



Short communication

Stream zoobenthos under extreme conditions in the high Andean plateau of Argentina (South America)

Alberto Rodrigues Capítulo^{a,b,c}, Fernando Spaccesi^{a,b,c}, Laura Armendáriz^{a,b,*}^a Instituto de Limnología "Dr. Raúl A. Ringuelet" (ILPLA-CONICET La Plata-UNLP), Boulevard 120 e/ 61 y 62, S/N, La Plata, Argentina^b Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Argentina^c Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

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ABSTRACT

The Puna de Atacama plateau (South America; altitude 3800 m)—with its endorheic basins and containing one of the principal deposits of lithium worldwide—is one of the most extensive tablelands on the planet. Information on the invertebrates of those internal catchment areas, however, is scarce and fragmentary. We describe here for the first time the structure and composition of the invertebrate assemblage of the Olaroz Salar (Argentina), analyze the spatial-temporal changes, and examine the relationships between the organisms and their environment. Samplings of the sediment and aquatic vegetation were carried out in three affluent streams of the salar during the wet season and the limnologic variables were measured in situ. Of the 26 taxa collected, the most highly represented were Nematoda, Harpacticoida, *Paranais litoralis*, and *Limnocythere* sp.; while *Heterocypris incongruens* registered the highest abundance. The total density was correlated with the sediment organic matter and differed among the streams. The abundance, richness, and diversity decreased upon proximity to the salar. The invertebrate assemblage varied spatially, with the conductivity gradient being one of the principal conditions influencing the distribution. Redundancy-detrended analysis demonstrated that within these environments the conductivity, amount of organic matter, and vegetation were the principal determinants of benthic development. The insularity, fragility, and low resilience of these wetlands necessitate adequate administration policies for their long-term management and utilization, particularly in view of the growing demand for mineral exploitation in the region.

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1. Introduction

Although most of the rainfall over land is drained to the oceans, some water bodies are located in closed hydrologic systems—endorheic watersheds—where the topography prevents access to the seas (Demergasso et al., 2003; Reutter et al., 2006). The inland water flows into those arid basins, where evaporation occurs, leaving a high concentration of minerals and other products of erosion from the input water flow. In South America these dry lakes are referred to as salars. Their surface is typically dry, hard, and rough during the dry season, but wet and very soft in the rainy period, usually encrusted with precipitated salts. Since the main drainage systems of these temporary water bodies are primarily produced through evaporation and seepage, salars are generally

more sensitive to the input of environmental pollutants and therefore more vulnerable to contamination than water bodies that have access to oceans (Gajardo et al., 2006). Salars are of limnological interest due to their insularity, specialized fauna and many endemic species (Moreno et al., 2010; Scheihing et al., 2010). Moreover, these systems exhibit a high fragility and low resilience to anthropogenic influences (Locascio de Mitrovich et al., 2005). However, to date, ecological information on them is still scarce.

As human development has expanded into previously uninhabited desert areas, many of these river systems have been altered (Gajardo et al., 2006; Wolfram et al., 1999), e.g. for mining. The Andean salt-lake sediments are very rich in lithium, and 49% of the world's lithium reserves are present there (Alonso, 2006; Gruber et al., 2011). Because of the increasing demand for lithium-based rechargeable batteries used in electronic products and hybrid motor vehicles, these ecosystems are attracting an increasing economic interest. In view of their high vulnerability to anthropic impact, these salars are in need of careful attention and responsible management. Therefore, the objectives of the present study were:

* Corresponding author. Instituto de Limnología, Laboratorio Bentos, Boulevard 120 e/62 y 64 S/N, La Plata, Argentina. Tel.: +54 0221 4222775.

E-mail address: larmendariz@ilpla.edu.ar (L. Armendáriz).

a) to conduct for the first time a characterization of the habitats in the three streams feeding the Salar de Olaroz, through a description of the structure and composition of the benthic communities; b) to analyze the spatial–temporal changes in the invertebrate assemblages; and c) to examine the relationship between the environmental conditions and the zoobenthos distribution, identifying which variables may be influential or causal.

2. Sampling design, data collection and statistic analysis

The Puna de Atacama is a high-altitude plain in western-central South America and one of the most extensive high plateaus in the world. Its altitude is ca. 3800 m (Alonso, 2006; Demergasso et al., 2003; Márquez-García et al., 2009), and is one of the driest regions on the entire planet. The climate is dry and cold with average temperatures that fluctuate daily to a greater extent (up to 30 °C) than the seasonal variation. The rainfall shows a high degree of seasonality (200 mm–800 mm) with a rainy period (November–April) and a dry one (June–October). The vegetation consists of scattered grasses, low shrubs, and thorny species such as the cactus pad. In the higher-altitude areas the vegetation is sparse, adapted to radiation, dryness, severe cold, and winds (Cabrera and Willink, 1973). The salars therein are considered to be the remnants of the extensive lakes that once occupied the high plains. The Salar de Olaroz is fed by three meandering streams: Rosario, Esquina Cerro Overo, and Archibarca. In the alluvial valley of Rosario Stream vegetation is scarce, while the terrain's perimeter has a xerophilous-type flora. Neither floating nor submerged aquatic vegetation is present, so the arrival of light and the radiation levels are maximal. The Esquina Cerro Overo Stream has ferruginous sediments; its floodplain contains grassy vegetation with little development of aquatic and riparian plants. The Archibarca Stream has soft, greenish sediments along with the greatest vegetation cover which at some sites spreads over the entire channel. The floodplain consists of a low-lying ground vegetation cover characteristic of saline soils.

The study area was located in a hardly accessible region characterized by a pronounced seasonal climate, so during the wet period two samplings were performed (December 2009 and April 2010) at six sites located in the three streams: Esquina Cerro Overo (S1–S2; upstream–downstream, respectively); Archibarca (S3–S4, upstream–downstream); and Rosario (S5–S6, upstream–downstream). The samples were removed with an Ekman grab (100 cm², triplicate per site) in combination with a sieve (500 µm pore size) for the collection of organisms on the vegetation, and fixed in situ (5% v/v formaldehyde). The percent vegetation cover and perimetral vegetation were estimated from a mapping of the site, performing transects in a stretch of 50 m (Cortezzi et al., 2013; Elosegui and Sabater, 2009). The following limnologic variables were measured: pH, conductivity, temperature, and dissolved-oxygen concentration.

In the laboratory, the samples were washed on a sieve (500 µm pore size) and stained with erythrosin B. The invertebrates were separated and their abundances expressed as ind./m². A fraction of the sediment (50 g wet weight) was separated for determination of the percent organic matter by the method of calcination (LOI) (APHA, 1998). For the identification of the organisms we followed Brinkhurst and Marchese (1992), Fernández and Domínguez (2001), Lopretto and Tell (1995), and Merritt et al. (2008).

The benthic community was analyzed on the basis of the average abundance of individuals and the season of the year along with ecologic parameters: Shannon diversity (H' ; in Shannon and Wiener, 1963), equitability (J), and taxonomic richness (S; i.e., the number of taxa). To establish the differences existing between these ecologic parameters vs.: (1) the streams under study, (2) the two seasons, and (3) the distance of the sites from the salar, the Kruskal Wallis test ($p < 0.05$; STATISTICA 8.0, StatSoft, Inc., 1984–2007) was used. To analyze the relationship between the percent organic matter and the average abundance of organisms, the Spearman rank correlation (r_s) was employed.

The detrended correspondence analysis (DCA) by segments was applied to determine if the taxa responded linearly to the gradients or passed through an optimum with respect to the environmental variables. Since the maximal length of the resulting gradient was 2.42; a linear response was assumed and the redundancy detrended analysis (RDA) applied in order to explore the relationship between the taxa studied and the environmental variables registered at the sampling sites (Ter Braak and Verdonschot, 1995). The data for the abundance were transformed to $\ln(x + 1)$, and all the taxa were included. The physicochemical variables were standardized and included in the analysis, except for the temperature. The inflation values of the data were <7 . The statistical significance of all the canonical axes was evaluated by the Monte-Carlo test (499 permutations, reduced model, $p < 0.05$). The first two ordination axes were selected for graphical representation.

3. Results and discussion

The water temperature and the conductivity showed wide variations; in contrast, the variations in the pH and dissolved-oxygen concentration were somewhat narrower, being the pH neutral, slightly tending to alkaline (Table 1). Sites S2, S3, and S5 contained aquatic vegetation represented by *Potamogeton conf. pusillus* and *Salicornia* sp. Their distribution was irregular and coverage varied considerably among the sampling sites. The invertebrates were represented by 26 taxa from 7 phyla. Nematoda, Harpacticoida, the ostracod *Limnocythere* sp., and the oligochaete *Paranais litoralis* were the most highly represented, with each one attaining a frequency of occurrence above 45%. Nematoda and Harpacticoida were registered at all the sites and on every sampling occasion except at S6 during the autumn and at S4 during the spring. Total abundance varied between 366,000 ind./m² (S2, in autumn) and

Table 1

Mean and standard deviation values of the physicochemical variables registered at the sampling sites in proximity to the Salar de Olaroz, Jujuy (Argentina). S1 (23°34'54" S, 66°40'24" W), and S2 (23°34'35" S, 66°40'41" W) were placed at Esquina Cerro Overo Stream; S3 (23°37'23" S, 66°51'15" W), and S4 (23°37'34" S, 66°50'40" W) at Archibarca Stream; while S5 (23°07'45" S, 66°39'45" W), and S6 (23°10'24" S, 66°37'15" W) at Rosario Stream. Sp (Spring), Au (Autumn), masl = meters above sea level.

Sites	Height (masl)	Width (m)	pH		Conductivity (µs/cm)		Dissolved oxygen (mg/l)		Temperature (°C)	
			Sp	Au	Sp	Au	Sp	Au	Sp	Au
S1	3915	3.1	7.38 (±0.13)	8.05 (±0.39)	2913.3 (±80.5)	3016.7 (±182.1)	5.8 (±0.33)	12.57 (±1.06)	20.53 (±2.57)	13.1 (±0.2)
S2	3913	3.8	8.68 (±0.02)	8.89 (±0.10)	3340 (±206)	4183.3 (±52.5)	5.2 (±0.14)	9.27 (±0.39)	27.33 (±0.46)	7.9 (±0.3)
S3	4033	0.7–4	7.18 (±0.12)	7.80 (±0.05)	2203.3 (±103.3)	1768 (±87.9)	6.52 (±0.10)	12.73 (±1.16)	16.67 (±0.46)	10.7 (±0.1)
S4	4021	0.19	7.99 (±0.03)	8.57 (±0.34)	2030 (±81.6)	2070.7 (±126.8)	6.24 (±0.19)	14.2 (±0.94)	13.30 (±0.16)	5.9 (±0.1)
S5	4009	3.9–4.5	8.48 (±0.04)	8.77 (±0.08)	9543.3 (±395)	5450 (±43.2)	7.35 (±0.25)	16.23 (±1.48)	22.30 (±0.62)	2.5 (±0.3)
S6	3976	5.6	8.47 (±0.01)	8.81 (±0.05)	11643.3 (±449.4)	5353.3 (±804)	7.39 (±0.46)	12.30 (±2.06)	28.53 (±0.25)	7.4 (±0.9)

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