FIRST REPORT OF ARTHROPOD FAUNA IN FLOODED PLAINS OF NORTHERN PATAGONIA (38° S, ARAUCANIA REGION CHILE)

P. De los Rios-Escalante[1,2*], F. Correa-Araneda[3], I. Salgado[4], E. Rudolph[5]

P. De los Rios-Escalante (https://orcid.org/0000-0001-5056-7003)
F. Correa-Araneda (https://orcid.org/0000-0003-4825-3018)

[1]*Universidad Católica de Temuco, Facultad de Recursos Naturales,*
Departamento de Ciencias Biológicas y Químicas, Casilla 15-D, Temuco, Chile
[2]*Universidad Católica de Temuco, Núcleo de Investigación en Estudios Ambientales (NEA)*
[3]*Instituto Iberoamericano de Desarrollo Sostenible (IIDS), Unidad de Cambio Climático y Medio Ambiente (UCCMA), Facultad de Arquitectura, Construcción y Medio Ambiente, Universidad Autónoma de Chile, Temuco, Chile*
[4]*Universidad Católica de Temuco, Facultad de Recursos Naturales, Departamento de Ciencias Agropecuarias y Acuícolas, Casilla 15-D, Temuco, Chile*
[5]*Universidad de Los Lagos, Departamento de Ciencias Biológicas y Biodiversidad, Casilla 933, Osorno, Chile*
*Corrisponding author
[*]*E-mail: prios@uct.cl*

First Report of Arthropod Fauna in Flooded Plains of Northern Patagonia (38° S, Araucania Region Chile). De los Rios-Escalante, P., Correa-Araneda, F., Salgado, I., Rudolph, E. — In northern Patagonia, there is a kind of water body characterized as flooded plains (*vegas*), resulting from heavy rains. They have submerged vegetation that sustains aquatic insects and crustaceans, including burrowing crayfish of the genus *Parastacus*. The object of the present study was to present the first description of the community structure of three such water bodies. The results revealed the existence of seven species in the only site with *Parastacus pugnax* Poeppig, 1835, whereas in the sites where *P. pugnax* was absent there were one and three species respectively. The niche-sharing null model revealed the absence of niche-sharing due to interspecific absence. This kind of habitat presents marked heterogeneity, attributable to specific micro-environmental variations.

K e y   w o r d s: flooded plains, crustaceans, insects, crayfish, *Parastacus.*

Introduction

Chile contains numerous kinds of shallow inland water bodies with different types of biotic components, mainly submerged vegetation, called locally *vega*, *mallín* or *pitranto* (Correa-Araneda et al., 2011, 2016). They can sustain broad aquatic invertebrate communities, mainly consisting of insects and crustaceans (Correa-Araneda et al., 2017 a, b; Gomez-Capponi et al., 2017).

Some of these water bodies are habitats of endemic local crayfishes of the genera *Parastacus* and *Virilastacus*, various species of which are widely distributed throughout central Chile (32–38° S). These include *P. pugnax* (Jara et al., 2006; Rudolph, 2013 a; De los Ríos-Escalante et al., 2016) and four micro-endemic species of *Virilastacus* that live in isolated valleys, mainly in the Coastal Range and the Central Depression between 38–40° S (Rudolph, 2013 a, 2015; De los Ríos-Escalante et al., 2016). These species are considered to be underground fauna because they excavate shelters in their habitats; they feed on decomposed plant matter (Rudolph, 2013 a, b; De los Ríos-Escalante et al., 2016). *P. pugnax* is essential for local economies because it is a food source for rural communities (Rudolph, 2013 a, b).

The fauna of these habitats is endangered by human intervention, mainly habitat reduction due to soil use change in which native vegetation is replaced by agricultural and urban zones (Jara et al., 2006; Almerao et al., 2014). Studies of their invertebrate ecology are very scarce (Correa-Araneda et al., 2017 a, b). Considering the endemic condition of *Parastacus* and *Virilastacus* spp. in Chile, there is exceptionally little basic information about Chilean crayfishes. There is therefore a need to make first descriptions of these habitats in order to understand their structure and function as a basis for future conservation studies.

Material and methods

S t u d y   s i t e s . Three shallow water bodies (*vegas*) were included: Pichinhual (P), Nehuentué (N) and Ranquilco (R), located close to coastal zones in the Araucanía Region of Chile (38° S) (fig. 1). The sites were visited in winter 2017, when they reached maximum extension due to winter rains. The sites were first inspected visually to determine the presence of crayfish shelters (Rudolph, 2013). Then 10 L water samples were collected and filtered at 80 μm to collect aquatic fauna following a similar method used for shallow pools (Soto & De los Ríos, 2006); this volume was considered sufficient due to the small size of the water bodies (De los Ríos, 2018; De los Ríos & Carreño, 2018). The collected specimens (Crustacea, Insecta, Acari) were fixed in absolute ethanol and then counted and identified using specialized literature (Araya & Zúñiga,1985; González, 2003; Domínguez & Fernandez, 2009; Rudolph, 2013 a).

D a t a   a n a l y s i s . The Shannon diversity index was estimated and compared for all the study sites, based on the description of Zar (1999). A niche overlap analysis was performed: an individual matrix was constructed
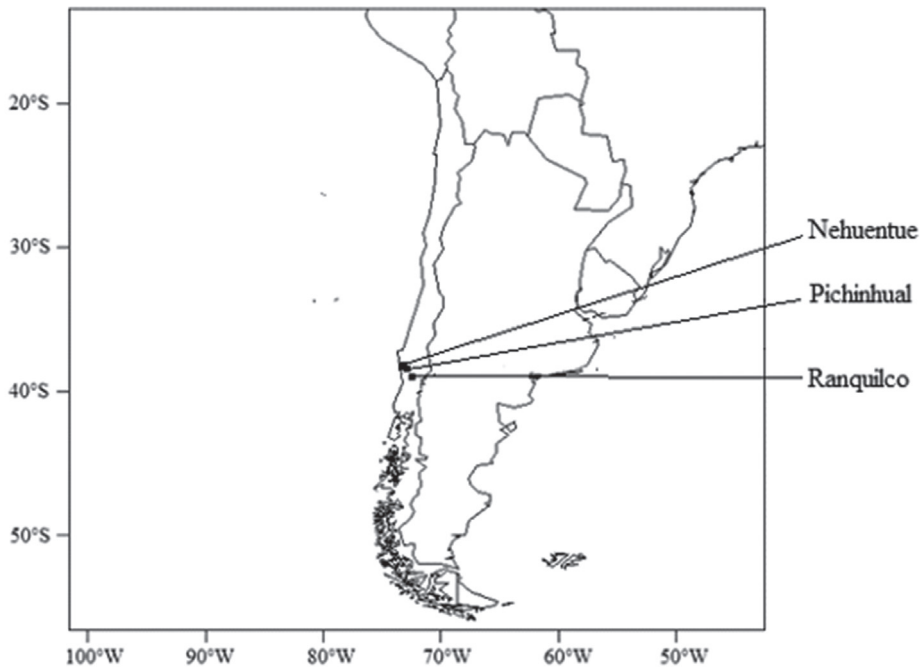

Fig. 1. Map of study sites (obtained by R package "dismo", Hijmans et al., 2011).

in which the rows and columns represented species and sites respectively; this matrix was used to test if the niche overlap differed significantly from the corresponding value under the null hypothesis (random assemblage). These analyses were applied to the data, based on Pianka's index. The models show the probability of niche-sharing compared to the niche overlap of a theoretically simulated community (Gotelli & Ellison, 2013). The niche amplitude can be retained or reshuffled: when it is retained it preserves the specialization of each species; 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 & Ellison, 2013; Carvajal-Quintero et al., 2015), which retains the amplitude and reshuffles the zero conditions (Gotelli & Ellison, 2013). This null model analysis was carried out using the R software (R Development Core Team, 2009) and the EcosimR package (Gotelli & Ellison, 2013; Carvajal-Quintero et al., 2015).

Finally, we explored the relation between invertebrate communities from the different sites using multidimensional metric scaling (MDS, Clarke & Green, 1988), based on a resemblance matrix using the Bray-Curtis index. We tested for the significance of the different groups generated by MDS ordination, using one-way ANOSIM with the site as a factor (Clarke & Warwick, 2001; Warton et al., 2012). Further, we identified the primary species associated with the differences between each group through similarity per cent analysis (SIMPER), based on the species abundance matrix. These analyses were performed using Primer v.6 software (Clarke & Gorley, 2006), as described by Correa-Araneda et al. (2017 a).

Results and discussion

The results revealed one site (P) with presence of crayfish, specifically *Parastacus pugnax* (Poeppig, 1858); the site presented a high species number, with five crustaceans, one insect and one acarus. In the other two sites, from which crayfish were absent, we recorded only three species (crustaceans) in Nehuentué and one species (aquatic insect) in Ranquilco (table 1). The results of the Shannon index comparison revealed significant differences between the study sites (table 2). Finally, the results of the niche-sharing analysis showed absence of niche-sharing between the species involved, indicating lack of interspecific competition (table 2).

T a b l e 1. Geographical location and invertebrate species abundance (ind/L) reported for the study sites

Sites	Pichinhual	Nehuentué	Ranquilco
Geographical location	38°43′ S; 73°22′ W	38°45′ S; 73°25′ W	38°43′S; 73°03′W
Crustacea			
Simosa exspinosa (De Geer, 1778)	3.33 ± 0.61	0.63 ± 0.25	0.00 ± 0.00
Daphnia sp. (juvenile)	0.00 ± 0.00	0.03 ± 0.06	0.00 ± 0.00
Mesocyclops araucanus Löffler, 1962	0.97 ± 0.45	0.00 ± 0.00	0.00 ± 0.00
Hyalella chiloensis González &Wattling 2001	3.83 ± 1.57	0.00 ± 0.00	0.00 ± 0.00
Parastacus pugnax (Poeppig, 1835)	0.33 ± 0.21	0.00 ± 0.00	0.00 ± 0.00
Calanoid copepodite	3.07 ± 1.55	0.00 ± 0.00	0.00 ± 0.00
Cyclopoid copepodite	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Ostracoda (juvenile)	0.00 ± 0.00	0.83 ± 0.40	0.00 ± 0.00
Insecta			
Chiloporter eatoni Letsague, 1931	0.00 ± 0.00	0.00 ± 0.00	0.73 ± 0.75
Diptera (not identified)	0.03 ± 0.06	0.00 ± 0.00	0.00 ± 0.00
Chelicerata			
Acari (not identified)	0.03 ± 0.06	0.00 ± 0.00	0.00 ± 0.00
Shannon Index	4.619	3.175	2.865

T a b l e 2. Results of Shannon diversity index comparison and niche-sharing null model for study sites

Sites	Results of Shannon Index comparison
Pichinhual–Nehuentué	$T_{observed} = 248.945 > T_{table} = 1.960; P < 0.001$
Pichinhual–Ranquilco	$T_{observed} = 302.536 > T_{table} = 1.960; P < 0.001$
Ranquilco–Nehuentué	$T_{observed} = 310.698 > T_{table} = 1.960; P < 0.001$

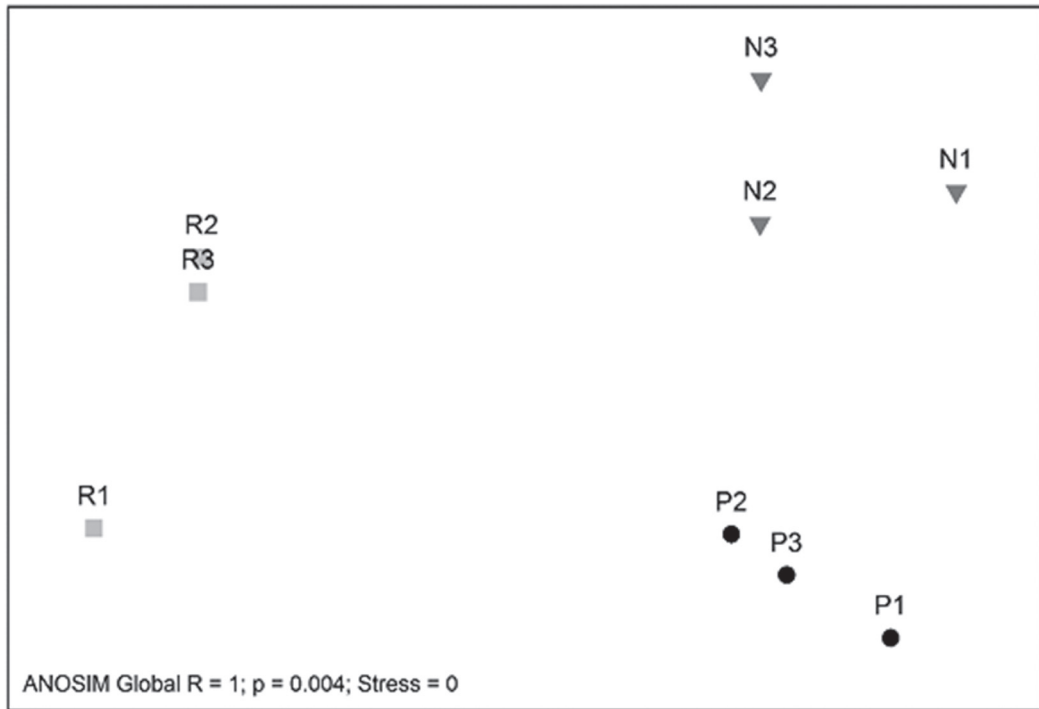| Observed index	Mean index	Standard effect size	Variance	P
0.555	0.389	3.540	0.003	0.006

Fig. 2. Results of NMDS ordination and ANOSIM analysis of study sites based on invertebrate resemblance matrix.

The NMDS analysis shows the exact formation of three groups, directly related to the different study sites (Stress = 0); this grouping indicates highly significant differences in the invertebrate community between sites (ANOSIM Global $R = 1$; $p = 0.005$) (fig. 2). The SIMPER analysis shows that the differences between sites P vs N and P vs R were mostly explained by *Hyalella chiloensis* Gonzalez & Wattling, 2001, Calanoid copepodites and *Simosa exspinosa* (De Gueer, 1778). The differences between N vs R were explained by juvenile Ostracoda, Calanoid copepodites and *Chiloporter eatoni* Letsague, 1931 (table 3).

The results for the species number would agree with descriptions for shallow ephemeral water bodies in mountains and coastal zones, with between three and seven crustacean species (De los Ríos & Roa, 2010; De los Ríos & Carreño, 2018). Correa-Araneda et al. (2017 a) described the presence of *P. pugnax* with three crustacean species in forested wetlands in northern Patagonia, including the amphipod *Hyalella patagonica*. This is similar to our description of Pichinhual, where the amphipod *H. chilensis* was found; however, Correa-Araneda et al. (2017 a) cite the presence of decapods (*Aegla*) and isopods (*Heterias*), which were not found in the present study.

T a b l e 3. Similarity Percent analysis (SIMPER) to identify the contribution (%) of each species to the dissimilarity of the site

Taxon	Average Abundance			Dissimilarity Contribution		
	P	N	R	P vs N	P vs R	N vs R
H. chiloensis	3.83	0.00	0.00	32.09	30.74	0.00
Calanoid copepodites	3.07	0.00	0.00	25.07	23.96	31.08
S. exspinosa	3.33	0.63	0.00	23.46	28.06	0.00
M. araucanus	0.97	0.00	0.00	8.4	8.07	0.00
Ostracoda (juvenile)	0.00	0.83	0.00	7.49	0.00	38.39
Ch. eatoni	0.00	0.00	0.73	0.00	0.00	29.09
Cumulative Contribution				96.51	90.83	98.56

Considering that burrowing crayfishes inhabit galleries excavated in the floor of these water bodies, crustaceans are likely to be found among the associated fauna (Grosso & Peralta, 2009; De los Ríos-Escalante et al., 2016), however the literature does not describe details of other related species. In this scenario, it would probably be the presence of dead plant matter that supports burrowing crayfish populations; the same matter would also probably sustain other crustacean species, and this would explain the high species number in the Pichinhual site, where we recorded seven species including *P. pugnax*. These results agree with observations for the Brazilian crayfish *P. defossus,* which coexists with 12 copepod species (Reid et al., 2006), and the description of a *P. pugnax* habitat in central Chile which has a highly diverse terrestrial plant community (Ramirez et al., 2014). The results reported here would indicate that more studies are needed of aquatic diversity in habitats of this kind, considering the presence of endemic species.

References

Almerao, M. P., Rudolph, E., Southy-Grosset, C., Crandall, K., Buckup, L., Amouret, J., Verdi, A., Santos, S., Araujo, P. B. 2014. The native South American crayfishes (Crustacea, Parastacidae): state of knowledge and conservation status. *Aquatic Conservation Marine and Freshwater Ecosystems*, **25** (2), 288–301.

Araya, J. M., Zúñiga, L. R. 1985. Manual taxonómico del zooplancton lacustre de Chile. *Boletin Limnológico, Universidad Austral de Chile,* **8**, 1–110.

Carvajal-Quintero, J. D., Escobar, F., Alvarado, F., Villa-Navarro, F. A., Jaramillo-Villa, U., Maldonado-Ocampo, J. A. 2015. Variation in freshwater fish assemblages along a regional elevation gradient in the northern Andes, Colombia. *Ecology and Evolution*, **5** (13), 2608–2620.

Clarke, K., Warwick, R. 2001. A further biodiversity index applicable to species lists: variation in taxonomic distinctness. *Marine Ecology Progress Series*, **216**, 265–278.

Clarke, K., Gorley, R. 2006. *Primer v.6.* Primer-E, Plymouth.

Clarke, K. R., Somerfield, P. J., Gorley, R. N. 2008. Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. *Journal of Experimental Marine Biology and Ecology*, **366** (1–2), 56–69.

Correa-Araneda, F., Urrutia, J., Figueroa, R. 2011. Estado del conocimiento y principales amenazas de los humedales boscosos de agua dulce de Chile. *Revista Chilena de Historia Natural*, **84** (3), 325–340.

Correa-Araneda, F., Guevara-Mora, M., Díaz, M.E., Figueroa, R. 2016. An edaphological, morphological and climatic classification of freshwater forested wetlands from Chile. *Gayana*, **80** (1), 6–15.

Correa-Araneda, F., De los Ríos-Escalante, P., Figueroa, R., Parra-Coloma, L. 2017 a. Temporal distribution of crustaceans in forested freshwater wetlands: responses to changes in the hydroperiod. *Crustaceana*, **90** (6), 721–734.

Correa-Araneda, F., De los Ríos-Escalante, P., Figueroa, R., Gómez-Capponi, F. 2017 b. Extension of the known distribution range and environmental preferences of the freshwater crustacean *Heterias* (*Fritzianira*) *exul* (Müller, 1892) (Isopoda) in forested wetlands of southern Chile. *Crustaceana*, **90** (6), 753–759.

De los Ríos, P. 2018. Abundance of *Boeckella gracilis* (Daday, 1902) (Copepoda, Calanoida) in seasonal coastal pools in the Araucania Region (38° S, Chile). *Crustaceana*, **91** (10), 1211–1217.

De los Ríos, P., Carreño, E., 2018. First report of *Branchinecta* (Anostraca) in seasonal coastal pools in the Araucania Region (Puaucho, 39° S, Chile). *Crustaceana*, **91** (10), 1219–1230.

De los Ríos-Escalante, P., Parra-Coloma, L., Peralta, M. A., Perez-Schultheiss, J., Rudolph, E. H. 2016. A checklist of subterranean water crustaceans from Chile (South America). *Proceedings of the Biological Society of Washington*, **129,** 114–128.

De los Ríos, P., Roa, G. 2010. Crustacean species assemblages in mountain shallow ponds: Parque Cañi (38°S Chile). *Zoologia Curitiba*, **27** (1), 81–86.

Dominguez, E., Fernandez, H. R., eds. 2009. *Macroinvertebrados bentónicos sudamericanos. Sistemática y Biología*. Fundación Miguel Lillo Tucuman, Argentina. 1–656.

Gomez-Capponi, F., Correa-Araneda, F., Díaz, M. E., Olguín, M., Encina-Montoya, F., Figueroa, R. 2017. Leaf litter decomposition from native and non-native species in a freshwater forested wetland of Chile. *Gayana*, **81** (1), 1–8.

Gotelli, N. J, Ellison, A. M. 2013. *EcoSimR 1.00.* Available at: http://www.uvm.edu/~ngotelli/EcoSim/EcoSim. html [Accessed: 3rd August 2018]

González, E. 2003. The freshwater amphipods *Hyalella* Smith, 1874 in Chile (Crustacea: Amphipoda). *Revista Chilena de Historia Natural*, **76** (4), 623–637.

Grosso, L. E., Peralta, M. 2009. A new Paraleptamphopidae (Crustacea, Amphipoda) in the burrow of *Virilastacus rucapihuelensis* (Parastacidae) and surrounding peat bogs. *Rudolphia macrodactylus* n. gen., n. sp. from southern South America. *Zootaxa*, **2243**, 40–52.

Hijmans, R. J., Phillips S., Leathwick, J., Elith, J. 2011. *Package 'dismo'*. Available at: http://cran.r-project.org/web/packages/dismo/index.html. Accessed 05 August, 2018.

Jara, C., Rudolph, E. H., Gonzalez, E. R. 2006. Estados de conocimiento de los malacostracos dulceacuícolas. *Gayana*, **70** (1), 40–49.

R Development Core Team. 2009. *R: A language and environment for statistical computing*. (R foundation for statistical computing, Vienna).

Ramirez, C., Fariña, J. M., Camaño, A., Contreras, D., San Martín, C., Varas, J., Vidal, O., Pérez, Y. 2014. Estructura y clasificación de la vegetación actual y potencial del humedal "ciénagas del Name" en Chile central: un estudio de la oferta de hábitats. *Chilean Journal of Agriculture and Animal Science*, **30** (1), 29–44

Reid, J. W., Noro C. K., Buckup, L., Bisol, J. 2006. Copepod crustaceans from burrows of *Parastacus defossus*¸ Faxon, 1898, in southern Brazil. *Nauplius*, **14** (1), 23–30.

Rudolph, E. H. 2013 a. A checklist of Chilean Parastacidae (Decapoda, Astacidea). *Crustaceana*, **86** (12), 1468–1510.

Rudolph, E. H. 2013 b. *Parastacus pugnax* (Poeppig, 1835) (Crustacea, Decapoda, Parastacidae): conocimiento biológico, presión extractiva y perspectivas de cultivo. *Latin American Journal of Aquatic Research*, **41** (4), 611–632.

Rudolph, E. H. 2015. Current state of knowledge on *Virilastacus* species (Crustacea, Decapoda, Parastacidae). *Latin American Journal of Aquatic Research*, **43** (5), 807–818.

Soto, D., De los Ríos, P. 2006. Influence of trophic status and conductivity as regulators in daphnid dominance and zooplankton assemblages in lakes and ponds of Torres del Paine National Park. *Biologia Bratislava*, **61** (5), 541–546.

Warton, D. I., Wright, S. T., Wang, Y. 2012. Distance based multivariate analyses confound location and dispersion effects. *Methods in Ecology and Evolution*, **3** (1), 89–101.

Zar, J. 1999. *Biostatistical analysis*. Prentice-Hall, Upper Saddle River, New Jersey, 1–661.