Volumen 41, Nº 3. Páginas 115-121
IDESIA (Chile) Septiembre, 2023

Null model for explain benthic macroinvertebrates communities in Salado River, (23ºS, Antofagasta Region, Chile).

Uso de Modelo nulo para explicar las comunidades de macroinvertebrados bentónicos en el río Salado, (23ºS, Región de Antofagasta, Chile).

Patricio R. De los Ríos-Escalante[1, 2] *Rodolfo Wilson*[3],
Juan-Alejandro Norambuena[4, 5], *Carlos Esse*[6], *Affef Baaloudj*[7]

ABSTRACT

The invertebrate fauna in Northern Chilean inland waters has poorly studied due the difficult access, and there are only studies on crustacea species based in scarce expeditions. The aim of the present study is do a first community study on aquatic invertebrate communities reported in Salado River, a subsaline river in north of Chile, that is a tributary of Loa River the most long river in Chile (23ºS, Antofagasta region), based on size overlap null models. The results revealed the presence of Diptera larvae (*Simulium* sp., *Gigantodax* sp., and Ortochladinae), coleoptera larvae (Elmidae), Odonata larvae, Aranae, and amphipod *Hyalella kochi*. The results revealed that there is a size overlap, this means that the reported species would share their ecological niches. It is the first description of niche overlap for invertebrate Chilean rivers, and the exposed results are similar for descriptions for decapods in marine environments.
Keywords: aquatic insects; crustacea; Salado River; null models; size overlap.

RESUMEN

*La fauna de invertebrados en aguas interiores del norte de Chile ha sido poco estudiada debido al difícil acceso, y solo existen estudios sobre especies de crustáceos basados en escasas expediciones. El objetivo del presente estudio es realizar un primer estudio comunitario de las comunidades de invertebrados acuáticos reportadas en el río Salado, un río subsalino del norte de Chile, afluente del río Loa, el río más largo de Chile (23ºS, región de Antofagasta), basado en modelos nulos de superposición de tamaño. Los resultados revelaron la presencia de larvas de dípteros (*Simulium *sp.,* Gigantodax *sp. y Ortochladinae), larvas de coleópteros (Elmidae), larvas de Odonata, Aranae y el anfípodo* Hyalella kochi. *Los resultados revelaron que existe una superposición de tamaño, esto significa que las especies reportadas compartirían sus nichos ecológicos. Es la primera descripción de superposición de nicho para ríos chilenos de invertebrados, y los resultados expuestos son similares para descripciones de decápodos en ambientes marinos.*
Palabras clave: *insectos acuáticos; crustáceos; Río Salado; modelos nulos; superposición de tamaño.*

INTRODUCTION

The invertebrate communities in Chilean rivers have been studied mainly for central Chilean and Patagonian rivers, being reported mainly the presence of aquatic insects larvae such as Ephemeroptera, Diptera, Plecoptera, Trichoptera, Molluscs, and crustacea specifically Peracarid and Decapods, and their abundances vary in function of water quality along river course (Figueroa *et al*. 2003, 2007; Oyanedel *et al*. 2008; Moya *et al*. 2009). Nevertheless in the North of Chile (18-23ºS), there

[1] Universidad Católica de Temuco, Facultad de Recursos Naturales, Departamento de Ciencias Biológicas y Químicas, Casilla. Temuco, Chile.
[2] Núcleo de Estudios Ambientales UC Temuco, Casilla,.Temuco, Chile.
[3] Departamento de Ciencias Acuáticas y Ambientales, Facultad de Recursos del Mar y Recursos Hidrobiológicos, Universidad de Antofagasta, Antofagasta Chile.
[4] Programa de Doctorado en Ciencia de los Recursos Naturales, Universidad de la Frontera. Temuco, Chile.
[5] Departamento de Ingeniería Química, Facultad de Ingeniería y Ciencias.Temuco, Chile.
[6] Instituto Iberoamericano de Desarrollo Sostenible (IIDS), Unidad de Cambio Climático y Medio Ambiente (UCCMA), Universidad Autónoma de Chile. Chile.
[7] Laboratoire Biologie, Eau et Environnement - LBEE, Université 8 Mai 1945 Guelma, Faculté SNV-STU. Guelma, Algeria.
* Author for correspondence, email: prios@uct.cl

Fecha de recepción: 27 de enero, 2023.
Fecha de aceptación: 19 de abril, 2023.

are three rivers (San José, Lluta, and Loa) with their respective tributaries rivers that have their outflow at Pacific coast, also there numerous endorreic streams that are originated in Andes mountains, and disappear in saline deposits, and there are many intermittent rivers (Niemeyer and Cereceda 1984; De los Ríos-Escalante and Woelfl, 2023).

In the north of Chile, one of the main rivers is Loa river that is located at 23ºS in Antofagasta region, it is the most long Chilean river with 440 km, with three tributaries that simultaneously have their tributaries, and with three reservoirs along the river bed (Niemeyer and Cereceda, 1984; De los Ríos *et al.* 2010). This river has native fishes populations, northern Chilean silversides (*Basilichthys semotilus*) in medium course, and flat head grey mullets (*Mugil cephalus*) in low zones, also there are the presence of introduced fishes such as mosquito fishes (*Gambussia affinis*) in low and medium zones, rainbow trouts (*Oncorhynchus mykiss*) and brown trouts (*Salmo trutta*) in high zones (De los Ríos-Escalante and Mardones 2013). The invertebrate fauna in Loa River has poorly studied, only crustaceans have been reported at species level (De los Ríos *et al.* 2010), nevertheless there is a report of presence of aquatic insects in *O. mykiss* stomach contents (Silva *et al.* 1985), and in according to Palma *et al.* (2013), there are aquatic larvae insects, but it mentioned it at order or family level without more taxonomic details. On the basis of these antecedents, the benthic invertebrate fauna would be important as prey on native and introduced fish species along Loa River course (Silva *et al.* 1985; De los Ríos-Escalante and Mardones 2013), but unfortunately there are not studies about structure on benthic invertebrate community in Loa River and its tributaries rivers. The aim of the present study is do a first community ecology structure study on benthic invertebrate fauna collected in low course of Salado river, close to its fusion with Loa river using size overlap null models.

Material and Methods

Studied site: Salado River is a tributary of Loa River, it is located close to Chiu Chiu village, at 40 km of Calama town, close to Inca Coya lagoon (22º20’24’S; 68º35’51’’W; Figure 1), it is characterized by its relative high salinity level (5 g/L), that increases salinity level in the following zone of Loa River (Niemeyer and Cereceda 1984; De los Ríos *et al.* 2010). Salado river has numerous tributaries that are originated in Andes mountains close to Bolivian boundary, and in the basin of Salado River and tributaries, there are many small aboriginal villages of prehispanic origin, that has a subsistence agriculture (Niemeyer and Cereceda 2004). Also, in Salado River it is possible found presence of introduced trouts (Northland-Leppe *et al.* 2009).

Sampling procedure: invertebrate samplings were collected using a Surber net of 100 µm mesh size 40*40 cm, in one site with ten replicates along water course, collected specimens were fixed in absolute ethanol. The specimens were identified and measured their total length with a caliper based on literature descriptions, considering the length between beginning of head and the end of last caudal segment (Fernandez and Dominguez 2001; Gonzalez 2003; Dominguez and Fernandez 2009).

Data analysis: it was applied null model analysis, this mean as first premise that communities are random that also involves for the analysis only species composition without environmental parameters, and the main hypothesis is the absence of community structure, this mean the community is random (Gotelli and Graves, 1996; Pie and Caron, 2022), and this kind of analysis is robust (Gotelli and Entsminger 2009; Gotelli and Ellison 2013; Zhang, 2020).

For this purpose, it was applied the size overlap null models, on this basis if the size mean of involved species in the community has low difference, it means that the involved species have low coexistence probability due shared resources (Gotelli and Graves, 2000; Gotelli and Entsminger 2009). For this purpose it was applied to investigate “size structure” called “size overlap”, i.e., for the total of specimens collected. The specific aim was to determine any random patterns in size overlap of the various species, the presence of random patterns revealed the absence of structure by competition (Gotelli and Entsminger, 2009). The data for such an analysis consist of a matrix in which each species is a row, and each site is a column (Gotelli and Graves 1996; Gotelli and Entsminger 2009). Entries in the matrix represent the mean size, i.e., the mean length, of each species. The original matrix is then reshuffled to produce random patterns that would be expected in the absence of competitive interactions. The following algorithms were used for that purpose: size uniform, size uniform user, and size uniform pool, combined with metrics of

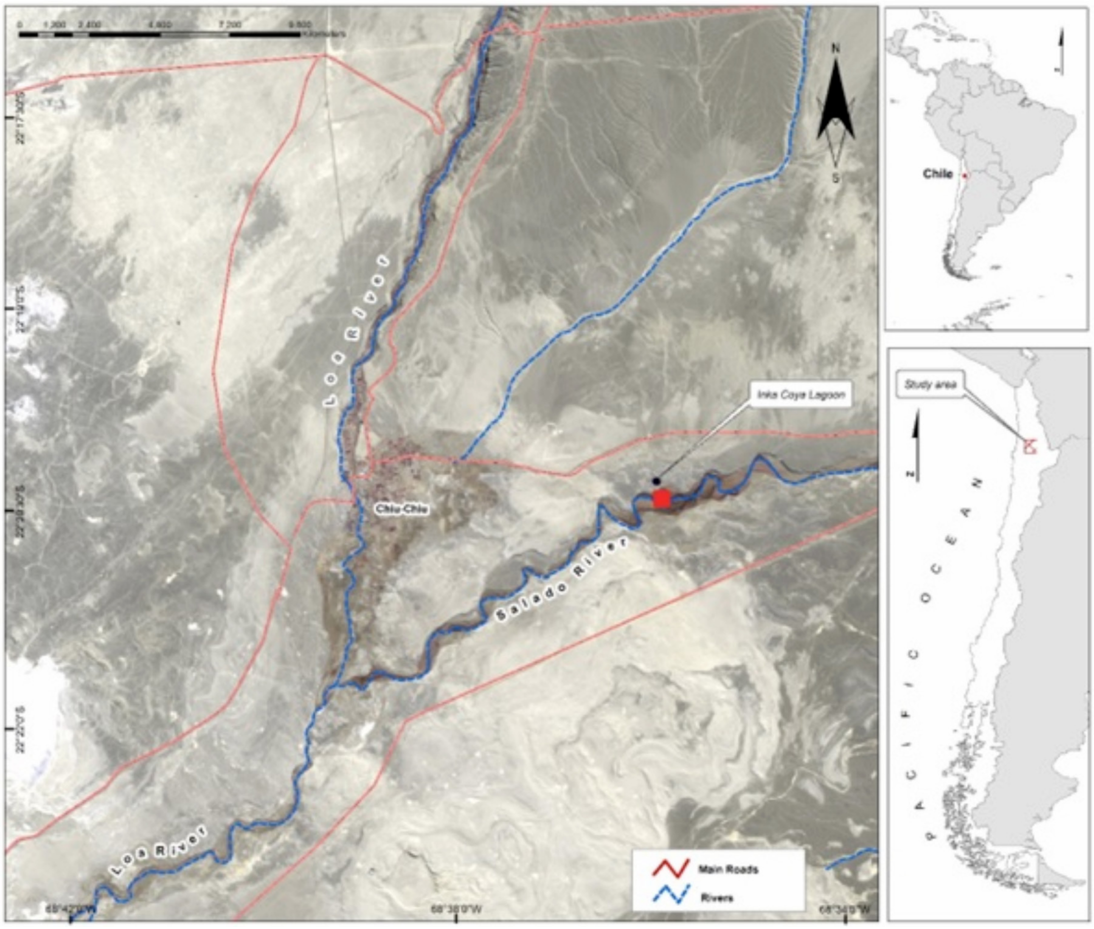

Figure 1. Map of studied site.

minimum difference and variance ratio (Gotelli and Entsminger 2009; Gotelli and Ellison 2013), together thus making six different simulations. These null model analyses were performed using the package EcosimR (Gotelli and Ellison 2013) and the software R (R Development Core Team 2022).

Results

The exposed results revealed the presence of high species number of insecta, being Diptera (Simulidae indet; *Simulium* sp., *Gigantodax* sp., and *Ortocladinae* sp) and Coleoptera (Elmidae indet, *Elmis* sp) the taxa with more species with four and two species respectively (Table 1). In size, Odonata has upper size with 13.0 + 4.8 mm, whereas the lower size was Aranae with 1.7 + 0.3 mm (Table 1). The results of size overlap null model revealed for all simulations the existence of size overlap for communities, that revealed that species reported share ecological niche and would have not interspecific competition (Table 2, Figure 2). The results of Figure 2, remarks the results of Table 2, because it is possible observe similarities between observed data and expected data for all simulations. Then these results remarks the existence of that species reported share ecological niche, and in consequence there are not interspecific competition.

Discussion

The results species reported are similar with descriptions of southern Chilean rivers where are not in high course, because there is not presence of typical insects of high oxygenated waters in high zones of the river (Figueroa *et al.* 2003, 2007, 2013; Figueroa and De los Ríos-Escalante 2022; Solís-Lufí *et al.* 2022). On the basis of descriptions of Figueroa

Table 1. Species reported for Salado River and total length (average ± standard deviation)

	Total length (mm)	n
Mollusca		
Gastropoda		
Littorinimorpha		
Cochiopidae		
Heleobia sp. Stimpson, 1865	5.1 ± 1.3	10
Insecta		
Coleoptera		
Elmidae		
Elmis sp. Latreille, 1802	5.2 ± 0.6	10
Elmidae indet.	2.8 ± 0.2	10
Odonata	13.0 ± 4.8	8
Diptera		
Chironomidae		
Orthocladinae indet.	7.1 ± 0.4	10
Simulidae		
Simulium sp. Latreille, 1802	4.3 ± 0.4	10
Gigantodax sp. Enderlein, 1925	7.1 ± 0.7	10
Simulidae indet.	4.5 ± 0.4	10
Chelicerata		
Aranae	1.7 ± 0.3	4
Crustacea		
Peracarida		
Amphipoda		
Hyalellidae		
Hyalella kochi Gonzalez and Watling, 2001	4.3 ± 1.2	10

Table 2. Results of size-overlap null model analysis for data collected at the studied site ("*P*" values higher than 0.05 denote size overlap)

Algorithm	Metric	Mean index	Observed index	Variance	Standard effect size	P
Size uniform	Minimum difference	0.144	< 0.001	0.016	–1.123	0.999
Size uniform user	Minimum difference	0.133	< 0.001	0.014	–1.119	0.999
Size source pool	Minimum difference	0.409	< 0.001	0.131	–1.129	0.999
Size uniform	Variance ratio	0.100	0.101	0.021	0.004	0.284
Size uniform user	Variance ratio	0.036	0.101	0.001	1.555	0.056
Size source pool	Variance ratio	0.186	0.101	0.037	–0.434	0.590

et al. (2003, 2007), the presence of Diptera and Coleoptera would be associated to low oxygenated waters and with high organic matter concentrations, nevertheless, there are not chemical data for support or reject it, although the relative high salinity level of Salado River in comparison to Loa River probably would generate alterations in water quality that in consequence would generate low species number in comparison to low salinity waters in other zones of Loa river (De los Ríos *et al.* 2010). Nevertheless, in recent observations for Loa and Salado river, it was reported that Salado river has low total benthic abundances, in comparison to upper zone of Loa river and lower zones of Loa river located at town, but the species number was similar between upper zones to Loa river and Salado river, in comparison to upper zones of Loa river within Calama (De los Ríos-Escalante *et al.,* 2023). The taxa reported in De los Ríos-Escalante *et al.*, 2023 coincides with the present study with the presence of Diptera and *Hyalella*, nevertheless the presence Ephemeroptera, Plecoptera and Trichoptera was not reported in the

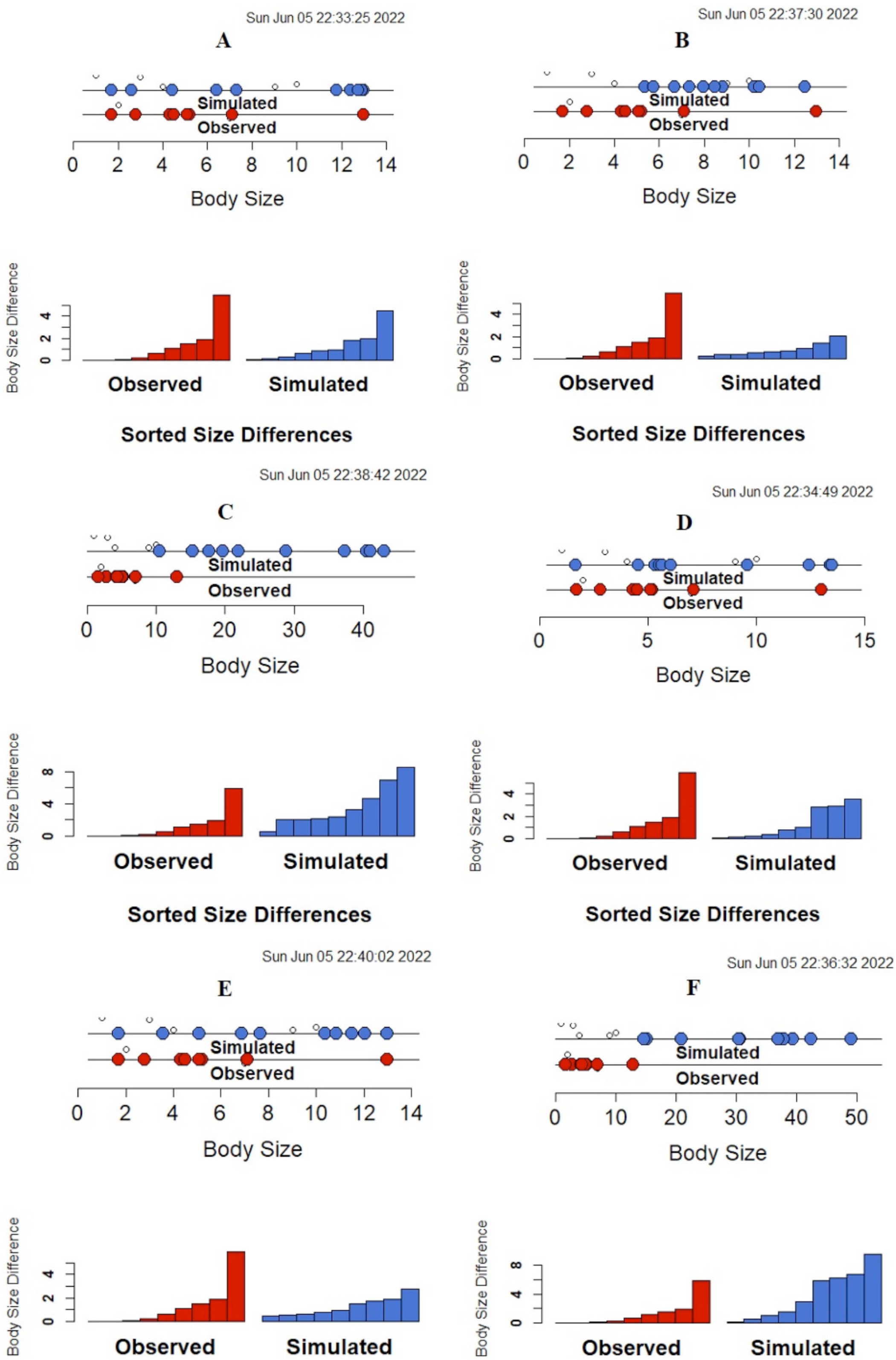

Figure 2. Results of size-overlap null model analysis for data collected at the studied site.

present study, that would be probably to seasonal effects, because the present study was done during southern spring (October), whereas De los Ríos-Escalante *et al.* (2023) was done in southern winter (Jule). On this basis, the relative high salinity level of studied site would explain the presence of high Diptera species, because the larval and pupa stages of this group is most halotolerant in comparison to other aquatic insects, becoming practically exclusive component if the salinity increases (Williams 1998; Bradley 2018). The exposed results of aquatic insect fauna in Salado river, is similar to reports for rivers in arid and semi-arid zones of Algeria, where the salinity is one of the main regulators components in aquatic fauna, being different diptera groups dominant when salinity increases (Chaib *et al.* 2023; Baaloudj *et al.* 2024; Gharbi *et al.* In press).

The results of null models for Salado river revealed revealed the absence of interspecific competition based in size overlap, similar results were reported for Algerian rivers based in niche sharing null models (Gharbi *et al.*, In press), also similar results were reported for middle zone of Loa river (De los Ríos-Escalante *et al.* 2023). The use of size overlap null models, revealed that under absence of interspecific competition, would not have niche sharing, that in consequence would indicate that species reported would not have specific ecological niche, such as was reported for aquatic insects assemblages (Guterrez *et al.,* 2020; Oliveira-Junior *et al.,* 2021). Although the results of null models does not involve as obligatory conditions the use of abiotic parameters and the results are robust (Gotelli and Graves, 1996; Gotelli and Entsminger 2009; Gotelli and Ellison 2013; Blanchet *et al.*, 2020), the recent literature of null models use as complement environmental parameters, and the results of null models with traditional exploratory multivariate analysis have concordance (Gutérrez *et al.* 2020; Oliveira-Junior *et al.,* 2021).

Also, probably the predation on introduced trouts, would have important component in invertebrate communities, because salmonids are opportunistic predators that predate on benthic invertebrates mainly insects (Silva *et al.* 1985; Vila *et al.* 1999; Soto *et al.* 2006, 2007). Although the trout presence in Loa River has at least five or six decades ago (Wetzlar 1979), unfortunately there is one studies that described the feeding habitat of O. mykiss in Loa river, that predate on invertebrates but there are not more specific details about its preys (Silva *et al.* 1985; De los Ríos-Escalante and Mardones 2013).

The exposed results revealed that it would be necessary more limnological studies in Loa River and its tributaries, including Salado River, considering their natural environmental heterogeneity, due salinity increases of Salado River apports and low precipitations combined with high evaporation in lower zones, that would affect the invertebrate community structure along Salado river and its tributaries.

Acknowledgements

The present study was financed by project MECESUP UCT 0804, Aquatic and Environmental Sciences Department (Antofagasta University). Also, the authors express their gratitude to M.I. and S.M.A. for their valuable suggestions.

Literature cited

Baaloudj, A.; De los Ríos-Escalante, P.R.; Esse, C.
2024. Benthic community ecology for Algerian river Seybouse. *Brazilian Journal of Biology*, 84: e251566.

Blanchet, F.G.; Cazelles, K.; Gravel, D.M.
2020. Co-occurrence is not evidence of ecological interactions. *Ecology Letters*, 23: 1050-063.

Bradley, T.J.
2018. Saline-water insects: ecology, physiology and evolution. In: J. Lankaster, & R.A. Briers R.A. (eds). Aquatic insects. Challenges to populations Procreedings of the Royal Entomological Society´s 24th Symposium. CABI, London U.K. pp. 20-35

Chaib, S.; Baaloudj, A.; De los Ríos-Escalante, P.R.; Esse, C.; Gharbi, M.; Houhamdi, M.
2023. Ecological structure of aquatic macroinvertebrate communities in the Hauts Plateaux of Northeast Algeria. *Brazilian Journal of Biology,* 83: e273010

De los Rios-Escalante P.R.; Wilson R.; Norambuena J.; Esse, C.
2023. Benthic macroinvertebrate communities in Salado and Loa Rivers, Antofagasta Region, Chile. *International Journal of Aquatic Biology*, 11(5): 383-390

De los Ríos-Escalante, P.; Woelfl S.
2023 A review of zooplankton research in Chile. *Limnologica,* 100: 126079

De los Ríos-Escalante P.; Mardones A.
2013. Ecology of the malacostracans of northern Chilean inland waters. *Crustaceana*, 86(12): 1511-1519

De los Ríos P.; Adamowicz S.; Witt J.D.S.
2010. Aquatic fauna on the driest desert on earth: first report on the crustacean fauna of the Loa river (Atacama desert, Antofagasta region, Chile). *Crustaceana*, 83(3): 257-266.

Domínguez E.; Fernandez H.R.
2009. Macroinvertebrados bentónicos sudamericanos. Sistemática y Biología. Fundación Miguel Lillo, Tucumán, Argentina. 656 p.

Fernández H.R.; Domínguez, E.
2001. Guía para la determinación de los artrópodos bentónicos sudamericanos. San Miguel de Tucumán, Argentina: Editorial Universitaria de Tucumán, Fundación Miguel Lillo, 282 p.

Figueroa R.; Bonada N.; Guevara M.; Pedreros P.; Correa-Araneda F.; Díaz M.E.; Ruiz, V.H.
2013. Freshwater biodiversity and conservation in Mediterranean climate streams of Chile. *Hydrobiologia*. 719: 269-289.

Figueroa R.; Palma A.; Ruiz V.; Niell X.
2007. Análisis comparativo de índices bióticos utilizados en la evaluación de la calidad de aguas en un río mediterráneo de Chile, río Chillán, VIII región. *Revista Chilena de Historia Natural*, 80(2): 225-242.

Figueroa R.; Valdovinos C.; Araya E.; Parra O.
2003. Macroinvertebrados bentónicos como indicadores de calidad de agua de ríos del sur de Chile. *Revista Chilena de Historia Natural*, 76(2): 275-285.

Figueroa D.; De los Ríos-Escalante P.
2022. Macrozoobenthos in an altitudinal gradient in North Patagonian Cautín River (Araucanía Region, Chile). *Brazilian Journal of Biology,* 82: e240484

Gharbi, M.; Baaloudj, A.; De los Ríos-Escalante, P.R.; Esse, C.; Chaib, S.; Houahmdi, M.
Distribution of benthic macroinvertebrate communities in different kind of inland water bodies in northeastern Algeria. *Brazilian Journal of Biology,* 22:84:e273662.

González E.R.
2003. Los anfípodos de agua dulce del género *Hyalella* Smith, 1874 en Chile (Crustacea: Amphipoda). *Revista Chilena de Historia Natural*, 76(4): 623-637.

Gotelli N.J.; Graves G.R.
1996. Null models in ecology. Smithsonian Institution Press, Washington, D.C. 357 p.

Gotelli N.J; Ellison A.M.
2013. EcoSimR 1.00. Available at: http://www.uvm.edu/~ngotelli/EcoSim/EcoSim.html

Guterres A.P.M.; Cunha, E.J.; Godoy, B.S.; Silva, R.R.; Juen, L.; 2020.
Co-occurrence patterns and morphological similarity of semiaquatic insects (Hemiptera: Gerromorpha) in streams of Eastern Amazonia. *Ecological Entomology*, 45: 155-166

Moya C.; Valdovinos C.; Moraga A.; Romero F.; Debels P.; Oyanedel A.
2009. Patrones de distribución espacial de ensambles de macroinvertebrados bentónicos de un sistema fluvial Andino Patagónico. *Revista Chilena de Historia Natural*, 82(3): 425-442.

Niemeyer H., Cereceda P.
1984. Hidrografia. Instituto Geográfico Militar, Santiago de Chile. 1-320.

Northland-Leppe I.; Lam N.; Jara-Seguel P.; Capetillo-Arcos, J.
2009. Chromosomes and Ag NOR location in fluviate populations of *Salmo trutta fario* L. 1758 (Salmoniformes: Salmonidae) from Atacama desert, Chile. *Gayana*, 73(1): 45-48.

Oliveira-Junior J.M.; Teodosio M.A.; Juen L.
2021. Patterns of co-occurrence and body size in dragonflies and damselflies (Insecta: Odonata) in preserved and altered Amazonian streams.
Austral Entomology 60: 436-450

Oyanedel A.; Valdovinos C.; Azocar M.; Moya C.; Mancilla G.; Pedreros P.; Figueroa R.
2008. Patrones de distribución espacial de los macro-invertebrados bentónicos de la cuenca del río Aysén (Patagonia Chilena). *Gayana*, 72(2): 241-257.

Pie M.R.; Caron F.S.
2022. Geographical range overlap networks and the macroecology of species co-occurrence. *PLoS ONE* 17: e0266275.

R Development Core Team.
2022. R: a language and environment for statistical computing. (R foundation for statistical computing, Vienna).

Silva A.; Franco L.; Iturra N.
1985. Antecedentes sobre la reproducción y alimentación de la trucha arco iris *Salmo gairdneri* del Embalse Conchi, Antofagasta, Chile. *Biologia Pesquera*, 14: 32-39.

Solis-Lufi K.; Suazo M.J.; Avila-Salem M.E.; Maldonado-Murúa C.; Aponte H.; Farias J.; De los Ríos-Escalante, P.
2022. Community structure of benthic invertebrates in the Allipén river basin, North Patagonia, Araucania region (39º S, Chile). *Brazilian Journal of Biology*, 82: e232805.

Soto D.; Arismendi, I.; Di Prinzio C.; Jara, F.
2007. Establishment of Chinook salmon (*Oncorhynchus tshawytscha*) in Pacific basins of southern South America and its potential ecosystem implications. *Revista Chilena de Historia Natural*, 80(1): 81-98.

Soto D., Arismendi I., González J., Sanzana J., Jara F., Jara C., Guzmán E., Lara, A.
2006. Southern Chile, trout and salmon country: invasion patterns and threat for native species. *Revista Chilena de Historia Natural*, 79(1): 97-117.

Vila I., Fuentes L., Saavedra M.
1999. Ictiofauna en los sistemas límnicos de la isla grande Tierra del Fuego, Chile. *Revista Chilena de Historia Natural*, 72(2): 273-284.

Wetzlar H.
1979. Beiträge zur Biologie und Bewirschaftung von Forellen (Salmo gairdneri und S. trutta) in Chile. Ph.D. Thesis, Universität Freiburg, Germany. 264 p.

Williams W.D.
1998. Salinity as a determinant of the structure of biological communities in salt lakes. *Hydrobiologia* 381: 191-201.

Zhang, M.
2020. The use and limitations of null-model-based hypothesis testing. *Biology & Philosophy*, 35: 31.