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Altitudinal and temporal variability of four macroinvertebrate communities in Andean streams, Sangay National Park, Ecuador

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Abstract

Studholme AM, Hipo León LF, Ríos Rivera AC, Recalde Moreno CG. 2014. Altitudinal and temporal variability of four macroinvertebrate communities in Andean streams, Sangay National Park, Ecuador. Entomotropica 29(3): 149-158.

Aquatic invertebrates are important indicators of water quality, however we need to better understand natural rhythms in order to adequately interpret macroinvertebrate data. Here we present intra-annual variation of four dominant macroinvertebrate families: Baetidae, Hyalellidae, Elmidae and Chironomidae, in high-altitude streams in central Ecuador. Additional analysis using the Kruskal-Wallis and Mann-Whitney tests show that altitude and therefore, vegetation, are important factors when analyzing macroinvertebrate distribution. We sampled 40 sites between January and December 2011 within Achupallas parish, which lies partially within Sangay National Park. The four aforementioned dominant families were most abundant in February/March and in September, with a pronounced midyear minimum. Life cycles and flow regimes play an important role in forming this pattern, but effects of altitude need be considered.

Additional key words: Baetidae, biomonitoring, Chironomidae, Elmidae, high-altitude streams, Hyalellidae.

Resumen

Studholme AM, Hipo León LF, Ríos Rivera AC, Recalde Moreno CG. 2014. Variabilidad temporal y altitudinal de cuatro comunidades de macroinvertebrados en ríos alto-andinos del Parque Nacional Sangay, Ecuador. Entomotropica 29(3): 149-158.

Invertebrados acuáticos son indicadores importantes de la calidad del agua, sin embargo es necesario comprender los ritmos naturales para interpretar adecuadamente los datos de macroinvertebrados. En este trabajo, se presenta la variabilidad anual de cuatro familias dominantes de macroinvertebrados: Baetidae, Hyalellidae, Elmidae y Chironomidae, en ríos alto-andinos en Ecuador central. Análisis adicional usando pruebas de Kruskal-Wallis y Mann-Whitney, indican que la altitud y por tanto, la vegetación, son factores importantes cuando se analizan la distribución de macroinvertebrados. Entre enero y diciembre de 2011, se tomaron muestras de 40 sitios en la parroquia Achupallas, que se encuentra parcialmente dentro de los límites del Parque Nacional Sangay. Las poblaciones de las cuatro familias dominantes fueron mayores en febrero/marzo y septiembre, con un mínimo pronunciado a mediados del año. Los ciclos de vida e hidrología desempeñan papeles importantes en la formación de este ritmo, pero hay que considerar los efectos de altura.

Palabras clave adicionales: Baetidae, biomonitoreo, Chironomidae, Elmidae, Hyalellidae, ríos alto-andinos.

Introduction

Aquatic macroinvertebrates are often used for in-stream monitoring programs (Carter and Resh 2011). Armitage et al. (1983) demonstrated how macroinvertebrate assemblages could be used to indicate water quality, while other studies have used such assemblages to better understand stream characteristics including stream substrate changes and flow regimes (see Cummins et al. 2005, De Jalon et al. 1994). However, studies in temperate regions have shown that aquatic macroinvertebrate communities vary seasonally, which may influence how data is interpreted (Hynes 1970, Lowell et al. 2002, Robinson et al. 2001). Šporka et al. (2006) recommended sampling streams in Slovakia in early spring and late autumn due to this seasonal variability; autumn was again shown to be an optimal time to sample in Northern Spain (Álvarez-Cabria et al. 2010).

Previous studies in tropical streams have not been as conclusive. Jacobsen (2005) argued that temporal variability is related to disturbance events since intervertebrates are claimed to have asynchronous life cycles, whereas Ríos-Touma et al. (2011) concluded that some synchronicity may exist in streams with strong seasonal changes. Turcotte and Harper (1982) described streams as non-seasonal, while Jacobsen and Encalada (1998) showed an increase in species abundance and richness during the dry season.

High-altitude tropical streams have been considered one of the least studied ecosystems in the world (Ward 1994). Despite studies in the last few decades, our knowledge is still far behind what we know of temperate streams (Jacobsen et al. 2008). Additional studies aimed at understanding natural rhythms would enhance monitoring practices capable of distinguishing between natural conditions and anthropogenic disturbances (Alvial et al. 2012, Moya et al. 2011). In this article we present temporal variability of four common macroinvertebrate families, define if and how they change along an altitudinal and therefore, vegetative gradient, and describe community structure. These results contribute to understanding common aquatic invertebrates and encourage further study in the area.

Materials and Methods

Study area

The study area is located in the Parish Achupallas, Canton Alausí, Chimborazo Province, along the eastern flank of the Andes corridor and includes the upper reaches of Sangay National Park, Ecuador. More than 60 lakes serve as important natural reservoirs and supply more than six major rivers throughout the region. Altitudes range between 2 480 m and 4 080 m and the area is characterized by steep slopes making the soil vulnerable to wind and water erosion.

The landscape is composed of six vegetation formations (Valencia et al. 1999, Table 1), which generally follow an altitudinal gradient. Paramo formations (high-altitude tropical grasslands) comprise the upper regions and cloud forest occurs at the lower altitudes. Montane shrubland/woodland is scattered throughout the middle elevations.

The climate differs across the altitudinal gradient ranging from humid subtropical to alpine (above 3 200 m) to a glacial climate in the highest peaks above 4 000 meters. Sarmiento (1986) used meteorological stations throughout South America and determined that rainfall in the Ecuadorian Andes exhibit a bimodal distribution with a pronounced midyear minimum and 787 mm of annual rainfall. Although 2011 was drier than normal (660 mm), particularly in March, rainfall followed a similar pattern compared to the average of the last 30 years (WMO 1989, Figure 1). In contrast, temperature differences between the highest monthly maximum and the lowest minimum differ by only 3.8 °C, according to data collected and managed by the National

Table 1. Vegetation formations that dominate the study area (Prieto-Albuja and Paucar 2011).

Watershed	Altitudinal Range (m)	Vegetative Formations
Ozogoche	3 760 – 4 080	Herbaceous Paramo Cushion Plant Paramo High Montane Lacustrian Grassland
Juval	2 480 – 3 765	High Montane Evergreen Forest Cloud Forest Herbaceous Paramo
Manzano	2 690 – 4 420	Montane Shrubland/Woodland High Montane Evergreen Forest Herbaceous Paramo Cushion Plant Paramo

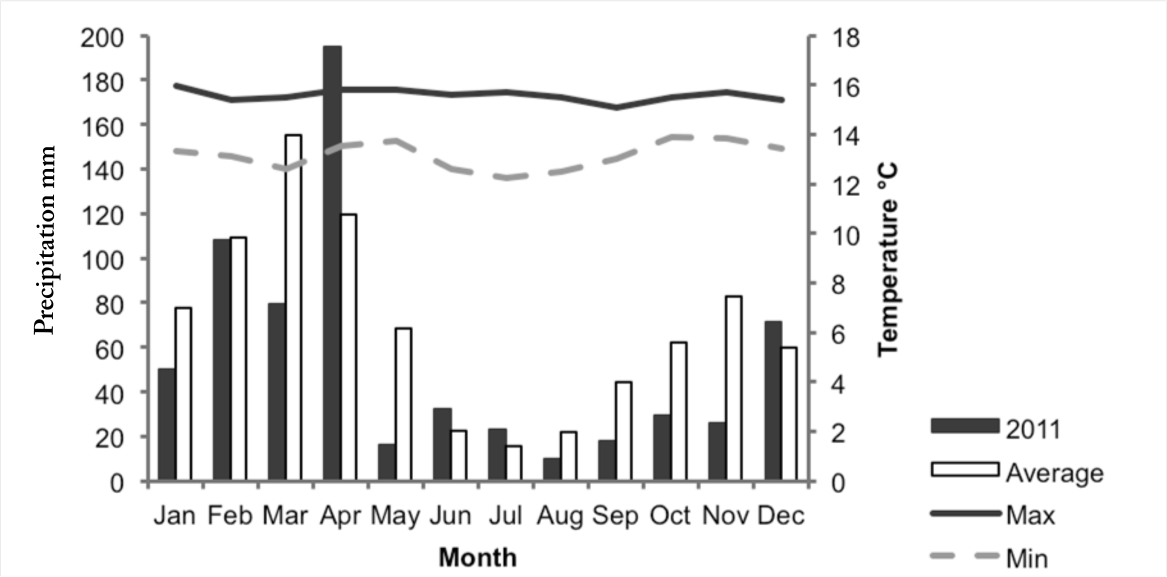

Figure 1. Average monthly precipitation during the last 30 years and the monthly sums of 2011 from the weather station in Achupallas-Chimborazo (3 178 m). Average monthly maximum and minimum temperatures of the last 30 years according to the Guaslán station (2 850 m) (INAMHI, personal communications).

Institute of Meteorology and Hydrology (INAMHI, personal communications). We used data from the stations nearest to the study area that provided the most comprehensive historical data: the Achupallas weather station provided the rainfall data and is located in the north-western limits of the study area, and the Guaslán station provided the temperature data and is located 50 km north of the study area.

Sampling and data analysis

We sampled 40 sites within three watersheds from January to December 2011 (Table 2): 14 sites within the Ozogoche river basin, 19 in Juval and 7 in Manzano (Figure 2). Sites were selected

Table 2. Samples (n) per month in the study area.

Month	(n)
January	9
February	25
March	19
April	54
May	54
June	11
July	23
August	57
September	25
October	32
November	7
December	13

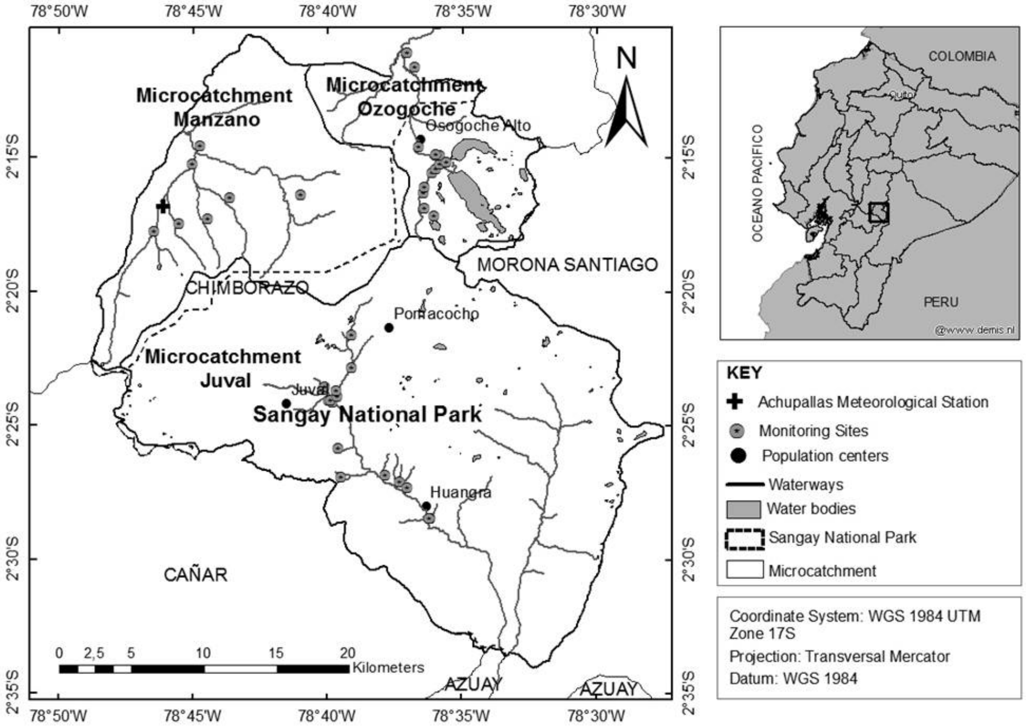

Figure 2. Map of sampling sites in Parish Achupallas within three delineated microcatchments.

based on access, ecosystem characteristics such as vegetation and orientation, elevation and anthropogenic influences. Due to the distance of some sites and additional operational limitations, some sites were not monitored monthly. We selected the data set that contained data for each month. Although it would have been optimal to collect monthly data from each site, we feel this data set is representative of the characteristics found throughout the year within the three basins.

Samples were collected using a D-frame net (32 cm wide and 22 cm deep) with 500 µm mesh size, by agitating the substrate for two minutes in riffles, pools and other habitats present along the stream reach. Leaf litter and large rocks were removed and the sample was preserved in a 1 L container with 70 % alcohol or 10 % formalin (Carrera and Fierro 2001).

In the laboratory we identified specimens to family level using keys in Roldán (1996), and Merritt et al. (1984) except for: Hydrachnidia, Gordioidea, and Oligochaeta, which were not further identified. We determined the four most abundant families – in terms of relative abundance - and analyzed how they varied throughout the year.

We used R 2.15.13 (R Core Team 2013) to graph temporal trends for each macroinvertebrate group. Outliers of more than three standard deviations from the monthly means were removed to avoid their perturbing effects on sample statistics; they were also excluded from subsequent statistical analyses. Then, according to the analysis described below, we divided the Baetidae and Hyalellidae community since results indicated significant differences ($P< 0.001$) along the altitudinal gradient. Temporal trends for Elmidae and Chironomidae were presented as collective abundances of the study area since the tests indicated no significant differences in abundance along the altitudinal gradient.

Previous studies have demonstrated altitudinal changes in macroinvertebrate assemblages and population abundances. Additionally, riparian vegetation has been shown to influence community structure (Dudgeon 1994, Pozo et al. 1997). Since vegetation changed along the altitudinal gradient, the sites were divided into three altitudinal ranges based on their respective riparian vegetation communities: > 3 400 m, herbaceous paramo; 3 400 m to 3 000 m, high montane evergreen forest and < 3000 m, cloud forest. Kruskal-Wallis tests were conducted for the four family groups to determine whether significant ($P < 0.05$) differences existed between communities over the three altitudinal ranges of the sites. Where differences existed, Mann-Whitney tests were used to compare populations between individual ranges. We also calculated Spearman Rank correlation among communities of the four families over all samples and significance level ($P <0.05$) to further look at community structure.

Results and Discussion

During 2011, we sampled on 68 occasions and collected 329 samples from 40 sites. We identified 32 families, of which the most common were: Baetidae, Elmidae, Chironomidae and Hyalellidae; they represented 75 % of the macroinvertebrates identified (Table 3). Elmidae were present most frequently, appearing in 57 % of the samples. Whereas Baetidae were present in 41% of the samples, but were 2.4 times as abundant as Elmidae.

Similarly, Jacobsen and Encalada (1998) studied high Andean rivers in northern Ecuador and showed that Baetidae, Simuliidae, Chironomidae, and Elmidae dominated their samples. Turcotte and Harper (1982) additionally noted Baetidae and Chironomidae dominating streams near Cuenca, Ecuador. The abundance of these families may be attributed to their faster life cycles that enable them to rapidly colonize new areas.

Table 3. Abundance (% total) and frequency of macroinvertebrates identified in the 329 samples collected in 2011.

Class	Order	Family	Abundance (%)	Frequency
Arachnida (Acari)	Trombidiformes (Hydrachnidia)		0.280	23
Bivalvia (Mollusca)	Veneroida	Sphaeriidae	1.536	48
Gastropoda (Mollusca)	Lymnaeoidea	Lymnaeidae	0.380	20
	Planorboidea	Planorbidae	0.009	1
Gordioidea (Nematamorpha)			0.660	15
Hirudinea (subclase)	Rhynchobdellida	Glossiphoniidae	0.090	7
Insecta	Coleoptera	Elmidae	11.006	189
		Psephenidae	0.009	1
		Scirtidae	0.497	25
	Diptera	Blepharoceridae	0.208	6
		Ceratopogonidae	1.798	72
		Chironomidae	20.439	186
		Empididae	0.108	7
		Muscidae	0.343	19
		Psychodidae	0.117	6
		Simuliidae	1.301	51
		Tabanidae	0.072	1
		Tipulidae	1.608	50
	Ephemeroptera	Baetidae	26.475	136
		Leptophlebiidae	0.018	1
	Odonata	Aeshnidae	0.036	2
		Libellulidae	0.027	3
	Plecoptera	Perlidae	2.187	39
	Trichoptera	Calamoceratidae	0.027	2
		Hydrobiosidae	0.127	8
		Hydropsychidae	0.777	26
		Leptoceridae	7.843	178
		Odontoceridae	0.081	4
		Philophotamilidae	0.361	16
Malacostraca (Crustacea)	Amphipoda	Hyalellidae	17.123	174
Oligochaeta (subclase)	Haplotaxida		2.919	72
Turbellaria	Tricladida	Planaridae	1.536	50

Kruskal-Wallis tests indicated significant ($P < 0.05$) differences for Baetidae and Hyalellidae communities among the three altitudinal groups. No significant ($P < 0.05$) differences in abundance were found for Chironomidae or Elmidae communities. We further compared Baetidae and Hyalellidae between the individual ranges using Mann-Whitney tests. For Baetidae, no significant ($P < 0.05$) differences existed between > 3 400 and 3 000 - 3 400 m, but were significantly ($P < 0.001$) less at 3 000 – 3 400 than < 3000 m. In contrast, differences were significantly ($P = 0.001$) greater in > 3 400 m than 3 000 – 3 400 m for Hyalellidae, but no significant ($P < 0.05$) difference existed between 3 000 – 3 400m and < 3 000 m.

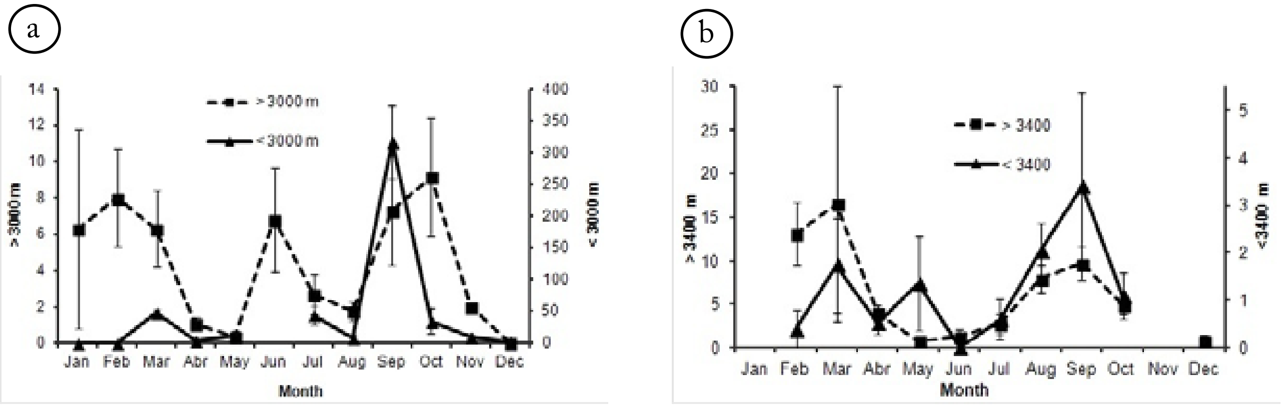

Figure 3. Abundance per month +/- SE throughout 2011 for Baetidae (a) and Hyalellidae (b).

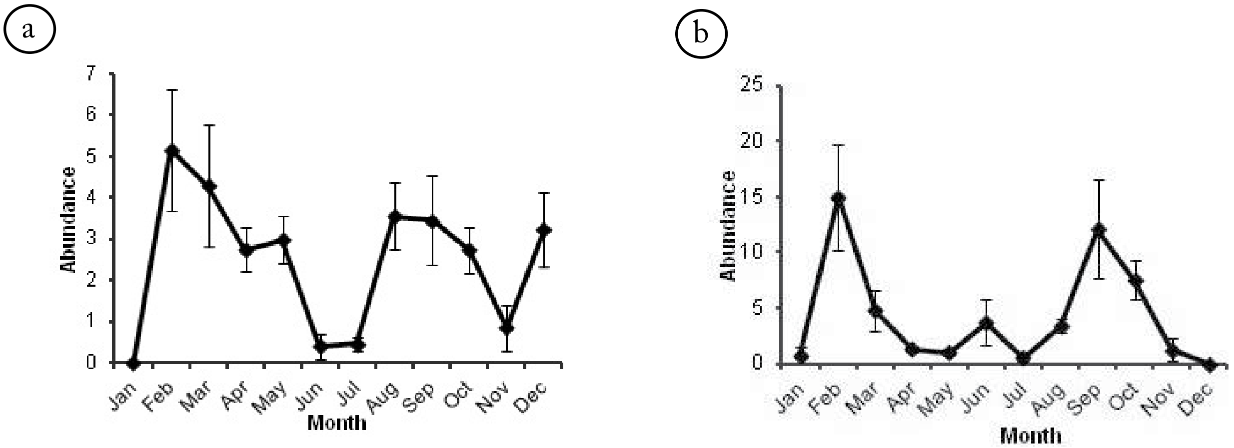

Figure 4. Abundance +/- SE of Elmidae (a) and Chironomidae (b) for each month.

As a result of the Mann-Whitney tests, we divided the Baetidae into two groups: > 3 000 m and < 3 000 m and divided the Hyalellidae into > 3 400 and < 3 400 m. The communities showed contrasting differences between elevations. Baetidae showed two different patterns between the elevation groups (Figure 3a). We saw more variability in the peaks and troughs at high elevations (> 3 000 m), whereas the peak amplitudes were greater at lower elevations (< 3 000 m). The September peak resulted from only sampling two sites, which accounted for 50 % of the total Baetidae sampled within this altitude group. Conversely, Hyalellidae at > 3 400 m were 500 % more abundant than < 3 400 m (Figure 3b).

In terms of monthly average abundance, we observed two coincident annual peaks occurring in February or March and again in September with a mid-year minimum (Figure 3 and 4). All community groups exhibited higher abundances during September. High standard errors were seen in January for Baetidae populations (> 3 000 m) due to the uneven abundance distribution

Table 4. Spearman Rank correlation (rho) matrix with corresponding p-values for each of the four dominant families with outliers removed of three standard deviations.

		Chironomidae	Elmidae	Hyalellidae > 3 400	Hyalellidae < 3 400
Elmidae	rho	0.216			
	P	<0.001			
Hyalellidae > 3 400	rho	0.423	-0.083		
	P	<0.001	0.243		
Hyalellidae < 3 400	rho	0.263	0.314	*	
	P	0.003	<0.001	*	
Baetidae > 3 000	rho	0.340	0.211	0.220	0.039
	P	<0.001	<0.001	0.002	0.722
Baetidae < 3 000	rho	0.271	0.336	*	0.416
	P	0.081	0.029	*	0.006

among the samples: five samples had no specimens and one sample had 39 individuals. The high standard error seen during March for Hyalellidae at > 3 400 m resulted from the small sampling size: we only sampled two sites which yielded a broad range. Discarding 10 -15 outliers of three or more standard deviations from each family retained the overall bimodal pattern, but reduced the peak amplitudes and standard error in each population group.

Peaks occurred in February or March during the rainy season, which contrasts with other studies that have demonstrated higher densities and richness during the dry season (Jacobsen and Encalada 1998, Mesa et al. 2009, Ríos-Touma et al. 2011). Turcotte and Harper (1982) showed that macroinvertebrate densities are generally inversely correlated with precipitation. However, they noted a peak in February after months of heavy rain, which is inconsistent with their overall findings, suggesting an additional biological factor.

Epele et al. (2011) determined that some species of Ephemeroptera have univoltine synchronous lifecycles while most species are multivoltine. The September peak seen at altitudes < 3 000 m for Baetidae populations needs to be addressed with higher sample sizes as this may represent a biological event. Conversely, some species of Elmidae have an extended larval stage lasting up to four years (Steedman and Anderson 1985). This suggests that greater taxonomic resolution and more information on life cycles are needed to resolve this apparent paradox.

A similar bimodal pattern occurred in Hyalellidae, which indicates the influence of other environmental factors (Dutra et al. 2007). As seen in previous studies, flood events redistribute fauna along the stream bed (Davis and Barmuta 1989, Jacobsen 2005, Statzner et al. 1988, Townsend and Hildrew 1976). Jacobsen et al. (1997) concluded that sizable knowledge gaps still need to be addressed regarding how variability in flow patterns affect regional richness; this would require localized meteorological and stream information that is currently unavailable.

Despite having coincident peaks, communities of the four families correlated dissimilarly (Table 4). Chironomidae correlated with each community group except Baetidae at altitudes < 3 000 m. Elmidae positively correlated with Hyalellidae at altitudes < 3 400 m, but not with Baetidae at lower altitudes or Hyalellidae at higher altitudes. Baetidae > 3 000 m correlated with Hyalellidae > 3 400 m but not with Hyalellidae < 3 400 m, while Baetidae < 3 000 m correlated with Hyalellidae < 3 400 m indicating a change in community structure occurring within 3 400 m and 3 000 m.

Conclusion

After analyzing the temporal variability of the four families we conclude that the pattern is partly intrinsic and partly caused by disturbance events prompted by rainfall patterns. Clearly, life cycle studies of common taxa in the region would be beneficial along with comprehensive rainfall and stream flow data. Additionally, it is necessary to address the effects of altitude, and therefore, vegetation cover when interpreting information on temporal variability from high altitude streams. Our results suggest a shift in community structure between 3 000 and 3 400 m in tropical montane streams. Further studies would elucidate factors controlling this transition.

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