Volumen 38, Nº 4. Páginas 77-81
IDESIA (Chile) Diciembre, 2020

First observations of invertebrate communities in Lauca bogs (18º S, Arica and Parinacota región, Chile)

Primeras observaciones de comunidades de invertebrados en el bofedal de Lauca (18º S, Región de Arica y Parinacota, Chile)

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ABSTRACT

Freshwaters of northern Chilean Andes include many bogs referred to as "bofedales". streams of snowmelt origin feed these endorheic water bodies at high altitudes in the arid mountain zone. Our knowledge of biota inhabiting these ecosystems is rudimentary due to their marked geographical isolation. The present study aimed to do a first characterization of invertebrate fauna in Lauca bogs (18º S, Chile) using species co-occurrence and niche sharing null models. The results revealed the presence of non-structured patterns in co-occurrence considering each site as well as all sites that is most probably an effect of the presence of many repeated species in the studied sites.

In contrast, niche sharing results revealed the existence of niche sharing due to interspecific competition at each site and among all sites. The results agree with similar observations for Chilean inland waters at lower altitudes. The present study contributes to understanding the invertebrate community patterns of Lauca bogs and gives the basis for more complex ecological studies.

Keywords: bogs, insect, crustacea, null models.

RESUMEN

Las aguas dulces del norte de los Andes chilenos incluyen muchos pantanos llamados "bofedales". Estos cuerpos de agua endorreicos son alimentados por corrientes de origen de deshielo a gran altura en zonas áridas de montaña. Nuestro conocimiento de la biota que habita en estos ecosistemas es rudimentario debido a su marcado aislamiento geográfico. El objetivo del presente estudio fue hacer una primera caracterización de la fauna de invertebrados en los pantanos de Lauca (18 º S, Chile) utilizando modelos de nulo de coexistencia de especies y nichos compartidos. Los resultados revelaron la presencia de patrones no estructurados en co-ocurrencia considerando cada sitio, así como todos los sitios, lo que probablemente sea un efecto de la presencia de muchas especies repetidas en los sitios estudiados. Mientras que los resultados de compartir nicho revelaron la existencia de compartir nicho debido a la competencia interespecífica en cada sitio y entre todos los sitios. Los resultados concuerdan con observaciones similares para las aguas continentales chilenas en altitudes más bajas. El presente estudio contribuye a la comprensión de los patrones comunitarios de invertebrados de los pantanos de Lauca y proporciona la base para estudios ecológicos más complejos.

Palabras clave: *pantanos, insectos, crustáceos, modelos nulos.*

Introduction

The Northern Chilean inland water bodies are characterized by the presence of saline lakes, intermittent streams, and small bogs located mainly at high altitudes in the Andes (Niemeyer and Cereceda, 1984). There are few limnological studies of these systems due to their geographical isolation and challenging logistical conditions for sampling (De los Ríos-Escalante, 2010). Few available biological studies reported low species numbers, mainly due to the sites' high mineral contents due to high evaporation rates in an arid climate and high mineral contents of the respective

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Fecha de Recepción: 11 de junio, 2020.
Fecha de Aceptación: 27 de septiembre, 2020.

surrounding basins (De los Ríos-Escalante, 2010; Muñoz-Pedreros *et al*., 2013, 2015, 2019). Similar results have been reported in large rivers in this zone, such as Loa river (De los Ríos *et al*., 2010). Fish presence is restricted to shallow water bodies with low mineral contents in their waters (Guzmán and Sielfield, 2009; Marquez-García *et al*., 2009; Riveros *et al*., 2012).

Aquatic invertebrate fauna that can be found in this zone is an important component in the diet of native fishes such as the *Orestias* genus (Guzmán and Sielfield, 2009; Marquez-García *et al*., 2009; Riveros *et al*., 2012) as well as introduced brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) (Silva *et al*., 1985). Nevertheless, up to date, our knowledge of aquatic invertebrate communities inhabiting northern Chilean bog ecosystems is rudimentary.

One of the important basins of northern Chile is the Lauca basin, located in the Andes at 18ºS. this basin accommodates numerous high altitude bogs and a river system (Niemeyer and Cereceda, 1984). Endemic fish species that are presently considered endangered have been reported in this zone and are presently under protection by the law (Habit *et al*., 2006). This study aims at the first assessment of invertebrate communities in the Lauca basin.

Material and methods

Studied sites are located in northern Chile in the Andes 18º S (Figure 1). Zooplankton samples were collected between the 18th and 20th of September 2018. Zooplankton samples were collected by filtering 60 L of water collected just below the surface using a 5 L bucket through a 45 µm mesh net (De los Ríos-Escalante *et al*., 2015). Material retained on the net was preserved in 60-70% ethanol (final concentration). González (2003) and Domínguez and Fernandez (2009) keys were used to identify Specimens in the laboratory.

Obtained data were analysed in the following steps. First, UPGMA cluster analyses were applied using the neighbour-joining method to determine potential similarities between sites based on species associations using the R package Phangorn (Schliep, 2011). Subsequently, a species presence/absence matrix was constructed, with the species in rows and the sites in columns. Then, a Checkerboard score ("C-score") was calculated. This score is a quantitative index of occurrence that measures the extent to which species co-occur less frequently than expected by chance (Gotelli, 2000). A community is structured by competition when the C-score is significantly larger than expected by chance (Gotelli, 2000; Tiho and Josens, 2007). Subsequently, co-occurrence patterns were compared with null expectations via simulation using statistical null models Fixed-Fixed (Gotelli and Ellison, 2013). In these models, the row and column sums of the matrix are preserved. Thus, each random community contains the same number of species as the original community (fixed column), and each species occurs with the same frequency as in the original community (fixed row). The null model analyses were performed using the software R (R Development Core Team, 2009) and the package EcosimR (Gotelli and Ellison, 2013).

For niche overlap analysis, an individual matrix was built in which rows and columns represented species and sites, respectively. This matrix was used to test if the niche overlap significantly differed from the corresponding value under the null hypothesis (random assemblage). These analyses were applied to data from the second field period and were based on the Pianka index. The models show the probability of niche sharing compared to the niche overlap of theoretically simulated communities (Gotelli and Ellison, 2013). The niche amplitude can be retained or reshuffled; when it is retained it preserves each species' specialization, whereas when it is reshuffled it uses a wide utilization gradient of specialization.

Furthermore, zero participation in the observed matrix can be maintained or omitted. In the present study, we used the RA3 algorithm (Gotelli and Ellison, 2013). This algorithm retains the amplitude and reshuffles the zero conditions (Gotelli and Ellison, 2013). This null model analysis was carried out using the software R (R Development Core Team, 2009) and the package EcosimR (Gotelli and Ellison, 2013).

Finally, diversity analyses (θ estimator and Preston analysis) were applied to test the unified neutral theory of biodiversity (UNTB; Hubbell, 2001) using the R package UNTB (Hankin, 2018). Furthermore, to assess community properties (Gotelli and Chao, 2013), data were ordered to make species richness estimations considering the presence-absence data using Chao 2, Jackknife 1, and Jackknife 2 indexes with "R" software (R Development Core Team, 2009) and the R package fossil (Vavrek, 2011).

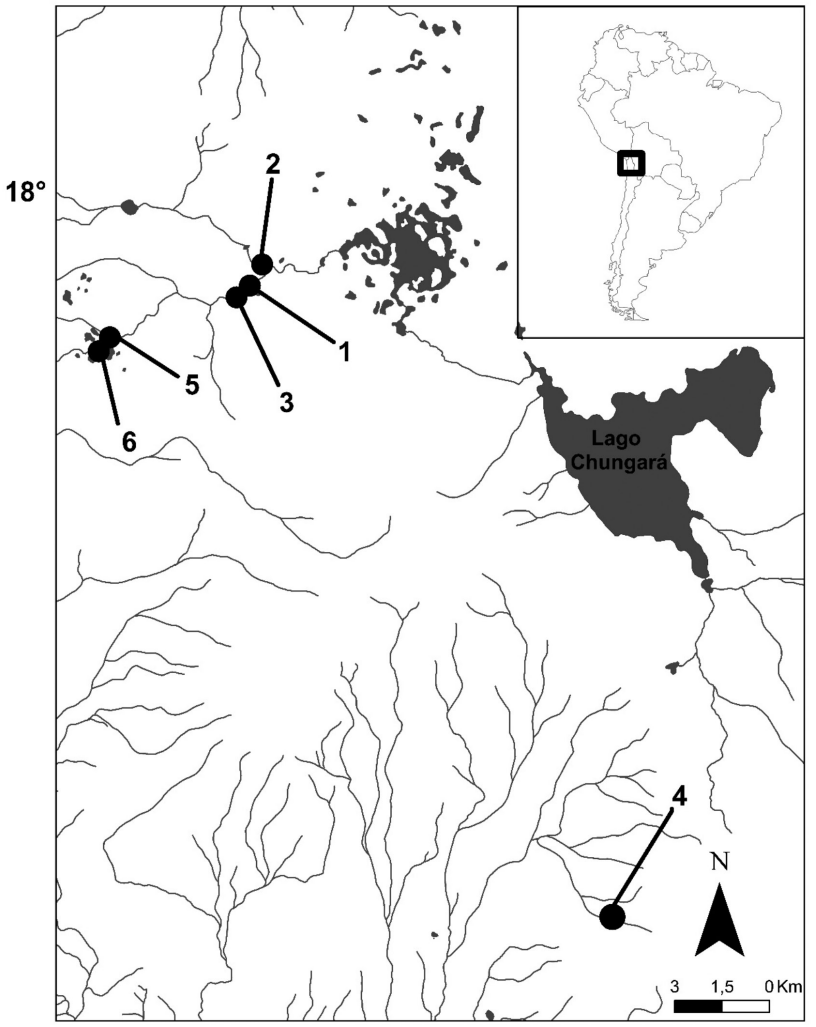

Figure 1. Map of studied sites.

Results and discussion

The results revealed a low species number with high insect larvae abundance, mainly Plecoptera order (Table 1). The results of the null model analyses revealed that the species associations were not structured, whereas the niche sharing null model analysis revealed the absence of niche segregation (Table 2). The results of UNTB revealed a low species number; the optimal θ was 0.579. Finally, Chao-2, Jack-1, and Jack-2 values were 42.16; 32.77. and 39.81, respectively. The results of UPGMA revealed that the most similar sites were Lauca lagoon 1 and 2, following in order by Guallatire river, Bofedal de Parinacota 3, Bofedal de Parinacota 2, and finally Bofedal de Parinacota 1 (Figure 2).

The low species number reported is in accordance with previous observations for high altitude freshwaters in the northern Andes in both benthic (De los Ríos *et al*., 2010) and pelagic environments (Marquez-García *et al*., 2009; De los Ríos-Escalante, 2010; Scheihing *et al,*, 2010). Low species numbers reported can be explained by extreme environmental conditions (Scheihing *et al*., 2010). Communities we reported here probably lack complexity and are characterized by linear vertical predator-prey interactions.

Obtained results agree with similar observations for zooplankton within Chilean continental territory (De los Ríos-Escalante *et al*., 2015), northern Andean shallow water bodies (Muñoz-Pedreros *et al*., 2015, 2019), and southern Patagonian shallow permanent and ephemeral pools (De los Ríos *et al*., 2018). Null

Table 1. Zooplanctonic individuals abundances (ind/L) observed for studied sites included in the present study.

Ind/L	Bofedal de Parinacota 1	Bofedal de Parinacota 2	Bofedal de Parinacota 3	Río Guallatiri	Lauca lagoon 1	Lauca lagoon 2
Geographical Location	18º12'44.2" S 69º16'30.84"W	18º12'44.61"S 69º16'30.73"W	18º12'44.78"S 69º16'30.61"W	18º31'58.32"S 69º10'10.49"W	18º12'58.73"S 69º19'02.37"W	18º12'59.01"S 69º19'02.03"W
Crustacea						
Maxillopoda						
Ostracoda indet.	0.00	0.00	0.00	0.00	0.03	0.01
Peracarida						
Hyalella kochi Gonzalez and Wattling, 2001.	0.01	0.02	0.00	0.00	0.00	0.00
Isopoda indet.	0.00	0.01	0.00	0.00	0.00	0.00
Insecta						
Coleoptera						
Stenhelmoides sp. Grouvelle, 1908	0.07	0.00	0.03	0.00	0.01	0.00
Ephemeroptera						
Guajirolus sp. Flowers, 1985	0.03	0.29	0.00	0.00	0.00	0.00
Trichoptera						
Leucotrichia sp. Mosely, 1934	0.00	0.00	0.00	0.02	0.00	0.00
Diptera indet.	0.00	0.00	0.00	0.01	0.00	0.00
Mollusca						
Chilina sp. Gray, 1828.	0.00	0.00	0.04	0.00	0.00	0.00

Table 2. Results of null models for data obtained in the present study.

Species co-occurrence			
Mean index	Observed index	Variance	P
1.788	1.785	0.001	0.677
Niche sharing			
Mean index	Observed index	Variance	P
0.173	0.234	0.002	0.907

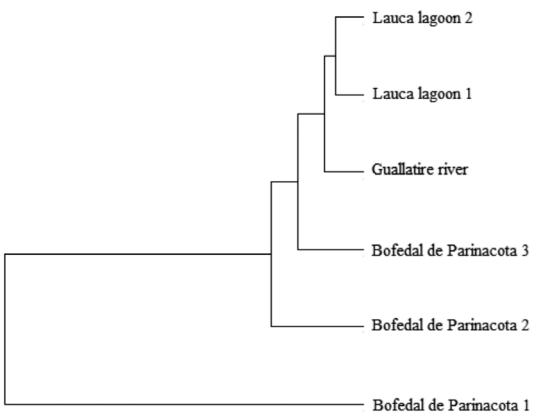

Figure 2. Results of UPGMA for studied sites.

model results revealed random species associations due to many repeated species in studied sites and low species number (Tiho and Johens, 2007). Similar patterns were observed in freshwaters across other parts of Chile (De los Ríos-Escalante, 2010). Furthermore, absence in niche segregation among zooplankton in high altitude bogs showed similarities with zooplankton niche patterns observed in lakes (De los Ríos-Escalante, 2010) and benthos in rivers (Schmid-Araya *et al*., 2012), where in spite of low species number, the existing species have a specific ecological niche, and niche sharing is low.

The exposed results provide the first report of aquatic communities of this kind of water bodies, and this would be a basis for future ecological studies that involving more sites or studies at a medium or long time.

Acknowledgements

Sergio Silva and Paula Meriño are kindly acknowledged for their assistance in field data collection. The present study was funded by MECESUP UCT 0804. The authors express their gratitude to M.I. and S.M.A. for their valuable comments and suggestions.

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