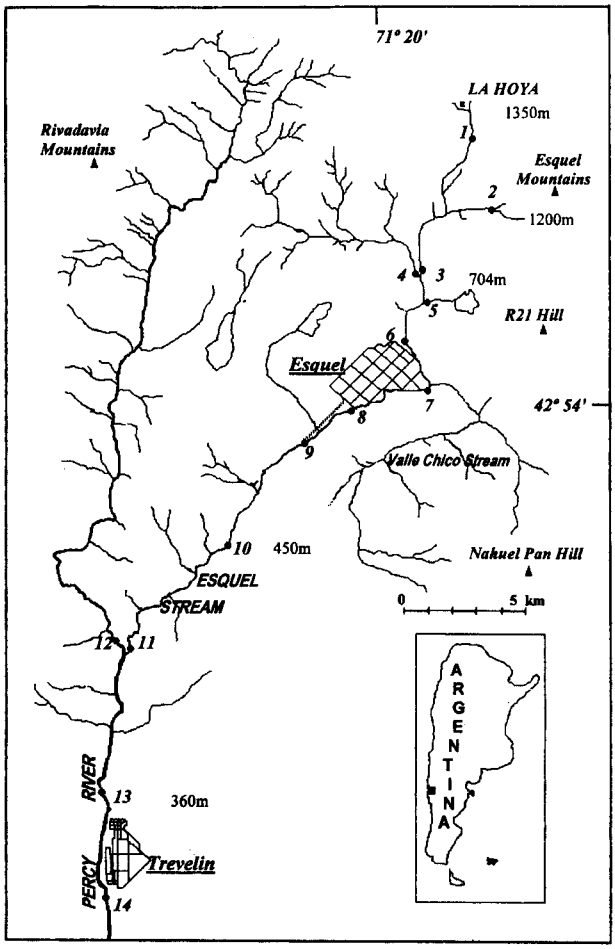

Fig. 1. Location of Esquel-Percy system and study sites. Representative heights are given.

with mountain environments of the Argentinian Patagonia (Wais, 1987, 1990; Wais and Campos, 1984; de Cabo and Wais, 1991). This situation contrasts with the numerous studies on insect zonation along altitudinal gradients carried out in northern hemisphere countries (e.g. Ward, 1986; Ward and Standford, 1991).

The present contribution is aimed at determining the distribution patterns of ephemeropterans along an altitudinal gradient in a lotic system of the Patagonian Cordillera, and exploring the influence of different physical and chemical variables on the distributions of the different species.

STUDY AREA

The system studied is formed by Esquel Stream and Percy River. It is located in the northwestern region of the Province of Chubut, in the Patagonian Cordillera (42°54'S-71°20'W). The system belongs to the catchment area of the rivers Futaleufú-Yelcho, which

drains to the Pacific Ocean through the Yelcho River in Chile. The drainage basin of Esquel Stream extends over 349 km^2, whereas the Percy River basin occupies 1093 km^2. There are two periods of maximum water flow, which coincide with winter precipitation and the spring thaw. The annual mean water flow of Esquel Stream ranges from 1 to 2 $m^3 s^{-1}$ and that of Percy River is about 15 $m^3 s^{-1}$ (EVARSA, 1994).

A remarkable west-east pluviometric gradient characterizes this region, located in the eastern fringe of the Andean cordillera, where the strong westerly winds prevail (Jobbágy *et al.*, 1995). The climate is clearly continental, with an annual mean temperature of 8.6°C, a coldest month mean of 2.98°C, and a warmest month mean of 15.6°C. Some stretches of the system are ice-covered during winter, particularly those in the upper reaches.

The native forest bordering the upper stream course are dominated by *Nothofagus pumilio, Austrocedrus chilensis*, and *Maitenus boaria*. In the lower stretches Salicaceae become more abundant, *Salix nigra* being the predominant species.

The upper course of Esquel Stream receives the very high conductivity waters from the shallow lake Willimanco. The stream then crosses the city of Esquel (25,000 inhabitants) and later joins Percy River, to cross the city of Trevelin (5,000 inhabitants) (Fig. 1). Untreated domestic sewage of the city of Esquel is discharged in the middle section of the stream, producing biological consequences that have been discussed elsewhere (Pizzolón *et al.*, 1992; Miserendino and Pizzolón, 1992; Miserendino, 1995).

Table 1. Physical and chemical features of the sampling sites. K20 (conductivity at 20°C), TA (total alkalinity), DO (dissolved oxygen), %DO (percentage oxygen saturation), BOD (biochemical oxygen demand) (Annual mean values n = 8).

Sampling site	Stream order	Water Depth. max-min cm	Veloc. max-min cm s^{-1}	Water temp °C	pH	K20 µS cm^{-1}	TA meq l^{-1}	DO mg l^{-1}	%DO	BOD_5 mg l^{-1}
1	2	40-15	120-67	3.8	7.5	28	0.45	12.91	116	1.31
2	2	40-11.5	120-43	4.8	7.7	97	1.31	12.94	116	1.35
3	4	40-15	125-68	8.9	7.5	60	0.87	12.08	114	1.11
4	3	10-10	125-36	7.8	7.8	89	1.23	12.74	116	1.84
5	3	10-16	110-50	9.7	8.0	545	2.41	12.10	115	1.79
6	4	10-10	125-60	9.3	7.9	184	1.40	12.73	118	2.11
7	5	60-0	120-60	7.7	7.7	265	1.84	11.09	98	2.79
8	5	40-13	110-60	8	8.1	304	1.89	14.67	136	3.71
9	5	40-15	111-60	8.6	7.9	342	2.49	9.6	78	31.83
10	5	50-35	116-52	10.4	8.1	306	2.23	12.50	116	5.92
11	5	60-26	115-81	8.8	8.0	283	2.18	12.25	110	2.89
12	5	60-39	133-53	7.7	7.8	58	0.85	13.94	121	3.00
13	6	60-39	111-50	6.9	7.8	83	0.97	13.71	116	2.75
14	6	60-40	111-50	7.2	7.9	81	0.96	14.07	120	2.86

METHODS

The study was carried out between November 1990 and October 1991. Samples were taken on a monthly basis during the spring-summer period, and bimonthly during the autumm-winter season. Fourteen monitoring stations, situated between 1350 and 300 m a.s.l., were

established along an extension of 51 km of the river system (Fig. 1). Data on water velocity and depth were recorded during low and high water periods. Substratum characterization as described in Ward (1992). Conductivity, pH, dissolved oxygen, biochemical oxygen demand, and total alkalinity were recorded monthly, following APHA recommendations (1978). Air and water temperature were recorded with a mercury thermometer (-10°C–60°C) (Table 1). The organisms were collected with a modified Surber sampler (Winget and Mangum, 1979), integrating eight subsamples. Samples were fixed *in situ* with 4% formaldehyde, and the specimens subsequently preserved in 70° ethanol. Ephemeropterans were identified according to the keys of Domínguez *et al.* (1994). Density and wet weight biomass per square metre, as well as the relative contributions by each species were calculated for every site and date (Kownacki, 1971). Abundance matrices by species, site, and date were then generated. A non-parametric analysis using Spearman's rank correlation coefficients was performed between species and abiotic variables.

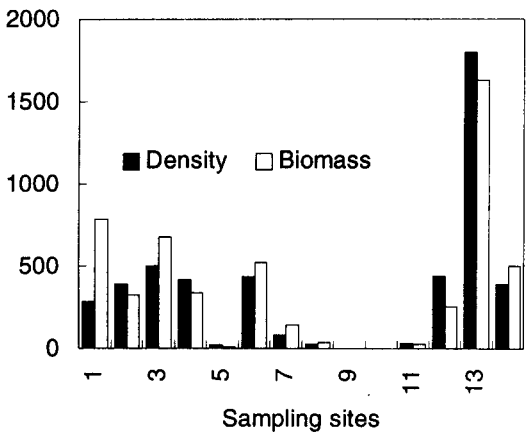

Fig. 2. Annual mean density (ind.m^{-2}) and biomass (mg.m^{-2}) of ephemeropterans in the Esquel-Percy system.

RESULTS

Ephemeropterans were present along the whole system, except for its middle reach. There was a strong decline at station 5, although species richness was high. After an increase in density at station 6, number again decreased from station 7 onwards. No Ephemeroptera were recorded from station 9 and 10 (Table 2, Fig. 2). Annual mean abundance ranged from 0 to 1798 ind.m^{-2} and annual mean wet weight biomass ranged from 0 to 1,627 mg.m^{-2}. Density and biomass both increased towards the lowest zones of the river system. Mayfly abundance was three times greater in station 13 in the Percy river than in the headwater. Station 13 showed two annual maximums of 10,002 and 1,885 ind.m^{-2} and in station 14 one peak of 2,086 ind.m^{-2} was recorded (Fig. 2). Annual mean biomass in station 1 reached 1,000 mg.m^{-2} due to Leptophlebbidae and Siphlonuriidae. In the other sampling sites Leptophlebiidae comprised most biomass values.

Table 2. Abundance ranges of ephemeropterans along the Esquel-Percy system according to Kownacki's Index (Kownacki, 1971). A: dominant (10-100), B: subdominant (1-9.99), C: non-dominant a (0.1-0.99), and D: non-dominant b (0-0.099).

Elevation →	1350	1200		704		600		560		450		400			340
Species: Sampling → ↓ Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Fam. Baetidae															
Baetis sp	A	A	A	A	B	B	C	C			C	B	B	B	
Fam. Caenidae															
Caenis sp					C		C								
Fam. Leptophlebiidae															
Meridialaris laminata					D	D	B	D			D	B	A	A	
Meridialaris diguilina			B	B	D	A	D	C			D	A	D	C	
Meridialaris chiloeensis	A	A	A	A	D	B	C								
Penaphlebia chilensis			D			D		D			B		D		
Fam. Ameletopsiidae															
Chiloporter eatoni		D				D									
Fam. Siphlonuriidae															
Metamonius sp	B	D													
Specific richness	3	4	4	3	5	6	5	4	0	0	4	3	4	3	

Eight species belonging to five families were identified. Only six of them were dominant or subdominant throughout the year (Table 2). In spite of being the most widely distributed taxon, *Baetis* sp was not the most abundant mayfly, *Meridialaris laminata* and *M. diguilina* were more numerous than *Baetis* sp. especially in the lower part of the system. *Meridialaris chiloeensis* was recorded only at the upper six sampling stations, whereas *M. diguilina* appeared in almost all the monitoring stations, except in the headwaters. *M. laminata* had very high densities in the Percy River. *Metamonius* sp, *Penaphlebia chilensis, Caenis* sp, and *Chiloporter eatoni* showed low densities and a restricted distribution.

The distribution of *Baetis* sp, *Meridialaris chiloeensis*, and *Metamonius* sp was positively correlated with altitude and negatively correlated with stream order, total alkalinity, and conductivity. The first two species were also negatively correlated with BOD (Table 3). The distribution of *M. laminata* was negatively correlated with altitude and positively correlated with stream order. All correlations were highly significant, but the distribution of *Caenis* sp was significantly, although weakly correlated with conductivity and total alkalinity.

Concerning seasonal factors, the distribution of *M. chiloeensis* and *Metamonius* sp was negatively correlated with water temperature.

DISCUSSION

Recent studies carried out in Patagonian rithral environments showed that ephemeropterans are among the insect groups with highest densities in the macrobenthic community (Miserendino, 1994; Miserendino and Pizzolón, 1996; Miserendino, 1997). Although well represented in the Esquel-Percy system, mayflies were absent both in polluted reaches and in highly conductive waters. The highest specific richness was recorded in the upper stations, although not in the headwaters. In spite of the high diversity recorded in station 5, densities were very low, probably owing to the high conductivity of the waters flowing in from Willi-

Table 3. Spearman's rank correlation coefficients between ephemeropteran species and the abiotic parameters: K20 (conductivity at 20°C), TA (total alkalinity), DO (dissolved oxygen), %DO (percentage oxygen saturation), BOD (biochemical oxygen demand).

Species	Abiotic parameters								
	Altitude	Stream order	Water temp.	pH	K20	TA	DO	%DO	BOD
Baetis sp.	0.42^{E}	-0.42^{E}	ns	ns	0.53^{E}	-0.52^{E}	ns	0.27^{B}	-0.64^{E}
Caenis sp.	ns	ns	ns	ns	0.27^{B}	0.18^{A}	-0.21^{A}	ns	ns
Meridialaris laminata	-0.57^{E}	0.56^{E}	ns	ns	-0.24^{A}	-0.26^{B}	ns	ns	ns
Meridialaris diguilina	ns	ns	ns	ns	ns	ns	ns	0.28^{B}	ns
Meridialaris chiloeensis	0.74^{E}	-0.69^{E}	-0.33^{C}	ns	-0.42^{E}	-0.36^{C}	ns	ns	-0.40^{D}
Metamonius sp.	0.74^{E}	-0.46^{E}	-0.31^{C}	-0.21^{A}	-0.43^{E}	-0.45^{E}	ns	ns	-0.24^{A}

$^{A} = p < 0.05$ $^{B} = p < 0.005$ $^{C} = p < 0.0005$ $^{D} = p < 0.00005$ $^{E} = p < 0.000005$

manco Lake. Mayflies composition presented similarities with different studies in other basins in Patagonia (Wais, 1990), however a major number of species was recorded in the present work. A previous study has mentioned the record of Heptageniidae in Patagonia (Wais and Campos, 1984); nevertheless this family was not included in the list of Ephemeroptera in Argentina (Domínguez *et al.*, 1994) and was not recorded in the Esquel-Percy system.

There has been a great deal of work on the effects of organic pollution on macroinvertebrates communities and mayflies are a frequently used group to asses organic enrichment (Mason, 1991). Studies carried out in New Zealand showed that certain ephemeropterans are even more sensitive as indicator species than plecopterans, mayflies appear to be useful in the detection of organic pollution as they are one of the first groups to disappear and the last to reappear downstream of an effluent outfall (Winterbourn, 1981). However, several mayflies species have been used as indicators of acid stress, rather than organic pollution in northern Europe, and some studies showed that Ephemeroptera was the most susceptible order of Insecta to acidification (Fjellheim and Raddum, 1990).

The abundance of the ephemeropterans found in this Patagonian system were similar to those reported from comparable environments in the northern hemisphere. Another similarity observed was the increase in density values in rivers of higher stream order (Ward, 1986).

The distribution of the different species along the altitudinal gradient was quite marked in this river system. The restricted presence of the siphlonurid, *Metamonius* sp, in the headwaters was expected, since the species belonging to this genus have been cited as dwellers of cold and well-oxygenated waters (Domínguez *et al.*, 1994). This mayfly nymph found in this system, but never recorded in any other basin of the region, is probably *M. fueguiensis*, the only species of this genus recorded for Argentina. It should be taken into account however, that previous studies did not cover altitudinal ranges of the magnitude herein considered (Miserendino, 1997). On the other hand, the only species that could characterize the lower parts of the system would be *Meridialaris laminata*, which was positively correlated with higher stream order. Succession of species belonging to the same functional group is a strategy that tends to minimize interspecific competition (Vannote *et al.*, 1980). The existence of three congeneric species, *Meridialaris laminata*, *M. chiloeensis*, and *M. diguilina*, showing partial spacial overlap in the different stretches of the system, is probably due to their different ecological requirements. All three species probably belong to the same trophic guild (collectors-scrapers), and as such they all exploit fine particulate organic matter, but in different stretches of the system. A comparative study of Chilean and Argentine basins has associated the density of *Meridialaris* with the relative abundance of detritus; furthermore this was the most represented genus all along the continuum (Wais and

Campos, 1984). The increase of *M. laminata* in Percy River may be attributed to the availability of fine particulate organic matter from the Esquel Stream. Sewage may contribute to develop dense communities of epilithic algae, as has been observed on several occasions in the field throughout the year. These three species of Leptophlebiidae are also most common mayflies in other basins of the Patagonian Cordillera (Miserendino, 1997).

It has been suggested that temperature is one of the main factors determining the distribution patterns of ephemeropterans (Ward and Standford, 1982). In this study, only two species showed clear correlation with water temperature: *Metamonius* sp and *M. chiloeensis*. Correlation analysis suggests that the factors determining ephemeropteran distribution in the Esquel-Percy system were both physical and chemical. Altitude and stream order seem to be important for the abundance of *Baetis* sp, *Meridialaris laminata*, and *M. chiloeensis*. However, all three species were negatively correlated with conductivity. *Baetis* sp, which had the widest distribution among the species recorded, showed a strong negative correlation with biochemical oxygen demand. Although baetid species tolerant of organic enrichment have been recorded in Europe and USA (Hynes, 1974; Rosenberg and Resh, 1993), the representatives of this family in the Esquel-Percy system did not tolerate high or even moderate levels of organic enrichment. Considering their diversity and biological importance, this family urgently require systematic revision in Argentina (Domínguez *et al.*, 1994).

Studies on altitudinal zonation in subtropical rivers (Tucumán, Argentina) show that besides ecological factors, zoogeographic factors may also affect species distribution. Thus, the absence of a taxa in a certain mountain system may allow the expansion of another taxa beyond is expected limits (Domínguez and Ballesteros Valez, 1992).

Previous studies corroborate the absence of ephemeropterans in other rivers of the Patagonian Cordillera subject to organic pollution (Pizzolón *et al.*, 1997). Previous observations together with the present results demostrate mayflies value as a water quality indicator, and can be to recommend for the assessment of the effects of organic sewage in other lotic systems of this region.

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