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Spatial and temporal patterns in the aquatic insect community of a high altitude Andean stream (Mendoza, Argentina)

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Benthic invertebrate communities have been poorly studied in Andean streams apart from the Patagonian region. The primary objective of this work was to analyse the faunal composition at three different altitudes and to observe whether there were differences in aquatic insect community structure at spatial and temporal scales. Physicochemical variables were measured on a monthly basis. Sixteen families were found, the most frequent and abundant taxa being *Massartellopsis* (Ephemeroptera), *Andesiops* (Ephemeroptera), *Metrichia neotropicalis* (Trichoptera), *Cailloma lucidula* (Trichoptera), *Austrelmis* (Coleoptera), and the Chironomidae (Diptera). There was a change in benthic composition associated with land use and with the diminution of water quality from the headwaters to the mouth of the system. The middle reach was a transitional area where headwater species coexisted with species characteristic of the lower reach, with *Austrelmis* and the family Chironomidae being the most abundant elements.

Keywords: mountain stream; arid central Andes; faunal composition; diversity

Introduction

Invertebrates show a high taxonomic and functional diversity and are important components of stream ecosystems (Rosenberg and Resh 1993). Aquatic organisms have specific hydraulic and substrate requirements (Finn and Poff 2005), which often results in a patchy distribution with spatial variability occurring at the habitat level (Pringle et al. 1988; Palmer, O'Keefe and Palmer 1991; Wohl, Wallace and Meyer 1995). It is widely recognised that organisms interact with one another and with many environmental variables to create spatially complex biotic assemblages. In addition, lotic systems often exhibit daily, seasonal and annual periodicity, particularly in regions with highly seasonal climates such as temperate South America. Seasonal variations in factors such as stream hydrology (Bogan and Lytle 2007), temperature (Johnson and Harp 2005) and biotope availability (Armitage and Pardo 1995) will also lead to variation in the distribution and abundance of macroinvertebrates.

Distributional patterns of insects along streams respond to many abiotic factors; current velocity, temperature, chemistry, substrate particle size, and food availability being the most common variables used to explain and predict abundance and distribution of species (Quinn and Hickey 1990; Maiolini and Lencioni 2001; Milner, Taylor and

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Winterbourn 2001) and community structure (Feld and Hering 2007). When these communities are affected by human disturbances (e.g. irrigation, cattle grazing and tourism development), some susceptible species may disappear while other more tolerant species dominate the community (Figueroa, Valdovinos, Araya and Parra 2003). This species turnover may have profound effects on community composition and functionality.

Benthic invertebrate communities in Andean streams have been poorly studied (Modenutti, Balseiro, Diéguez, Queimaliños and Albariño 1998), and no studies have been carried out in central Argentina. Patagonia has recently received more attention, and studies conducted in the area of Esquel (Chubut Province) have demonstrated that aquatic invertebrate richness and abundance are positively related to water temperature and altitude (Miserendino 2001), and also to current velocity and organic matter availability (Velásquez and Miserendino 2003). Also, Patagonian benthic communities contain Gondwanic elements, since they have affinities with New Zealand and Australian communities (Miserendino and Pizzolon 2003), whereas there are no data about the affinities of species inhabiting the streams of central Argentina. In regions adjoining the province of Mendoza, diverse ecological studies are underway, and river quality indices are being developed using macroinvertebrate communities. In the central area of Argentina (Córdoba province) the highest densities were recorded for the most ubiquitous taxa, Ephemeroptera and Chironomidae (Diptera) (Corigliano and Malpassi 1998), which occurred in pools and riffles all year round. In the province of San Luis (adjacent to the Province of Mendoza), orders with the highest specific richness were Ephemeroptera, Trichoptera and Diptera, with chironomids being very abundant and widely distributed over the hills of San Luis (Vallania, Garelis and Gil 2000; Medina and Paggi 2004). Among the Coleoptera, the family Elmidae was an abundant component at some localities in Córdoba, and was present in the province of San Luis (Vallania, Garelis, Trípole and Gil 1996; Mangeaud 1999); whereas in the northwest of Argentina, in the province of Tucumán, Leptophlebiidae and some genera of Plecoptera and Leptoceridae were sensitive to alterations in the physicochemical environmental conditions (Domínguez and Fernández 1998).

In the present study, three sites at different altitudes of the same stream were sampled during five consecutive months in order to assess community structure. This is the first monitoring of this stream using benthic aquatic insects, and it constitutes a basis for comparison with other studies underway in this Andean region. We predict an important species turnover from winter to summer samples, due to an increase in current velocity and sediment movement during late spring and summer, when snowmelt and possibly glacier melt occur in the headwaters. In addition, we expect higher species richness and abundance at mid-altitude because this area is a transitional zone for species from higher and lower reaches. It is also in this sector where the Uspallata village is located, with camping areas, hotels and rural development. We therefore predict that the highest environmental heterogeneity, in agreement with the intermediate-disturbance hypothesis, will co-occur in this area (Ward and Standford 1982a).

Materials and methods

Study area

This study was conducted in the Uspallata stream, a permanent tributary of the Mendoza River. This system is located in the Uspallata valley depression, between the Frontal and Precordillera mountain chains, in the NW of Mendoza Province, Argentina (Figure 1). The local climate is markedly arid with high temperatures and low precipitation. Mean annual rainfall is 136.3 mm, concentrated during the summer (53%) (Carretero 2000).

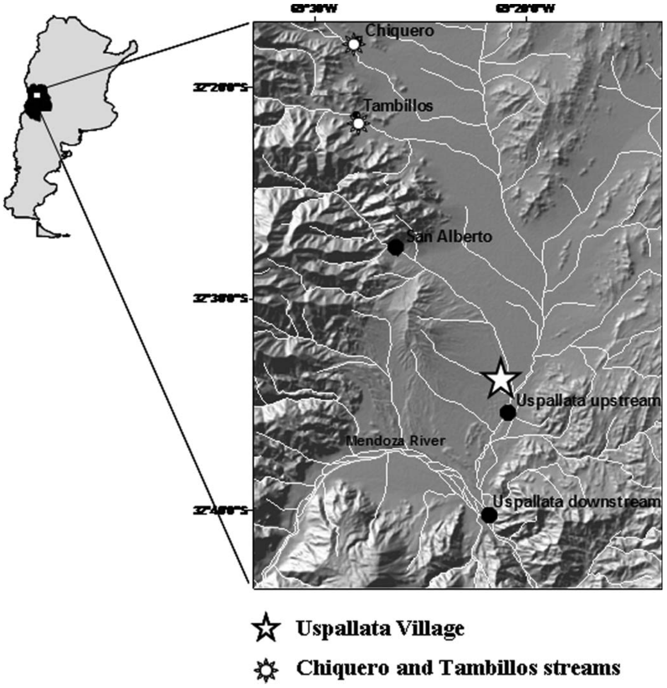

Figure 1. Geographical location of the study sites and configuration of the Uspallata stream and its tributaries. UD = Downstream Uspallata (low reach); UU = Upstream Uspallata (middle reach); SA = San Alberto stream (upper reach); and the complementary streams CH = Chiquero and TA = Tambillos.

The Uspallata valley is dominated by open shrublands of *Larrea divaricata* and *Verbena aspera*, with a high proportion of bare soil. Southward and in lower areas of the valley, these plant communities are replaced by shrublands of *Larrea cuneifolia* (Ambrosetti and Méndez 1986). Several endemisms occur in the area (Carretero 2000). Riparian vegetation is limited to the stream borders and is composed of shrubs and grasses dominated by *Cortaderia rudiuscula* and *Proustia cuneifolia*, with the stream being unshaded for all of its length. During autumn and winter, when the stream water flow is minimal, its waters are highly transparent, but turbidity increases during snowmelt (spring and summer).

Originally, the Uspallata stream collected the waters of three tributary streams: Chiquero, Tambillos and San Alberto. All three streams, which belong to the sub-basin of the Cordillera del Tigre, are fed by both snowmelt and glacier meltwater. San Alberto has the highest percentage of ice mass and perennial snow (glaciers, snowfields, ice-cored moraines, rock glaciers and thermokarst), less in Tambillos and even less in Chiquero (Corte and Espizua 1981). Currently, the Chiquero (mean discharge: 0.503 m^3 s^{-1}) and Tambillos (mean discharge: 1.61 m^3 s^{-1}) streams do not drain their waters into the Uspallata stream because they are used for irrigation, having small dams that regulate their waters before their confluence with the Uspallata stream. San Alberto has become the most important tributary of this stream, since it is the only watercourse that contributes permanent and good quality waters (Armando 1985). The maximum stream water flow of the Uspallata stream is linked to precipitation and mainly to snowmelt during spring and summer along with the contribution of glacier melt, with an approximate total discharge of 2 m^3 s^{-1} (Departamento General de Irrigación 2006).

Sampling

Three sampling sites were established in the river system at different altitudes. San Alberto (hereinafter SA) was the upper stream site of the system (2236 m a.s.l., 32° 27′S, 69° 26′W). The site in the middle section of the river was located near the Uspallata village (1890 m a.s.l., 32° 35′S, 69° 21′W), denoted as "Upstream Uspallata" (UU). The lowermost site was located in the Uspallata stream (1715 m a.s.l., 32° 40′S, 69° 21′W), just before its confluence with the Mendoza River, and denoted as "Downstream Uspallata" (UD) (Figure 1).

During the year 2000, quantitative samples of benthic communities were taken during five consecutive months (August–December), using a Surber sampler (0.09 m^2, 300 μm pore size). At each site, three sampling units were taken and pooled for analysis. At SA and UU, samples were collected monthly from the mid-channel. At UD, instead, samples were collected from the stream banks due to the high discharge observed. No late summer sampling was undertaken for this same reason.

The following physicochemical parameters were measured: pH (microcomputer pH meter Hanna HI 9025), conductivity (multi-range conductivity meter Hanna HI 9033), current speed (m seg^{-1}), water temperature (°C), discharge (m^3 s^{-1}) and transparency (m). Additionally, other environmental features like depth, channel width, stream order, slope, dominant riparian vegetation, width wet of the stream, substrate composition and land use, were taken into consideration to characterise the study sites.

Surface current speed was measured along the mid-channel on five occasions by timing a float (average of five trials) as it moved over a distance of 5 m (Gordon, McMahon and Finlayson 1994). Air and water temperature were measured with a mercury thermometer, and substrate composition was estimated visually as a percentage of boulder, cobble, gravel, pebble and sand (Cummins 1992). Water transparency was measured in the middle of the river using a Secchi disc. Surface current, water transparency and substrate composition were measured by the stream banks at UD. At SA and UU, the wetted width of the streambed was measured across the channel. Discharge data were obtained and calculated by the formula:

$$\begin{aligned} Q = {} & \text{maximum current velocity (m/sec)} \ast \\ & \text{wet width of the streambed (m)} \ast \text{maximum depth (m)}. \end{aligned}$$

The average depth of the reach was calculated over five measurements from a single transverse profile across the channel. Stream order and slope were obtained according to Strahler (1957) and Dangavs (1995), respectively.

In the field, samples were fixed *in situ* with ethanol (96%), and in the laboratory the insects were sorted and identified. As the family Chironomidae showed the highest abundance, 80 larvae were randomly selected and prepared on microscopic slides for estimating the generic composition of this family in the community. All organisms were identified to the lowest possible taxonomic level using regional available keys (Lopretto and Tell 1995; Fernández and Domínguez 2001; Froehlich 2002; Domínguez, Molineri, Pescador, Hubbard and Nieto 2006). Voucher specimens were deposited in the Laboratorio de Entomología collection (IADIZA-CCT Mendoza, CONICET).

Data analysis

The following community attributes were analysed: aquatic insect density (individuals/m^2), taxonomic richness, Shannon and Weaver's diversity index, and Simpson's dominance index. Additionally, the % EPT metric (Ephemeroptera, Plecoptera and Trichoptera abundance/total abundance of each sample), and the abundance of the dominant family relative to the total number of organisms in the sample (% DF) (Rosenberg and Resh 1993) were calculated.

Based on taxonomic composition and density, a cluster analysis (Modified Morisita's Similarity index) was used to assess similarity among sampling sites and dates for the three reaches of the Uspallata stream (SA, UU and UD). The Modified Morisita's Similarity index is a quantitative–qualitative index because it takes into account both species presence–absence and species density for each sample being compared. Detailed procedures for this kind of analysis are given in Magurran (1988) and Moreno (2001).

Total density and taxon density were statistically analysed using contingency tables under a Generalized Linear Models environment. Data expressed as counts such as total abundance (density) and abundance of each family were analysed using logarithmic regression, assuming a Poisson distribution. In the case of data expressed as proportions, such as % EPT and % DF, they were analysed using logistic regression and assuming a binomial distribution. Finally, when data were continuous like diversity, evenness, and dominance, they were analysed by normal regression with a normal distribution (ANOVA analysis). Detailed procedures for these analyses are given in McCullagh and Nelder (1983), Crawley (1993), and McConway, Jones and Taylor (1999).

Principal component analysis (PCA) was undertaken to examine which combinations of physicochemical variables were more predictive in describing each sampled site. All data were normalised. Data on wetted width and discharge were not used in the analysis because they were incomplete for the UD site.

Results

Analysis of physicochemical variables

PCA results (Figure 2) revealed that PC1 accounted for 84% of the variability, whereas PC2 explained 16%. PC1 was defined mostly from pH, altitude, stream order and slope. PC2 was defined mainly from conductivity, current speed and transparency (eigenvectors are given in Table 1). The SA site was associated with high values of pH, current speed, transparency, depth, slope and had the greatest altitude. UD was associated with the highest conductivity values and UU with the highest water temperature values. Stream water flows increased notably towards the summer, when they reached their peak values (1.94 m^3 s^{-1} at SA and 4.27 m^3 s^{-1} at UU), and concurrently water transparency decreased abruptly towards the summer months. Substrate composition was typical of mountain streams: the system's headwaters were characterised by a higher proportion of cobble and pebble and, to a lesser extent, boulder, gravel and sand. UU and UD exhibited dominance of pebble and, in lesser proportions, cobble, gravel and sand. A physicochemical characterisation is given in Table 2.

Aquatic insect distribution and faunal composition

At all three sampling sites (SA, UU and UD) we found a total of 27,627 individuals, belonging to five orders (Table 3). Sixteen taxa were recognised as morphospecies, three of

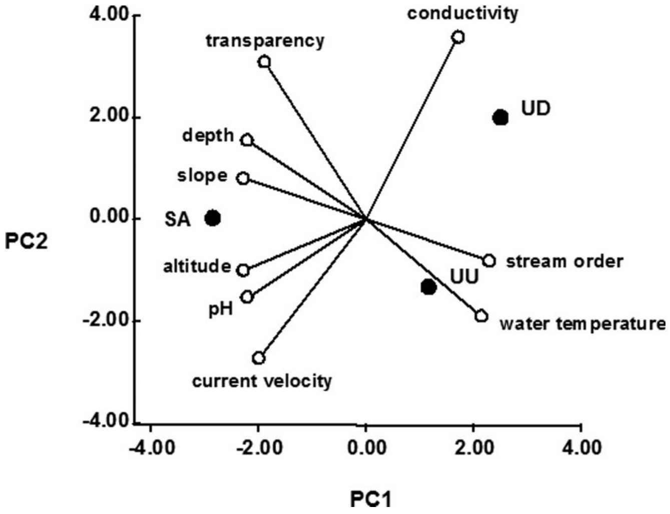

Figure 2. Biplot of sampled sites and physical-chemical variables resulting from a PCA.

Table 1. Eigenvalues for the first (PC1) and second (PC2) principal components.

Variables	PC1	PC2
pH	−0.35	−0.24
Conductivity	0.27	0.56
Water temperature	0.34	−0.30
Current velocity	−0.31	−0.43
Altitude	−0.36	−0.15
Stream order	0.36	−0.13
Transparency	−0.30	0.49
Slope	−0.36	0.13
Depth	−0.35	0.25

them were identified to species level, nine to generic level, whereas the remaining one was assigned to family level (see Appendix). The aquatic insect community was dominated by Ephemeroptera at the SA site, but Diptera and Coleoptera were also important. At UU, Diptera were dominant followed by Coleoptera; and Trichoptera, which had not been detected in the headwaters, were recorded. At UD, Diptera had the same dominance as at UU, but Trichoptera were more abundant than at UU, whereas Coleoptera decreased in abundance compared to UU. Plecoptera was present at UU and UD but their abundance was low (Table 3).

Based on its benthic community composition and density, SA showed low similarity with the upper and lower reaches of the Uspallata stream for all sampling dates (Figure 3). In general, there was low similarity between successive sampling dates for all sampling sites.

Mayflies, *Massartellopsis* and *Andesiops*, were the most abundant and frequent taxa during the study period at SA, diminishing abruptly in the middle (UU) and lower (UD) reaches of the Uspallata stream. In contrast, *Metrichia neotropicalis* (Trichoptera) showed their highest abundance and frequency in the mid and lower sections of the Uspallata

Table 2. Environmental features of the study sites.

	SA	UU	UD
Latitude (S)	32° 27′	32° 35′	32° 40′
Longitude (W)	69° 26′	69° 21′	69° 21′
Altitude (m.a.s.l.)	2236	1890	1715
Stream order	3	4	4
Slope (%)	7	3	3
Mean depth (m)	0.35 (middle channel)	0.17 (middle channel)	0.20 (stream bank)
Mean width wet (m)	7.59	9.54	–
Dominant substrate	cobble-pebble	pebble	pebble
Substrate size (m)	0.032–0.25	0.032–0.064	0.032–0.064
Dominant streamside vegetation	*Cortaderia rudiuscula*	*Cortaderia rudiuscula*	*Cortaderia rudiuscula*
Land use	rural	urban	rural
pH	8.57 (7.2–10.05)	8.44 (7.30–9.80)	8.35 (7.20–9.40)
Conductivity (μS/cm)	237 (180–276)	302 (212–322)	615 (509–682)
Water temperature (°C)	8.90 (1.20–14.30)	14.90 (13.30–16.90)	13.60 (13–15.30)
Current speed (m/sec)	0.82 (0.55–1.13)	0.64 (0.43–1.09)	0.32 (0.29–0.38)
Discharge (m^3/sec)	0.93 (1.94–0.20)	1.70 (4.27–0.70)	–
Transparency (m)	0.25 (0.50–0.02)	0.21 (0.35–0.01)	0.23 (0.32–0.01)
Other observations		great abundance of *Cladophora* sp. (Chlorophytes)	

Mean and range in parenthesis of physicochemical variables: pH, conductivity, water temperature, current speed, discharge and transparency. SA = San Alberto stream; UU = Upstream Uspallata; and UD = Downstream Uspallata.

Table 3. Mean density values of taxa (ind./m^2).

TAXA	SA	UU	UD
PLECOPTERA (%)	0	0.48	1.42
Anacroneuria sp	0 (0)	11 (19.05)	6.60 (14.76)
Claudiperla sp	0 (0)	0 (0)	8.80 (14.34)
EPHEMEROPTERA (%)	73.67	0.58	0.29
Massartellopsis sp	873.40 (639.20)	0 (0)	3.20 (7.15)
Andesiops sp	715.20 (1109.90)	8.80 (12.05)	0 (0)
Leptohyphes eximius	0 (0)	4.40 (9.84)	0 (0)
TRICHOPTERA (%)	0.71	12.34	33.73
Cailloma lucidula	11.00 (19.05)	33.20 (47.08)	31.00 (69.32)
Metrichia neotropicalis	4.40 (9.84)	248.60 (421.40)	335.40 (326.20)
DIPTERA (%)	21.41	51.67	51.38
Chironomidae	359.60 (622.80)	1087 (1197)	504 (498)
Simuliidae	99.80 (93.52)	82 (147)	1 (2.23)
Ceratopogonidae	2.20 (4.92)	0 (0)	0 (0)
Chelifera sp	0 (0)	4.40 (9.84)	48.80 (109.12)
Dolichopodidae	0 (0)	2.20 (4.92)	0 (0)
Ephydridae	0 (0)	4.40 (9.84)	4.40 (9.84)
COLEOPTERA (%)	4.21	34.93	13.18
Austrelmis sp	33 (33.990)	686.40 (805.80)	143.20 (99.40)
Thinobius sp	57.60 (111.27)	108.60 (146.10)	0 (0)
Dytiscidae	0 (0)	2.20 (4.92)	0 (0)

Standard deviation in parenthesis (±SD) and relative abundance by orders (%) at sampling sites during the study period. SA = San Alberto stream; UU = Upstream Uspallata; and UD = Downstream Uspallata.

stream (UU and UD). *Austrelmis* (Coleoptera) was a common taxon in the headwaters and at upstream Uspallata, where it was present in high numbers (Table 3). Dipterans were mainly represented by three subfamilies of Chironomidae. Tanypodinae, with the genus *Pentaneura*, and Podonominae, with the genus *Podonomus*, were restricted to the San Alberto site. The subfamily Chironominae was represented by *Polypedilum*, which was recorded only at the UU and UD sites, whereas *Cricotopus* (Orthocladiinae) was a ubiquitous genus occurring at all sampling sites and dates. The remaining benthic insects had low to moderate frequency and abundance. Simuliidae and *Thinobius* had their highest abundance in the headwaters and at upstream Uspallata. By contrast, *Cailloma lucidula* Ulmer 1909 was the most common species at UU and UD (Table 3). *Claudiperla* and *Anacroneuria* (Plecoptera), *Lepthohyphes eximius* Eaton 1882 (Ephemeroptera), and *Chelifera*, Dolichopodidae and Ephydridae (Diptera) were minor taxa along the sampling period, absent at some sites, and with very low density throughout the sampling period.

Analysis of the community structure

Richness, diversity, dominance, and evenness did not differ among locations or among dates. However, the highest diversity was found for the UU and UD sites (Table 4) and the highest taxon richness for UU (see Appendix). In contrast, the density varied significantly among sites ($\chi^2 = 2563.7$; df = 2; $P < 0.001$) and dates ($\chi^2 = 14046.2$; df = 4; $P < 0.001$), and interaction between sites and dates ($\chi^2 = 5607.2$; df = 8; $P < 0.001$) was also significant, indicating that differences in abundance among sites varied according to sampling date. Date was the most important factor, explaining 63% of the total deviance. UU showed a significantly higher number of individuals than SA and UD ($P < 0.001$). Additionally, the highest density was observed during October ($P < 0.001$) compared to the other sampling dates (Figure 4A).

Chironomidae was the most common and abundant family (Table 3). Chironomid density closely mirrored the abundance pattern recorded for all insect groups. Like total

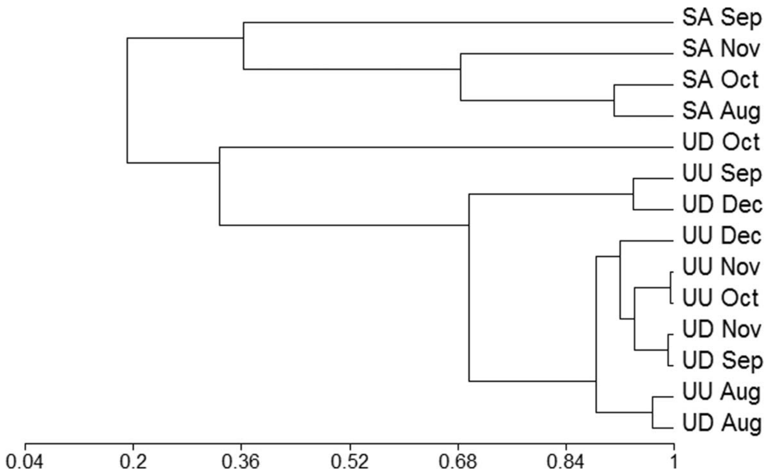

Figure 3. Similarity between sites and dates using the modified Morisita's index. The sampling period extended from August to December 2000. Code sites as in Figure 2 and dates by the prefix (aug = August, sep = September, oct = October, nov = November and dec = December).

Table 4. Shannon diversity index (±SD) at three sampling sites in the Uspallata system during the study period.

Site/Months	SA	UU	UD
August	1.10	0.78	0.67
September	1.00	1.21	0.93
October	0.98	**1.38**	**1.39**
November	0.90	1.27	0.90
December	0	1.36	0.94
Mean values (SD)	**0.79 (0.44)**	**1.20 (0.24)**	**1.03 (0.22)**

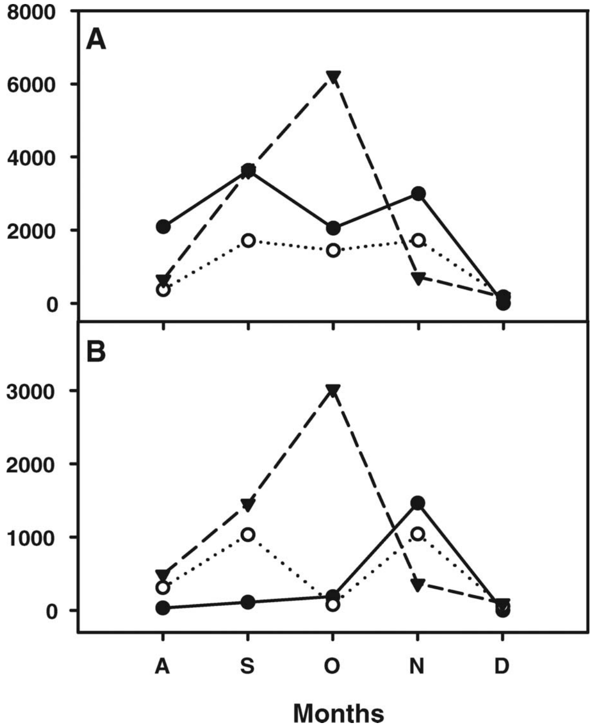

Figure 4. Total density (individuals/m^2) at each site during the study period (A) (August to December 2000). Chironomid density. (B) Filled triangles = UD; open circles = UU; filled circles = SA.

abundance, this family had a peak during October at UU (Figure 4B). The subfamily Orthocladiinae was dominant on all sampling sites, with its relative abundance ranking between 76 and 96%.

M. neotropicalis showed an abundance peak during October at upstream and downstream Uspallata. By contrast, mayflies were clearly dominant in SA, with a replacement of *Massartellopsis* by *Andesiops* during September (Figure 5). Site was the most important factor explaining mayfly variability, accounting for more than 77% and 54% of variability for *Massartellopsis* and *Andesiops*, respectively. *Austrelmis* had its

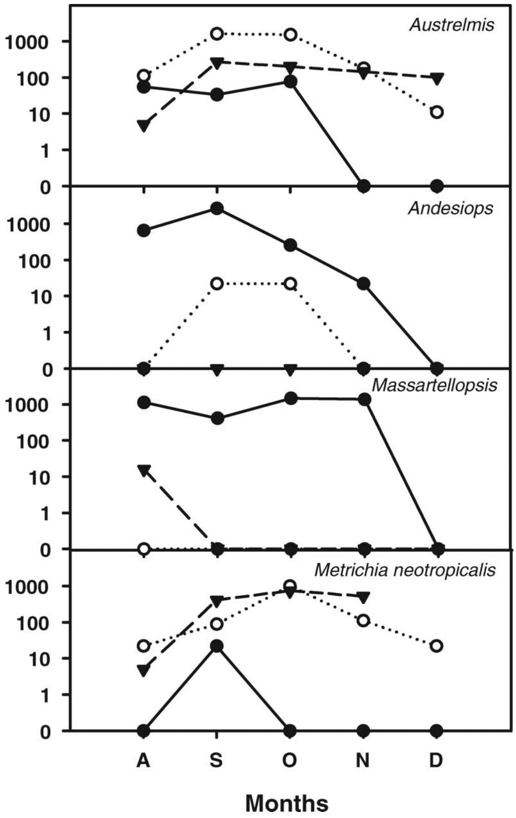

Figure 5. Density of the most common taxa recorded at the three studied sites during the study period (August to December 2000). Filled triangles = UD; open circles = UU; filled circles = SA. Values of *y* axis are in logarithmic scale.

maximum density during September and October at UU, whereas on the other sites its density was similar over the entire sampling period (Figure 5).

Biotic indices

Both biotic indices (% EPT and % DF) showed significant differences among sites and dates, and also interaction among sites and dates was significant ($P < 0.001$ for all cases). The % EPT index was higher at SA during winter and early spring (August to October) compared to the other sites, but it diminished abruptly towards the summer. The values of this index were lower at UU and UD during the whole sampling period, except for UD during October (Figure 6A).

Differences in the % DF index were more marked among dates than among sites. At UU and UD, the values of this index fluctuated between 50 and 80%, whereas at SA they rose during spring to 73%, decreasing to 0% in December (Figure 6B).

Discussion

In our studied system, the community of insects was mainly lithophilous and characteristic of high-gradient mountain streams of cool, turbulent, well-oxygenated waters (Ward 1992).

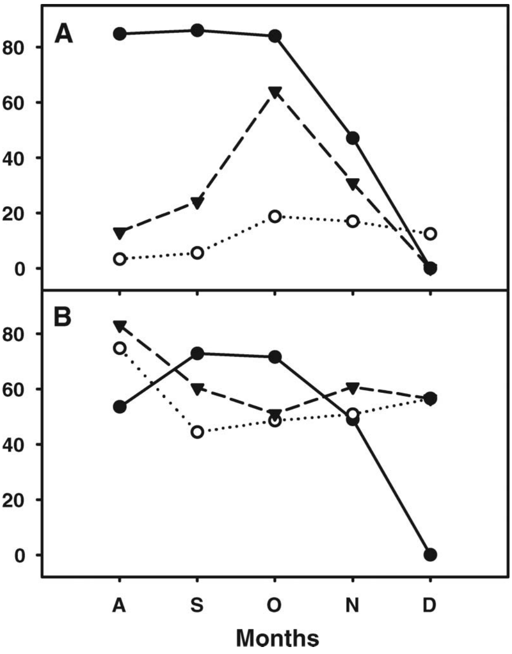

Figure 6. Biotic indices, % EPT (A) and % DF (B), measured at the three studied sites along the study period (August to December 2000). Filled triangles = UD; open circles = UU; filled circles = SA. See text for details of interpretation of these indices.

Diptera and Ephemeroptera comprised 70% of total individuals of the community at all sites, whereas Trichoptera and Coleoptera represented almost the remaining 30%. These results differ from other Andean mountain rivers where aquatic insect communities are composed of more than 60% Plecoptera, Ephemeroptera, Trichoptera and Diptera (Miserendino and Pizzolon 2003). However, there are major affinities with some families found in north and south Patagonia (Wais 1985; Miserendino 2001; Miserendino and Pizzolon 2003), in semi-arid streams in the province of San Luis (Vallania et al. 1996, 2000), in Córdoba streams (central Argentina) (Corigliano, Gualdoni, Oberto and Raffaini 1996), in streams of Tucumán (northern Argentina) (Domínguez and Fernández 1998) and in Patagonian streams on the Chilean side (Figueroa et al. 2003). The following were among the most closely related families: Baetidae, Leptophlebiidae, Gripopterygidae, Hydrobiosidae, Hydropsychidae, Hydroptilidae, Chironomidae, Simuliidae, Tipulidae, Athericidae, Empididae, Muscidae, Ceratopogonidae, Tabanidae, Blephariceridae, Ephydridae and Elmidae. Nevertheless, diversity and taxonomic richness in the Uspallata system was much lower than reported in those studies.

It is worth noting the unsuspected presence of larvae and adults of *Thinobius* (Staphylinidae) in the mid channel at SA and UU but not at UD where samples were taken from the stream bank. Staphylinidae are especially diverse and abundant in terrestrial habitats, but also occur in periaquatic habitats (Newton, Gutiérrez Chacón and Chandler 2005). Many species of *Thinobius* inhabit sandy and gravel banks in and adjacent to streams (Gusarov and Makranczy 2004) or on sandy substrate near mountain streams (Coiffait and Saiz 1968), and both larvae and pupae associated with algae have been found inside small egg-shaped constructions made up of fine sediments (Archangelsky, personal communication). A high abundance of algae was observed at UU, and the density of *Thinobius* on this site was double that at SA (Table 3). They probably lead a semi-aquatic life, inhabit gravel bars and stream banks, and are carried away by the current to mid channel, especially during high flows.

The low taxonomic richness found in the studied Andean system is consistent with that suggested by Coffman (1989) for lotic communities of Chironomidae. He predicted that streams at high altitudes and latitudes have low specific richness, and in those environments the ecological heterogeneity of the stream plays a key role in species richness structuring communities. In addition, in northwestern Mendoza province, a longitudinal and seasonal study (2000–2002) has been carried out on aquatic insect communities (Scheibler 2007). This study revealed very low diversity, with values of the Shannon and Weaver diversity index for both years ranging between 0.21 and 0.60.

The aquatic insect found in the Uspallata stream belongs to the type of Patagonian biota related to the fauna of the southern continents (Australia, New Zealand and Antarctica) (Roig-Juñent, Tognelli and Morrone, in press) and to the Andean region (Patagonian subregion) according to Morrone's (2006) classification. Some rivers of New Zealand have shown a similar composition and richness to those in our study area (Milner et al. 2001), indicating a high affinity in faunal elements like the dominance of Chironomidae and Ephemeroptera. Another similarity was the very low number of invertebrates found when discharge was high, and the fact that the few stoneflies found were confined to the lower reach (UD) of the system. The Mendoza and New Zealand both had cool, cobble substrate, high current velocity and discharge.

All sites and dates sampled at the Uspallata system had a similar number of species and similar diversity values. In spite of this, community composition was very different when taking into account the low similarity shown in the cluster analysis. In addition, we did not find any clear sequence of similarity between different dates at each sampling site. As we used a qualitative–quantitative index (the modified Morisita index), relationships found among clusters are indicative of differences in community composition and/or in the abundance of their species. Indeed, abundance showed major fluctuations between dates and sites, especially during spring for the most frequent taxa (*Massartellopsis*, *Andesiops*, *M. neotropicalis*, *Austrelmis* and Chironomidae).

Abundance was higher at mid altitude (UU), especially during early spring (September and October). Although richness showed no significant difference among locations or among dates it showed a slight tendency to increase in the middle reach (see Appendix). There was also an overall tendency to achieve the highest richness during early spring. These characteristics, along with the above mentioned increase in the stream water flow, were similar to the findings of studies conducted in streams of the European Alps that revealed higher density and richness in spring, late autumn and early winter, indicating that these periods may be more favourable for these organisms than summer (Füreder, Schütz, Wallinger and Burger 2001), when discharge is maximal (Burgherr and Ward 2001). The negative influence of the stream water flow, which in particular affects suspended sediment load, turbidity, hydraulic stress and bedload transport, has been revealed in several studies of mountain rivers (Allan 1995; Brittain and Milner 2001; Milner et al. 2001; Snook and Milner 2001) as well as the increase in taxonomic richness with increasing distance from the glacier snout (Brittain and Milner 2001; Maiolini and Lencioni 2001; Milner et al. 2001). This might be a possible explanation for increased taxonomic richness toward the middle reach of the stream, although we consider that there is another set of abiotic variables that could be involved in the changes in both faunal composition and taxonomic richness, such as land use and water temperature.

The middle reach is an urban site, located in the midst of the Uspallata Village in which the main anthropogenic impact are tourism, agriculture and livestock. Sites like these may exhibit a higher taxonomic diversity and richness, as a result of moderate disturbance

(Ward and Stanford 1982a). These ecological disturbances of natural or anthropogenic origin produce discontinuities in watercourses which can be considered transitional zones (Verneaux, Schmitt, Verneaux and Prouteau 2003, 2004). Studies carried out in other mountain rivers (central Argentina) showed that taxonomic richness was higher in urban than in rural sites (Principe and Corigliano 2006), which is consistent with our findings. Changes in the invertebrate communities of heavily impacted urban streams typically include reductions in diversity and increasing dominance of pollution-tolerant taxa such as oligochaetes and chironomids (Hall, Closs and Riley 2001). In contrast, diversity levels were maintained on all three sampling sites, although the total abundance of the family Chironomidae at the UU site was threefold greater than it was at SA.

Water temperature has also been reported as one of the most important factors in regulating the distribution of many aquatic insects (Ward and Stanford 1982b; Allan 1995). SA showed the lowest mean water temperature and lower richness, whereas UD had the same richness as SA (11 taxa, see Appendix) but similar temperature to UU. Upstream Uspallata can be considered as a transition area between upper and lower segments of the river. Some taxa from SA were almost absent from this site, since their abundance was very low compared to SA (i.e. *Andesiops*, *Massartellopsis* and Simuliidae); other taxa were exclusive to this site (like *L. eximius* and Dolichopodidae), whereas other taxa had their highest abundance in lower segments of the Uspallata River (i.e. *Anacroneuria*, *M. neotropicalis*, *Chelifera* and *Austrelmis*). It is worthwhile to note at UU, Chironomidae and *Austrelmis* dominated, whereas at SA two species of Ephemeroptera occurred in high numbers. Higher numbers of Ephemeroptera at SA may indicate good water quality (Figueroa et al. 2003). In general, mayfly, stonefly, and caddisfly larvae are considered to be sensitive to pollution, and are therefore expected to increase with improving water quality (Rosenberg and Resh 1993). In general, community compositions of even abundance among Ephemeroptera, Plecoptera, Trichoptera and Chironomidae are considered to indicate a good water quality, whereas communities with high numbers and dominance of chironomids indicate environmental stress (Plafkin, Barbour, Porter, Gross and Hughes 1989; Griffith et al. 2005).

In the Uspallata river system, the % EPT was higher at SA from August through October and abruptly decreased towards summer, with a change in community composition related to increased discharge due to snow melt, as well as emergence of certain taxa. However, the % EPT showed the lowest value in upstream Uspallata on most of the sampling dates, indicating that some perturbation was occurring at the mid altitude of the Uspallata River. The disproportionately high numbers of Chironomidae in this reach support this argument. As previously mentioned, the middle segment of the Uspallata stream (UU) is more urbanised. Such land use is associated with deterioration of stream health (Hall et al. 2001). The percentage contribution of the dominant family (% DF) showed a different trend than the % EPT. It was highest at UU and UD in August, when Chironomidae were the dominant taxa, whereas during September and October this index was highest at SA, with *Andesiops* and *Massartellopsis*, respectively, being dominant. Interestingly, these taxa showed a turnover in abundance during the study period, although *Massartellopsis* was replaced by *Andesiops* during September.

Finally, although physicochemical variables varied among sites, they did not show a clear relationship with the community parameters. The upper reach was characterised by colder waters, lower conductivity, higher water velocity and greater transparency than the middle and lower reaches, whereas biotic variables like richness, diversity, and abundance had their maximum at mid altitude. Other environmental variables like organic matter concentration, substrate stability, dissolved oxygen, and food availability were not measured in this study and they may also play an important role in the distribution of aquatic insects.

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Appendix

List of taxa found in the study sites: UD = Downstream Uspallata (low reach); UU = Upstream Uspallata (middle reach); and SA = San Alberto stream (upper reach).

TAXA	SA	UU	UD
PLECOPTERA			
Gripopterygidae			
Claudiperla sp.			X
Perlidae			
Anacroneuria sp.		X	X
EPHEMEROPTERA			
Leptophlebiidae			
Massartellopsis sp.	X		X
Baetidae			
Andesiops sp.	X	X	
Leptohyphidae			
Leptohyphes eximius Eaton 1882		X	
TRICHOPTERA			
Hydrobiosidae			
Cailloma lucidula Ulmer 1909	X	X	X
Hydroptilidae			
Metrichia neotropicalis Schmid 1958	X	X	X
COLEOPTERA			
Elmidae			
Austrelmis sp.	X	X	X
Staphylinidae			
Thinobius sp.	X	X	
Dytiscidae		X	
DIPTERA			
Chironomidae			
Orthocladiinae			
Cricotopus sp.	X	X	X
Tanypodinae			
Pentaneura sp.	X		
Podonominae			
Podonomus sp.	X		
Chironominae			
Polypedilum sp.		X	X
Simuliidae	X	X	X
Ceratopogonidae	X		
Empididae			
Chelifera sp.		X	X
Dolichopodidae		X	
Ephydridae		X	X
Taxa richness	**11**	**14**	**11**