






## Community structure of invertebrate fauna in Central Chilean Rivers

Estrutura da comunidade de invertebrados em rios da região central do Chile

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**Abstract: Aim:** River systems of Central Chile are short, steep and fast flowing. They are characterized by discharge regimes dominated by rainfall and snowmelt. Invertebrate fauna is highly endemic. This study aimed to describe the community structure of invertebrate in eight river systems in Central Chile (33-39°S) using species co-occurrence and niche sharing null models. **Methods:** Invertebrate samples were collected from Central Chilean rivers (33-39°S), data were analyzed co-occurrence species and niche sharing null models for determine potential structuring patterns. **Results:** 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 presence of many repeated species in the studied sites. Furthermore, we found the existence of niche overlap due to interspecific competition at each site and among all sites. The results obtained from these river systems corroborate observations from Chilean Patagonian Rivers. **Conclusion:** This study contributes to understanding of biogeographical and ecological patterns of invertebrate communities in central Chilean Rivers and provide foundations for more complex ecological studies.

**Keywords:** fluvial ecosystems; zooplankton; aquatic insects; crustaceans; null models.

**Resumo: Objetivo:** Os sistemas fluviais do Chile central são curtos, íngremes e fluem rapidamente. Eles são caracterizados por regimes de descarga dominados por chuvas e neve derretida. A fauna de invertebrados desses sistemas fluviais é altamente endêmica. O objetivo do presente estudo foi descrever a estrutura da comunidade de invertebrados em oito sistemas fluviais na região central do Chile (33-39°S), utilizando co-ocorrência de espécies e modelos nulos de compartilhamento de nichos. **Métodos:** Amostras de invertebrados foram coletadas de rios chilenos centrais (33-39 ° S), os dados foram analisados com as espécies de coocorrência e os modelos nulos de compartilhamento de nichos para determinar potenciais padrões de estruturação. **Resultados:** Os resultados revelaram a presença de padrões não estruturados em coocorrência, considerando cada local, bem como todos os locais,



que é mais provavelmente um efeito da presença de muitas espécies repetidas nos locais estudados. A sobreposição de nicho revelou a existência de competição interespecífica em cada local e entre locais. Os resultados obtidos para estes sistemas fluviais corroboram observações dos rios patagônicos chilenos. **Conclusões:** O presente estudo contribui para a compreensão dos padrões biogeográficos e ecológicos das comunidades de invertebrados nos rios da região central do Chile e, como tal, constitui a base para estudos ecológicos mais complexos.

**Palavras-chave:** ecossistemas fluviais; zooplâncton; insetos aquáticos; crustáceos; modelos nulos.

## Introduction

Freshwater invertebrate fauna of Chile is characterized by low species number, high endemism at regional scale and the highest species richness in lacustrine systems between 39-41°S (Soto & Zúñiga, 1991; De los Ríos-Escalante et al., 2013, 2015a). Many Chilean rivers and streams at latitudes above 33°S originate from glacial lakes (Niemeyer & Cereceda, 1984; De los Ríos-Escalante, 2010) and their zooplankton communities are highly influenced by lake-dwelling species that are transported downstream by the outflow. Similar pattern has been observed for rivers in North America and Europe (Havel & Shurin, 2004; Walks & Cyr, 2004) and southern systems in Patagonia (De los Ríos-Escalante et al., 2015b, 2016). Previous studies have also reported that the presence of recurrent species over a wide gradient of latitudes dominates the biogeographical pattern of zooplankton invertebrates in Chilean freshwaters (Bayly, 1992; Menu-Marque et al., 2000; De los Ríos-Escalante et al., 2013). Still, our knowledge on invertebrate fauna community ecology in Chilean rivers and specific environmental drivers remains poor (De los Ríos-Escalante et al., 2015a, b).

Community structure describes the community composition, richness and abundance of species. Null models became a powerful statistical tool to describe the ecological mechanisms that drive the structure of an ecological community and underlying diversity patterns. Null models for species co-occurrence assume a random pattern of species associations (Tiho & Josens, 2007), and the absence of niche overlap, that is no interspecific competition (Gotelli & Ellison, 2013; Carvajal-Quintero et al., 2015)

Central Chilean rivers accommodate multiple invertebrate species of high conservation value and, at the same time, are marked by human intervention e.g., urbanization, flow regime alterations due to hydropower developments, intensified land use and water withdrawal for irrigation due to agricultural activities (Figueroa et al., 2013). Therefore, the area allows assessment of both environmental and

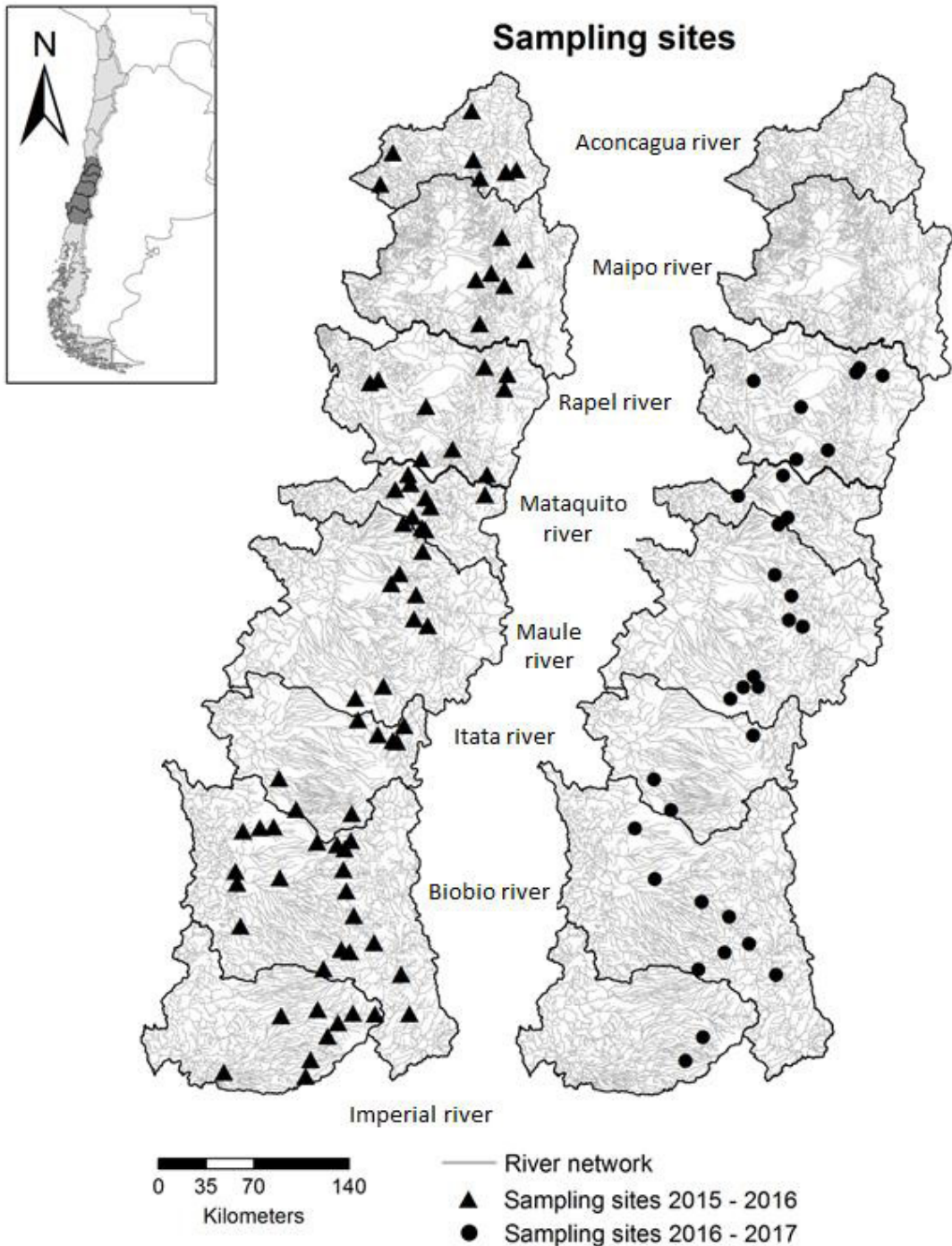
ecological factors that drive community structure of riverine invertebrate. This study aimed describe the community structure of invertebrate fauna in rivers of Central Chile (33-39°S) using species richness and null models based on species presence/absence and niche overlap.

## Material and Methods

Studied sites are located in Central Chilean Rivers at latitudes of 33-39°S. Invertebrate fauna samples were collected during two sampling campaigns, the first between December 2015 and May 2016 and the second between December 2016 and February 2017 (Table 1; Figure 1). Invertebrate fauna was collected by filtering 60 L of water collected just below the surface using a 10L bucket through a 45 µm mesh net (De Los Ríos-Escalante et al., 2015a, b). The material retained on the net was preserved in 60-70% ethanol (final concentration). Specimens were identified in the laboratory according to identification keys in Araya & Zúñiga (1985), González (2003), and Domínguez & Fernandez (2009).

Data on dissolved oxygen concentrations, conductivity, total dissolved solids, pH, temperature and turbidity were also collected in studied sites. An equipment failure did not allow sampling of dissolved oxygen in the second campaign.

The dependent and independent variables were used in multiple regression analyses using software R (R Development Core Team, 2009) and the HSAUR R package (Everitt & Hothorn, 2016). We ran two models: first one using species number and the second one using total abundance as dependent variable. Furthermore, we built a species presence/absence matrix. It calculated the Checkerboard score ("C-score"). C-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; Tondoh, 2006; Tiho & Josens, 2007). Consequently, we compared co-occurrence



**Figure 1.** Location of sampling sites in the study area.

patterns with null expectations via simulation using statistical Fixed-Fixed null models (Gotelli & Ellison, 2013). In this model the row and column sums of the matrix are preserved and, each random community contains the same number of species (fixed column) and each species occurs with the same frequency as 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 & Ellison, 2013; Carvajal-Quintero et al., 2015).

We calculated the niche overlap using Pianka index calculated on an individual matrix with rows representing species and columns representing sites. This index was used to test if niche overlap significantly differed from corresponding value

Table 1. Geographical coordinates included in the present study.

Site	Latitude	Longitude	Site	Latitude	Longitude	Site	Latitude	Longitude
Aconcagua 1	32°54'05.00"S	70°14'41.78"W	Mataquito 1	35° 02'57.90"S	70°31'44.46"W	Biobio 15	37°29'43.51"S	72°38'57.01"W
Aconcagua 2	32°54'57.63"S	70°19'38.14"W	Mataquito 2	34°58'03.67"S	71° 07'37.63"W	Biobio 17	37°39'03.79"S	71°44'07.37"W
Aconcagua 3	32°49'55.82"S	70°34'52.28"W	Mataquito 3	35°15'35.25"S	71° 02'37.28"W	Biobio 18	38° 02'14.07"S	71°47'27.81"W
Aconcagua 4	32°57'15.41"S	70°31'54.78"W	Mataquito 4	35°11'04.18"S	71° 06'58.08"W	Biobio 19	38° 03'09.99"S	71°43'23.60"W
Aconcagua 5	32°30'27.43"S	70°35'19.98"W	Mataquito 5	35° 07'25.69"S	70°58'03.36"W	Biobio 20	37°30'33.51"S	71°45'19.06"W
Aconcagua 6	32°46'34.91"S	71°12'43.47"W	Mataquito 6	35° 00'17.38"S	71°15'02.27"W	Biobio 21	37°33'02.63"S	72°17'05.06"W
Maipo 1	33°40'04.28"S	70°21'3.10"W	Mataquito 7	35° 03'42.28"S	71° 00'30.68"W	Biobio 22	37°20'32.70"S	71°48'00.30"W
Maipo 3	33°34'56.91"S	70°27'07.85"W	Mataquito 8	35°16'28.04"S	71° 00'51.52"W	Biobio 23	37°22'24.18"S	71°44'23.48"W
Maipo 4	33°20'57.83"S	70°21'54.21"W	Mataquito 10	34°54'26.47"S	71° 08'42.82"W	Biobio 24	37°19'04.02"S	71°41'08.51"W
Rapel 1	34°48'10.89"S	71° 02'03.88"W	Itata 1	36°34'04.62"S	71°13'25.94"W	Biobio 25	37°19'18.78"S	71°57'54.56"W
Rapel 2	34°44'41.96"S	70°46'55.14"W	Itata 2	36°40'22.87"S	71°17'01.00"W	Imperial 1	38°27'37.80"S	71°42'30.50"W
Rapel 3	34°27'26.25"S	70°59'22.08"W	Itata 3	36°39'53.88"S	71°19'01.29"W	Imperial 2	38°31'16.84"S	71°50'17.03"W
Rapel 4	34°16'35.93"S	71°21'53.89"W	Itata 4	36°37'23.12"S	71°26'18.90"W	Imperial 3	38°28'18.53"S	71°31'31.91"W
Rapel 5	34°21'07.85"S	70°21'39.30"W	Itata 5	36°31'21.10"S	71°35'55.83"W	Imperial 4	38°25'48.47"S	72° 00'21.84"W
Rapel 6	34°15'18.84"S	70°20'07.66"W	Itata 6	37° 08'24.32"S	71°40'15.20"W	Imperial 5	38°27'40.43"S	72°18'44.15"W
Rapel 7	34°12'17.95"S	70°31'4.04"W	Itata 7	37° 06'02.69"S	72° 07'49.27"W	Imperial 6	38°49'13.26"S	72°48'55.84"W
Rapel 9	34°14'06.89"S	70°32'45.19"W	Itata 8	37°12'49.01"S	72°26'04.71"W	Imperial 7	38°45'37.64"S	72° 04'47.26"W
Rapel 10	34°55'30.35"S	70°29'45.16"W	Itata 9	36°53'31.50"S	72°15'44.55"W	Imperial 8	38°36'26.20"S	71°55'41.58"W
Maule 1	35°37'35.94"S	71°18'00.54"W	Biobio 1	38°28'23.60"S	71°14'10.14"W	Imperial 9	38°52'05.40"S	72° 07'26.14"W
Maule 3	36°18'08.94"S	71°23'06.35"W	Biobio 2	38°12'40.03"S	71°17'47.86"W			
Maule 4	36°22'38.08"S	71°36'54.14"W	Biobio 3	37°59'56.18"S	71°30'55.16"W			
Maule 5	35°24'58.39"S	71° 02'27.69"W	Biobio 5	37°49'02.76"S	71°40'37.51"W			
Maule 6	35°13'50.47"S	71°11'26.65"W	Biobio 7	37°12'39.31"S	72°19'15.78"W			
Maule 7	35°54'30.91"S	71° 00'44.05"W	Biobio 8	37°12'49.01"S	72°26'4.71"W			
Maule 8	35°42'18.92"S	71° 06'1.33"W	Biobio 9	37°13'55.11"S	72°34'25.46"W			
Maule 9	35°51'47.75"S	71° 07'19.47"W	Biobio 10	38° 09'37.90"S	71°56'43.91"W			
Maule 10	35°33'41.27"S	71°13'47.40"W	Biobio 13	37°51'34.99"S	72°37'33.85"W			
			Biobio 14	37°34'36.91"S	72°38'17.91"W			

under the null hypothesis (random assemblage). The model allows to evaluate the probability of the calculated niche overlap differing from the theoretically simulated community (Gotelli & Ellison, 2013). In the model, the niche amplitude can be fixed or reshuffled. A fixed amplitude preserves the specialization of each species, whereas a reshuffled amplitude uses a wide utilization gradient of specialization. Furthermore, the presence of zeros 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). RA3 algorithm retains the amplitude and reshuffles the zero conditions (Gotelli & Ellison, 2013). The null model analysis were carried out using the software R (R Development Core Team,

2009) and the package EcosimR (Gotelli & Ellison, 2013; Carvajal-Quintero et al., 2015).

## Results and Discussion

Overall, the abundance of invertebrate fauna was very low and characterized by a limited numbers of species (Table 2). For the first sampling period (2016), significant inverse associations were observed between species richness and turbidity, total number of individuals and conductivity as well as total number of individuals and turbidity (Table 3), whereas for second sampling period there were no significant associations with environmental variables (Table 3). These results suggest higher species number in less polluted waters often characterized by low turbidity and low mineral content (Figuroa et al., 2003, 2007).

**Table 2.** List of taxa reported for two sampling periods.

Taxa reported in 2016	Taxa reported in 2017
Turbellaria	Mollusca
Turbellaria indet.	Gastropoda indet.
Nematoda	Insecta
Nematora indet.	Ephemeroptera
Insecta	Baetidae indet.
Ephemeroptera	Leptophlebiidae indet.
<i>Asthenops</i> sp.	Diptera
<i>Coryphorus</i> sp.	Chironomidae indet.
<i>Chaquihua</i> sp.	Diptera indet.
<i>Hagenulopsis</i> sp.	Plecoptera
Ephemeroptera indet.	Notoneuridae indet.
Plecoptera	Trichoptera
<i>Austronemura</i> sp.	Trichoptera indet.
Coeloptera	Crustacea
Ptilodactylidae indet.	Branchiopoda
Elmidae indet.	<i>Daphnia</i> sp.
Coleoptera indet.	Copepoda
Diptera	<i>B. gracilipes</i>
Ceratopogonidae	Calanoid copepodites
Blepharicidae indet.	Ostracoda
Chironomidae indet.	Ostracoda indet.
Ephidridae indet.	Amphipoda
Diptera indet	<i>Hyalella</i> sp.
Acari	
Acari indet.	
Crustacea	
Branchiopoda	
<i>Daphnia ambigua</i> Scourfield, 1947	
<i>Chydorus sphaericus</i> O.F. Müller 1776	
Copepoda	
<i>Boeckella gracilipes</i> Daday, 1902.	
Cyclopoid copepodites	
Ostracoda	
Ostracoda indet.	



The results of null model analysis revealed that species associations in all sites and for each river are random (Table 4 and 5). The niche overlap null model revealed that species have niche sharing and in consequence interspecific competition both among rivers and within each river exist (Table 4 and 5).

**Table 3.** Results of the model averaging for selection of the variables with the highest contribution to the species number.

	Temperature	pH	Conductivity	Turbidity
Species richness				
2016	-0.0007 (P = 0.980)	-0.2478 (P = 0.120)	-0.0003 (P = 0.595)	-0.1000 (P = 0.007)*
2017	-0.0756 (P = 0.111)	0.3561 (P = 0.378)	0.0004 (P = 0.658)	-0.0073 (P = 0.164)
Total individuals				
2016	-0.1539 (P = 0.272)	-0.6619 (P = 0.382)	0.0068 (P = 0.023)*	-0.4010 (P = 0.024)*
2017	-0.2236 (P = 0.264)	0.3297 (P = 0.848)	0.0005 (P = 0.911)	-0.0211 (P = 0.348)

\*Significant associations (P < 0.05); P = probability level.

**Table 4.** Results of null models for data of first sampling period.

Species co-occurrence				
	Mean index	Observed index	Variance	P
Total	16.79	16.78	0.05	0.49
Aconcagua	2.00	1.43	0.05	0.14
Maipo	2.00	1.43	0.05	0.14
Rapel	2.06	1.83	0.01	0.08
Maule	2.67	2.46	0.01	0.05
Mataquito	0.46	0.51	<0.01	0.99
Itata	3.60	3.54	0.04	0.36
Biobio	3.15	3.10	<0.01	0.32
Imperial	1.13	1.24	0.01	0.84
Niche sharing				
	Mean index	Observed index	Variance	P
Total	0.55	0.38	< 0.01	<0.01*
Aconcagua	0.55	0.38	< 0.01	<0.01*
Maipo	0.55	0.39	< 0.01	<0.01*
Rapel	0.55	0.38	< 0.01	<0.01*
Maule	0.55	0.39	< 0.01	<0.01*
Mataquito	0.55	0.38	< 0.01	<0.01*
Itata	0.55	0.38	< 0.01	<0.01*
Biobio	0.55	0.39	< 0.01	<0.01*
Imperial	0.55	0.39	< 0.01	<0.01*

\*Significant associations (P < 0.05); P = probability level.

**Table 5.** Results of null models for data of second sampling period.

Species co-occurrence				
	Mean index	Observed index	Variance	P
Total	6.03	5.90	0.01	0.19
Rapel	0.83	0.83	0.00	0.99
Maule	1.33	1.06	0.01	0.20
Mataquito	1.33	1.06	0.01	0.20
Itata	1.61	1.57	<0.01	0.64
Biobio	2.90	2.87	<0.01	0.45
Niche sharing				
	Mean index	Observed index	Variance	P
Total	0.55	0.39	<0.01	<0.01*
Rape	0.55	0.39	<0.01	<0.01*
Maule	0.55	0.39	<0.01	<0.01*
Mataquito	0.55	0.39	<0.01	<0.01*
Itata	0.55	0.39	<0.01	<0.01*
Biobio	0.55	0.39	<0.01	<0.01*

\*Significant associations (P < 0.05); P = probability level.

The null model results revealed random presence that is probably due the presence of few species, their low abundance and repetition of species among studied sites. Similar patterns were observed in Patagonian rivers (De los Ríos-Escalante et al., 2015b; De los Ríos-Escalante, 2016). Nevertheless, the results of niche sharing revealed that the reported species share their niches, and they are expected to have interspecific competition (Kamjunke et al., 2009, 2012; Muñoz-Pedrerros et al., 2013; De los Ríos-Escalante & Woelfl, 2017). Furthermore, due to low productivity of these systems, complex trophic interactions (Gray, 2005; Ings et al., 2009; Woodward et al., 2010; Schmid-Araya et al., 2012). Similar processes were observed in some northern Patagonian rivers in Chile and Argentina where low diversity but complex trophic interactions were reported (Encina et al., 2017; Vega et al., 2017; Alvear et al., 2007; Pascual & Ciancio, 2007). Present study contributes to understanding of biogeographical and ecological patterns of invertebrate communities in central Chilean rivers and as such forms foundations for more complex ecological studies.

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