

Aquatic Crustaceans in the Driest Desert on Earth: Reports from the Loa River, Atacama Desert, Antofagasta Region, Chile

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1. Introduction

Northern Chile includes the Atacama Desert, which is characterized by scarce, shallow, saline shallow endorheic lakes, small intermittent streams, and a few rivers (Niemeyer & Cereceda, 1984). One of the main rivers of this zone is the Loa River which is 440 km long and is the longest river in Chile. The river basin occupies 33,570 km². Situated in the Antofagasta region of Chile, it originates in the Andes Mountains, close to Bolivia, and receives flow from four tributaries rivers: the Salado, San Pedro, Toconce, and San Salvador Rivers. The Loa basin contains two reservoirs, the Conchi and Sloman (Pumarino, 1978; Niemeyer & Cereceda, 1984; Gutiérrez et al., 1998). Studies of the native Loa aquatic fauna to date have only described the presence of the freshwater shrimp, *Cryphiops caementarius* (Molina, 1782) (Jara et al., 2006), amphipods such as *Hyalella fossamanchini* and *H. kochi* (González, 2003), and the native silverside *Basilichthys near semotilus*; Dyer 2000a,b; Ruiz & Marchant 2004; Vila et al., 2006). Introduced fish taxa in the Loa River and its tributaries include *Oncorhynchus mykiss* and *Salmo trutta* (Pumarino, 1978; Wetzlar, 1979; Iriarte et al., 2005). Overall, there is little detailed information about aquatic species, their distribution, population status, and associations in the Loa River.

The Loa River and its basin are subjected to strong human influences due to water use for mining, domestic needs, and agriculture (Niemeyer & Cereceda, 1984; Gutiérrez et al., 1998). The biological resources of the basin also are known to be under pressure from fishing, particularly in the case of the shrimp, *C. caementarius* (Meruane et al., 2006a,b), and rainbow and brown trout populations (Pumarino, 1978; personal observations). Nevertheless, it is difficult to determine the status of the aquatic fauna in the Loa basin due to a lack of study stemming largely from the inaccessibility of water bodies in northern Chile (Chong, 1988). Our study aims to rectify this lack of knowledge by determining the faunal species inhabiting the Loa River, characterizing species associations along altitudinal and spatial gradients within the river, and testing for regulating factors potentially influencing aquatic community composition.

2. Material and methods

The Loa River originates in the Andes Mountains close to the boundary with Bolivia, and flows first from north to south, proceeds in a westerly direction, changes back to a northerly direction, and finally flows west to its confluence with the Pacific Ocean (Fig. 1). We compiled information from two data sets, one collected during field studies in January 2008 that included nine sites along the Loa River (De los Ríos et al., 2010; Table I), and the other from field studies in 1980 from lower reaches of the Loa River between the outlet to the middle zone. The latter dataset included *C. caementarius* habitat (Alfaro et al., 1980; Table II). Altitude, in meters above sea level, was recorded for all sites. We tested for relationships between species richness and two physical variables, salinity (using a YSI-30 sensor) and altitude, using correlation coefficients (Rho-Spearman), calculated in the software SPSS v.12.

Crustacean community structure was explored using a co-occurrence null model analysis, which tests whether species co-occur less frequently than expected by chance (Gotelli, 2000). A checkerboard score ("C-score") was calculated based upon an absence/ presence matrix, representing a quantitative index of co-occurrence. We used this method for analysis and evaluated results in relation to those of other studies (Tondoh, 2007; De los Ríos et al., 2008; De los Ríos-Escalante, 2011). A community may be structured by competition when the C-score is significantly larger than that expected by chance (Gotelli, 2000, 2001). In order to determine whether a particular score is statistically significant, a set of randomizations of the species occurrence data are performed and a null distribution for the coexistence index is created. Gotelli & Entsminger (1997) Tiho & Johens (2006), and Tondoh (2007), suggested the following three statistical models for creating randomized communities, with the species placed in rows and the sites in columns:

1. Fixed-Fixed Model. In this model, 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).
2. Fixed-Equiprobable Model. In this algorithm only the row sums are fixed and the columns are treated as equiprobable. This null model considers all the samples (column) as equally available for all species.
3. Fixed-Proportion Model. In this algorithm species occurrence totals are maintained as in the original community, and the probability that a species occurs at a site (column) is proportional to the column total for that sample.

All three of these models exhibit fairly reasonable combinations of Type I and Type II error rates, although model 3 has a high Type I error rate (false positives) using the C-score index, with differences in underlying assumptions and behaviour (Gotelli, 2000). The fixed-fixed model is suggested to be most appropriate for island species lists, in which species-area effects are expected, while the fixed-equiprobable model would be most appropriate for standardized samples in a homogeneous environment (Gotelli, 2000). The fixed-proportional algorithm represents an intermediate model, which might be most appropriate in our system due to habitat connectivity and heterogeneity, as well as differences in depth and width along the river. Differing results among models can provide insights into community structure. The null model analysis was using the software ECOSIM, version 7.0 (Gotelli & Entsminger, 1997).

	Santa Bárbara	Conchi	Salado	Chiuchiu	Chacance	Salvador
Geographical location	21° 58.7'	22° 00.5'	20° 20.4'	20° 20.4'	22° 23.8'	22° 23.8'
(South latitude / West longitude)	68° 36.7'	68° 36.7'	68° 39.2'	68° 39.2'	69° 31.6'	69° 31.6'
Altitude (m a.s.l.)	3304	3272	2784	2768	1328	1328
Salinity (g/l)	1.8	1.5	4.2	1.5	8.3	4.8
Cladocera						
<i>Ceriodaphnia dubia</i> (Richard, 1894)		x				
<i>Daphnia pulex</i> (De Geer, 1877)		x				
<i>Chydorus sphaericus</i> (O.F. Müller, 1785)			x			
Copepoda						
<i>Eucyclops serrulatus</i> (Fisher, 1851)		x				
Unidentified cyclopoida			x			
<i>Tigriopus</i> sp.						
Ostracoda						
<i>Heterocypris panningi</i> (Brehm, 1934)			x		x	
<i>Cubacandona</i> spp. (Broodbakker, 1983)						
Amphipoda						
<i>Hyalella fossamanchini</i> (Cavalieri, 1959)	x	x	x			x
<i>H. kochi</i> (González & Watling, 2001)	x	x	x			

Table 1. Geographical location, altitude, conductivity, salinity, and species reported for the studied 2008 sampling period.

3. Results and discussion

Our results revealed the presence of a small number of crustacean species in the Loa River (Table 1). In the Quillagua River, no crustacean species were found, but the introduced fish species *Gambusia affinis* was abundant, whereas in Sloman and Chacance River, only the ostracod *Heterocypris panningi* was detected. By contrast, the Salado River harbored unidentified cyclopoid copepods, the cladoceran *Chydorus sphaericus*, *H. panningi*, and the amphipods *H. fossamanchini* and *H. kochi*. The Conchi Reservoir supported similarly high species richness, with *H. fossamanchini*, *H. kochi*, *Eucyclops serrulatus*, *Ceriodaphnia dubia*, and *Daphnia pulex* (Table I). Among data collected in 1980 in the lower Loa River basin, *H. panningi* was reported at all sites, and unidentified Harpacticoida were reported at all sites except in the Sloman reservoir, and *E. serrulatus* was found in El Borax, La Poroma and Angostura (Table 2).

	Chacance	San Lorenzo	El Borax	Sloman	La Poroma	Angostura	Desembocadura
Geographical location	22° 23.8'	22° 12.0'	21° 06.0'	21° 51.2'	21° 39.0'	21° 36.0'	21° 27.0'
(South latitude / West longitude)	69° 31.6'	69° 24.0'	69° 30.0'	69° 30.9'	69° 30.0'	69° 36.0'	71° 00.0'
Altitude (m a.s.l)	1328	1180	1100	1085	800	700	1.5
Salinity (g/l)	4.99	5.64	6.33	6.33	7.46	7.61	8.72
Cladocera							
Cladocera							
<i>Ceriodaphnia dubia</i> (Richard, 1894)							
<i>Daphnia pulex</i> (De Geer, 1877)							
<i>Chydorus sphaericus</i> (O.F. Müller, 1785)							
Copepoda							
<i>Eucyclops serrulatus</i> (Fisher, 1851)			x		x	x	
Unidentified cyclopoida							
Unidentified harpacticoida sp.	x	x	x	x	x	x	x
Ostracoda							
<i>Heterocypris panningi</i> (Brehm, 1934)	x	x	x		x	x	x
<i>Cubacandona</i> spp. (Broodbakker, 1983)							
Amphipoda							
<i>H. fossamanchini</i> (Cavalieri, 1959)							
<i>H. kochi</i> (González & Watling, 2001)							

Table 2. Geographical location, altitude, conductivity, salinity, and species reported for the studied sites in the Loa River during the 1980 sampling period.

Among data collected in 2008, Spearman rho correlation values indicated no relation between species number and salinity ($r = -0.39$; $P = 0.149$) however, a significant and positive relationship was detected between species richness and altitude ($r = 0.61$; $P = 0.041$) (Table 2). In contrast, among data collected in 1980, the Spearman rho correlation values indicated no relation between species number and salinity ($r = -0.391$; $P = 0.149$) or between diversity and altitude ($r = 0,189$; $P > 0,05$) (Table 3)).

	Salinity	Altitude		
Number of species	R = -0.391; P = 0.149	R = 0.610; P = 0.041		
Results of null model analysis				
Simulation	Observed index	Mean	Standard effect size	P
Fixed-Fixed	1.250	1.132	1.066	0.155
Fixed- Proportional	1.250	1.105	0.443	0.372
Fixed- Equiprobable	1.250	1.873	-2.301	0.982

Table 3. Results of correlation and null-model analyses. Correlation coefficients are provided between species richness and conductivity, salinity, and altitude, respectively, along the Loa River (sampling period 2008). The null-model analysis (see text) suggests that crustacean community structure is random.

The results of the null model analysis among all simulations within 2008 data revealed that crustacean community composition appears to be random (Table 4). However, small sample size can mask other underlying patterns (De los Ríos-Escalante, 2011). A different situation was observed within the 1980 data, where the fixed-proportional denoted the presence of regulatory factors, and the fixed-equiprobable analysis indicated a weak presence of regulator factor presence (Table 4).

Unfortunately chemical and other physical parameters were not measured in situ; however, human influences on the river may be potentially regulatory factors. Such influences have been documented on central Chilean rivers (Figueroa et al., 2003). The upper reaches of the Loa River are subject to lower levels of anthropogenic impact, given that human population size is small in relation to that in the lower reaches, which are subject to urbanization and and mining activities (Alvarez, 1999; Melcher, 2004).

The present literature on Chilean rivers only contains descriptions of invertebrate species associations in south-central rivers, and most studies attempt to use such information for bio-indication of water quality (Figueroa et al., 2003, 2007). These studies generally report differences in macroinvertebrate assemblages (mainly insects and crustaceans) in relation to water pollution along the river courses (Figueroa et al., 2003, 2006). These studies indicate that the fluvial aquatic fauna of Chilean is regulated by deterministic factors, namely water quality as influenced by the level of human alteration (Figueroa et al., 2003, 2006). However, Figueroa et al., (2003, 2006) only described the riverine biota to the family level, and this lack of species-level data precludes more precise statistical treatments of community structure (Gotelli & Graves, 1996; Gotelli & Ellison, 2000; Jaksic, 2001). Our study included only

crustaceans, but emphasized species-level taxonomy, whereas Figueroa et al., (2003, 2006) studied all benthic invertebrates including aquatic insects, which are diverse compared to crustaceans. Future studies of riverine community structure should expand upon our studies in order to include aquatic insects at the species level. Aquatic insects are likely to ecologically interact with crustaceans in fluvial benthic communities, in turn affecting abundances and patterns of co-occurrence among both taxonomic groups (Parra et al, 2001).

Biogeographically, the presence of the amphipods *H. fossamanchini* and *H. kochi* in the Loa River has been previously described by Gonzalez (2003) and Jara et al. (2006). However, those descriptions did not specify details about the localities at which the species were found. Thus, our study presents new information to the knowledge of crustacean distribution. The absence of specimens of the northern river shrimp, *C. caementarius*, indicates that this species is threatened by excessive fishing as human food (Jara et al., 2006), and probably also by the presence of exotic fishes, such as *Gambusia affinis*, *Oncorhynchus mykiss* and *Salmo trutta*. All of those fish species are active predators on native aquatic invertebrates (Leyse et al., 2005).

Regarding the presence of ostracods in Chile, there are currently only records of *H. panningi* and *Cucacandona* spp., which also have been reported for other South American inland waters (Martens & Behen, 1994). Spatial differences in community composition were detected, with the presence of ostracods related to the absence of amphipods in the lower reaches of the Loa River, reaches that exhibit relatively high salinity and conductivity (Table 3). In contrast, the high-altitude zones of the Loa, as well as the Salvador River, have relatively lower salinity, with species associations between the amphipods *H. fossamanchini* and *H. kochi* (Table 1). The presence of microcrustaceans, specifically copepods and cladocerans in Conchi Reservoir, corroborates their distribution as reported in the literature (Araya & Zúñiga, 1985; Reid, 1985, Ruiz & Bahamonde, 1989). Although distributional data denote a segregation of species into low and high altitude reaches (Table 1), with significantly higher species richness at higher altitudes, the null model results suggest that crustacean species associations are random (Table 3). These results are seemingly in disagreement; however, the low total species richness and small number of study sites may preclude the detection of a true underlying pattern (De los Ríos-Escalante, 2011).

Nevertheless, the negative relationship between species richness with salinity and altitude (Table 4), is explained by predation by *C. caementarius* on microcrustaceans (Alfaro et al., 1980; López et al., 1986). This may represent a top-down trophic cascade that affects community structure. This scenario would be similar to descriptions of Chilean (Soto et al., 1994; De los Ríos, 2003) and Argentinean (Reissig et al., 2004) Patagonian lakes. Considering the present results, two main forces likely regulate aquatic community structure: salinity variation and predator presence. Such a combination of factors have been reported in shallow Andean mountain saline and sub-saline lakes (Hurlbert et al., 1986; De los Ríos-Escalante, 2011).

Our results contribute to understanding of the community ecology of inland water invertebrates in northern Chilean streams. Unfortunately, these ecosystems have been understudied to date due primarily to problems of accessibility. Further work on the crustacean and other aquatic faunae of northern Chilean rivers is clearly needed.

	Salinity	Altitude		
Number of species	R = -0.031; P > 0,05	R = 0,189; P > 0,05		
Results of null model analysis				
Simulation	Observed index	Mean	Standard effect size	P
Fixed-Fixed	2.833	2.764	0.272	0.346
Fixed- Proportional	2.833	1.506	1.715	0.039
Fixed- Equiprobable	2.833	1.665	1.523	0.057

Table 4. Results of correlation and null-model analyses. Correlation coefficients are provided between species richness and conductivity, salinity, and altitude, respectively, along the Loa River (sampling period 1980). The null-model analysis (see text) suggests that crustacean community structure is random.

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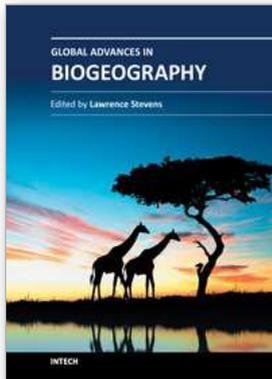
5. References

- Alfaro, D., Bueno G., Mardones A., Neira A., Segovia E. & Venegas E. (1980). Contribución al conocimiento de *Cryphiops caementarius* (molina, 1782) en el Río Loa, Antofagasta. Seminario para optar al título de Ingeniero (E) en Acuicultura. Universidad de Chile. Instituto de Investigaciones Oceanológicas. 58 pp.
- Alvarez, A. (1999). Geo Biografía. Impresos Universitaria S.A., Santiago de Chile. 176 p.
- Araya, J.M. & Zúñiga, L.R. (1985). Manual taxonómico del zooplancton lacustre de Chile. Boletín Limnológico, Universidad Austral de Chile, 8: 1-169 p.
- Chong, G., (1988). The Cenozoic saline deposit of the Chilean Andes between 18°00 and 27°00 south latitude. Lecture Notes on Earth Sciences, 17: 137-151.
- De los Ríos, P., (2003). Efectos de las disponibilidades de recursos energéticos, estructurales y de protección sobre la distribución y abundancia de crustáceos zooplanktónicos lacustres chilenos: 1-163. Doctoral Thesis, Austral University of Chile, Science Faculty.
- De los Ríos, P., (2008). A null model for explain crustacean zooplankton species associations in central and southern Patagonian inland waters. *Anales del Instituto de la Patagonia*, 36: 25-33.
- De los Ríos, P., Rivera N., & Galindo, M. (2008). The use of null models to explain crustacean zooplankton associations in shallow water bodies of the Magellan region, Chile. *Crustaceana*, 81: 1219-1228.

- De los Ríos P., (2008). A null model for explain crustacean zooplankton species associations in central and southern Patagonian inland waters. *Anales del Instituto de la Patagonia* 36: 25-33.
- De los Ríos-Escalante P., (2010). Crustacean zooplankton communities in Chilean inland waters. *Crustaceana Monographs* 12: 1-109 p.
- De los Ríos-Escalante P., (2011). A null model to study community structure of microcrustacean assemblages in northern Chilean shallow lakes. *Crustaceana*, 84: 513-521.
- Dyer, B, (2000a). Systematic review and biogeography of the freshwater fishes of Chile. *Estudios Oceanológicos* 19: 77-98.
- Dyer, B, (2000b). Revisión sistemática de los pejerreyes de Chile (Teleostei, Atheriniformes). *Estudios Oceanológicos* 19: 99-127.
- 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 Historia Natural*, 76: 275-285
- Figueroa, R, Palma A., Ruiz V. & Niell, X., (2007). Análisis comparativo de índices bióticos utilizados en la evaluación de la calidad de las aguas en un río mediterráneo de Chile: río Chillán, VIII Región. *Revista Chilena Historia Natural*, 80: 225-242.
- González, E.R., (2003). Los anfípodos de agua dulce del género *Hyaella* Smith, 1874 en Chile (Crustacea: Amphipoda). *Revista Chilena Historia Natural*, 76: 623-637.
- Gotelli, N.J., (2000). Null models of species co-occurrence patterns. *Ecology*, 81: 2606-2621.
- Gotelli, N.J., (2001). Research frontiers in null model analysis. *Global Ecology and Biogeography*, 10: 337-343.
- Gotelli, N.J. & G.L. Entsminger. (1997). EcoSim: Null models software for ecology. Version 7. Acquired Intelligence Inc. & Kesey-Bear. Jericho, VT 05465.
<http://garyentsminger.com/ecosim.htm>.
- Gotelli, N.J. & Graves, G.R. (1996). Null models in Ecology. Smithsonian Institution Press, Washington, USA, 357 p.
- Gotelli, N.J. & Ellison, A.M. (2000). A primer of Ecological Statistics. Sinauer Associated Inc., Publishers, Sunderland, Massachusetts, U.S.A. 510 p.
- Gutiérrez, J.R., López-Cortés F., & Marquet, P.A. (1998). Vegetation in an altitudinal gradient along the Rio Loa in the Atacama desert of northern Chile. *Journal of Arid Environments*, 40: 383-399
- Hurlbert, S.H., Loayza, W., & Moreno, T., (1986). Fish-flamingo-plankton interactions in the Peruvian Andes. *Limnology & Oceanography*, 31: 457-468.
- Iriarte, A., Lobos G.A., & Jaksic, F. M., (2005). Invasive vertebrate species in Chile and their control and monitoring by governmental agencies. *Revista Chilena de Historia Natural*, 78: 143-151.
- Jaksic, F., 2001. Ecología de Comunidades. Ediciones Pontificia Universidad Católica de Chile, Santiago de Chile.
- Jara, C.G., Rudolph E.H., & González, E.R., (2006). Estado de conocimiento de los malacostráceos dulceacuícolas de Chile. *Gayana (Concepción)*, 70: 40-49.

- Leyse, K., S.P. Lawler & Strange, T., (2005). Effects of an alien fish *Gambusia affinis*, on an endemic fairy shrimp, *Linderella occidentalis*: implications for conservation of diversity in fishless waters. *Biological Conservation*, 118: 57-65
- López, M., Segovia, E., & Alfaro, D., (1986). Microalgas: su importancia como recurso alimentario del Camarón de Río del Norte de Chile, *Cryphiops caementarius* (Molina, 1782). *Medio Ambiente*. 78: 39-47.
- Martens, K. & Behen, F. (1994). A check list of the recent non marine ostracods (Crustacea, Ostracoda) from the inland waters of South America and adjacent islands. Ministerie des Affaires Culturelles. Travaux Scientifiques du Musee National D'Histoire Naturelle de Luxembourg, 1-84 p.
- Melcher, G. (2004). El norte de Chile, su gente, desiertos y volcanes. Editorial Universitaria, Santiago de Chile. 149 p.
- Meruane, J., Rivera J., Morales M., Morales C., Galleguillos C., & Hosokawa, H. (2006a). Juvenile production of the freshwater prawn *Cryphiops caementarius* (Decapoda: Palaemonidae) under laboratory conditions in Coquimbo, Chile. *Gayana (Concepción)*, 70: 228-236.
- Meruane, J., Rivera J., Morales M., Morales C., Galleguillos C., Rivera M.A. & Hosokawa, H. (2006b). Experiencias y resultados de investigaciones sobre el camarón de río del norte *Cryphiops caementarius* (Molina 1782) (Decapoda: Palaemonidae): historia natural y cultivo. *Gayana (Concepción)*, 70: 280-292.
- Niemeyer, H., & Cereceda, P. (1984). Hidrografía. Colección Geografía de Chile, VIII. Military Geographical Institute (Chilean Army), Santiago de Chile. 320 p.
- Parra, O, N. Della Croce & Valdovinos, C. (2001). Elementos de limnología teórica y aplicada. Microart's Edizioni, Italia. 303 pp.
- Pumarino, H., (1978). El Loa de ayer y hoy. Editorial Universitaria, Santiago de Chile. 203 p.
- Reid, J., (1985). Chave de identificao e lista de referencias bibliográficas para as espécies continentais sudamericanas de vida livre da orden Cyclopoida (Crustacea, Copepoda). *Boletim Zoologico da Univerdidade do Sao Paulo*, 9: 17-143.
- Reissig, M., B. Modenutti, Balseiro E. & Queimaliños, C., (2004). The role of the predaceous copepod *Parabroteas sarsi* in the pelagic food web of a large deep Andean lake. *Hydrobiologia*, 524: 67-77.
- Soto D., Campos H., Steffen, W., Parra O., & Zúñiga, L., (1994). The Torres del Paine lake district (Chilean Patagonia): a case of potentially N-limited lakes and ponds. *Archiv für Hydrobiologie*, 99: 181-197.
- Tiho, S. & Johens, J., (2007). Co-occurrence of earthworms in urban surroundings: a null models of community structure. *European Journal of Soil Biology*, 43: 84-90.
- Tondoh, J.E., (2006). Seasonal changes in earthworm diversity and community structure in central Côte d'Ivoire. *European Journal of Soil Biology*, 42: 334-340.
- Ruiz, V. & Marchant, M., (2004). Ictiofauna de aguas continentales chilenas. Dirección de Docencia, Universidad de Concepción. 356 pp.
- 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. *Biología Pesquera*, 14: 32-39.

- Vila, I., Pardo, R. , Dyer, B. , & Habit, E. , (2006). Peces limnicos: diversidad, origen y estado de conservación. In: Vila I, A Veloso, R Schlatter & C Ramírez (Eds). *Macrófitas y vertebrados de los sistemas límnicos de Chile*. Editorial Universitaria, Santiago de Chile, 73-102 p.
- Wetzlar, H. (1979). *Beiträge zur biologie und bewirtschaftung von Forellen (Salmo gairdneri und S. trutta) in Chile*. PhD Thesis, Universität Freiburg, 1-264 p.



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