Crustacean communities in coastal ephemeral pools in the Araucanía region (38° S, Chile)

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Abstract

The fauna communities of ephemeral pools in southern Chile are characterized by heterogeneity of crustacean taxa; nevertheless, no detailed studies exist of their community structure. The aim of the present study was to analyze the crustacean community structure in two groups of ephemeral pools (Puaucho and Nigue pools) in the coastal zone of the Araucanía region. A correlation matrix was made by species abundance against temperature, conductivity, pH and total dissolved solids. In a second step, a null model for species co-occurrence was applied to the total data and to each group. The results for total data revealed a significant direct relation between the abundance of *H. costera, C. dubia* and *Mesocyclops*. For the Puaucho pools, the same results were found together with direct associations with total dissolved solids, conductivity and pH. Finally, different results were found for the Nigue pools, with no clear significant associations, either direct or indirect, between the abundance of different crustacean taxa and abiotic parameters. These results were supported by the co-occurrence null model analysis, which revealed the presence of regulator factors for the total data, and for each of the two groups. Ecological topics are discussed with emphasis on meta-community dynamics.

Keywords: cladocerans, copepods, ostracods, amphipods, communities.

Comunidades de crustáceos em lagoas efêmeras costeiras na região de Araucanía (38° S, Chile)

Resumo

As comunidades faunísticas das lagoas efêmeras do sul do Chile são caracterizadas pela heterogeneidade dos seus táxons. Entretanto, estudos detalhados da sua estrutura de comunidade ainda não existem. O objetivo do presente estudo foi analisar a estrutura da comunidade de crustáceos em dois grupos de lagoas efêmeras (Puaucho e Nigue) na zona costeira da região de Araucanía. A matriz de correlação foi feita com a abundância das espécies em função da temperatura, condutividade, pH e sólidos totais dissolvidos. Num segundo passo, um modelo nulo para as espécies de coocorrência foi aplicado aos dados totais e para cada grupo. Os resultados para os dados totais revelaram uma relação direta e significativa entre a abundância de *H. costera, C. dubia* e *Mesocyclops*. Para as lagoas Puaucho, os mesmos resultados foram encontrados, juntamente com associações diretas com sólidos totais dissolvidos, condutividade e pH. Finalmente, diferentes resultados foram encontrados para as lagoas Nigue, sem associações significativas claras, diretas ou indiretas entre a abundância de diferentes táxons de crustáceos e parâmetros abióticos. Estes resultados foram suportados pela análise de modelo de coocorrência nula, a qual revelou a presença de fatores reguladores para o total de dados, e para cada um dos dois grupos. Temas ecológicos são discutidos com ênfase na dinâmica de meta-comunidade.

Palavras-chave: cladóceros, copépodes, ostrácodes, anfípodes, comunidades.

1. Introduction

Ephemeral pools are characterized by the presence of species adapted to environments characterized with drying periods. These species present diapause egg production: development is suspended during the dry period and the eggs hatch when the lagoon fills (Schwartz and Jenkins, 2000; Spencer and Blaustein, 2001; Altermatt, 2008). The principal groups are crustaceans such as Branchiopods and some Copepods (Spencer and Blaustein, 2001).

From an ecological view point, these kinds of environments are well-suited to the study of meta-population and meta-community models, because if they are located close to one another, or are connected during determined periods, migrations can occur during which individuals are exchanged. These results in local colonization and extinction processes (Gotelli, 2000, 2001). Furthermore, from the bio-geographical angle, these kinds of habitats are important for understanding species dispersion caused by the carriage of dormant cysts by natural agents such as aquatic birds or wind (Spencer and Blaustein, 2001). This would generate consequences in the genetic structure of populations (Gajardo et al., 1995, 2004) and species dispersion over large distances (Menu-Marque et al., 2000). Based on this information, the populations of a group of small, and shallow ponds located close together will be similar due to exchanges of individuals, and the ecological units in these microhabitats will differ from those found in other similar but distant groups of shallow lagoons (De los Ríos-Escalante, 2012).

In Chile there are a number of plains with groups of shallow lagoons located close together, for example in the Magallanes Region (51-54°S), Balmaceda plains (46°S) and small plains in the coastal and mountain zones of the Araucanía Region, where the principles of meta-populations and meta-communities ecology can be applied (De los Ríos-Escalante, 2012). The literature describes the presence mainly of cladocerans of genus *Daphnia* and copepods of genus *Boeckella*, (De los Ríos-Escalante et al., 2010; De los Ríos-Escalante, 2012). In the south of Chile (46-54° S), the main representative species in ephemeral pools would be *B. poppei* (Mrázek, 1901), *Daphnia dadayana* Paggi, 1999 and *Parabroteas sarsi* (Ekman, 1905) (De los Ríos-Escalante et al., 2010), whereas in the Araucanía Region the main species would be *D. pulex* Leydig, 1860, and *B. gracilis* (Daday, 1902) (De los Ríos-Escalante, 2012). The aim of the present study was to compare two groups of lagoons located in the Araucanía Region in order to understand the existence of potential regulator mechanisms for crustacean community structure.

2. Material and Methods

Study site: two groups of shallow ephemeral pools (depth < 1 m, area < 1 km2; Figure 1), these lagoons are located in two plains that have the groups of pools relatively closely at 500 average distance each one. These groups were studied: the first group is located in a pristine coastal sand plain called Puaucho, south of the town of Puerto Saavedra; the second is located south of the village of La Barra. This zone is subject to human intervention due to forestry and agriculture (Figure 1). For this study it considered six and five groups for both groups of sites respectively (Figure 1), and considering their relatively close distance between lagoons and between groups of lagoons it would have homogeneity at species composition in both groups and it would have not risk of collect new species in lagoons of first group with six lagoons, in comparison to second group with five lagoons (Figure 1), similar situation has been reported for systems of close water bodies in Chilean Patagonia (Soto and De los Ríos, 2006; De los Ríos and Roa, 2010). In previous observations between 2009 and 2011 these groups of lagoons were present during early and middle southern spring (September to October; De los Ríos-Escalante et al., 2010); during late spring and summer they are dry, and the filling occurs during the rainy season in autumn and winter.

Field works and sample analysis: micro-crustacean samples for both groups of sites were taken from pelagial and littoral zones using the descriptions of Soto and De los Ríos (2006) who proposed that these ponds due its low depth (< 1 m) and wind exposition have homogeneous composition in littoral, pelagial, surface and bottom communities, in this context it filtered a volume of 5-10 L at 100 m into a plastic recipient. Collected specimens were fixed with absolute ethanol, identified with help of specialized literature (Araya and Zúñiga, 1985; Reid, 1985; Bayly, 1992; González, 2003) quantified under stereoscopic microscope and deposited in the Catholic University of Temuco. Temperature, conductivity, total dissolved solids and pH were measured *in situ* using a Hanna sensor HI98130, and the geographical location was determined using a Garmin GPS.

2.1. Data analysis

Temperature, pH, total dissolved solids and conductivity were analyzed, using Xlstat 6.0 software, to determine the grouping variables using a principal component analysis (PCA). In the second step, a Checkerboard score ("C-score") was calculated, which 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). Finally the co-occurrence patterns were compared with null expectations via simulation. Gotelli and Entsminger (2007) and Gotelli (2000) suggested the following robust statistical null models: (1) Fixed-Fixed: 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: in this algorithm only the row sums are fixed and the columns are treated as equiprobable. This null model considers all the samples (columns) as equally available for all species. (3) Fixed-Proportional: in this algorithm the species occurrence totals are maintained as in the original community, and the probability that a species will occur at a site (column) is proportional to the column total for that sample. The null model analyses were performed using Ecosim version 7.0 software (Gotelli and Entsminger, 2007; Tiho and Josens, 2007; Tondoh, 2006).

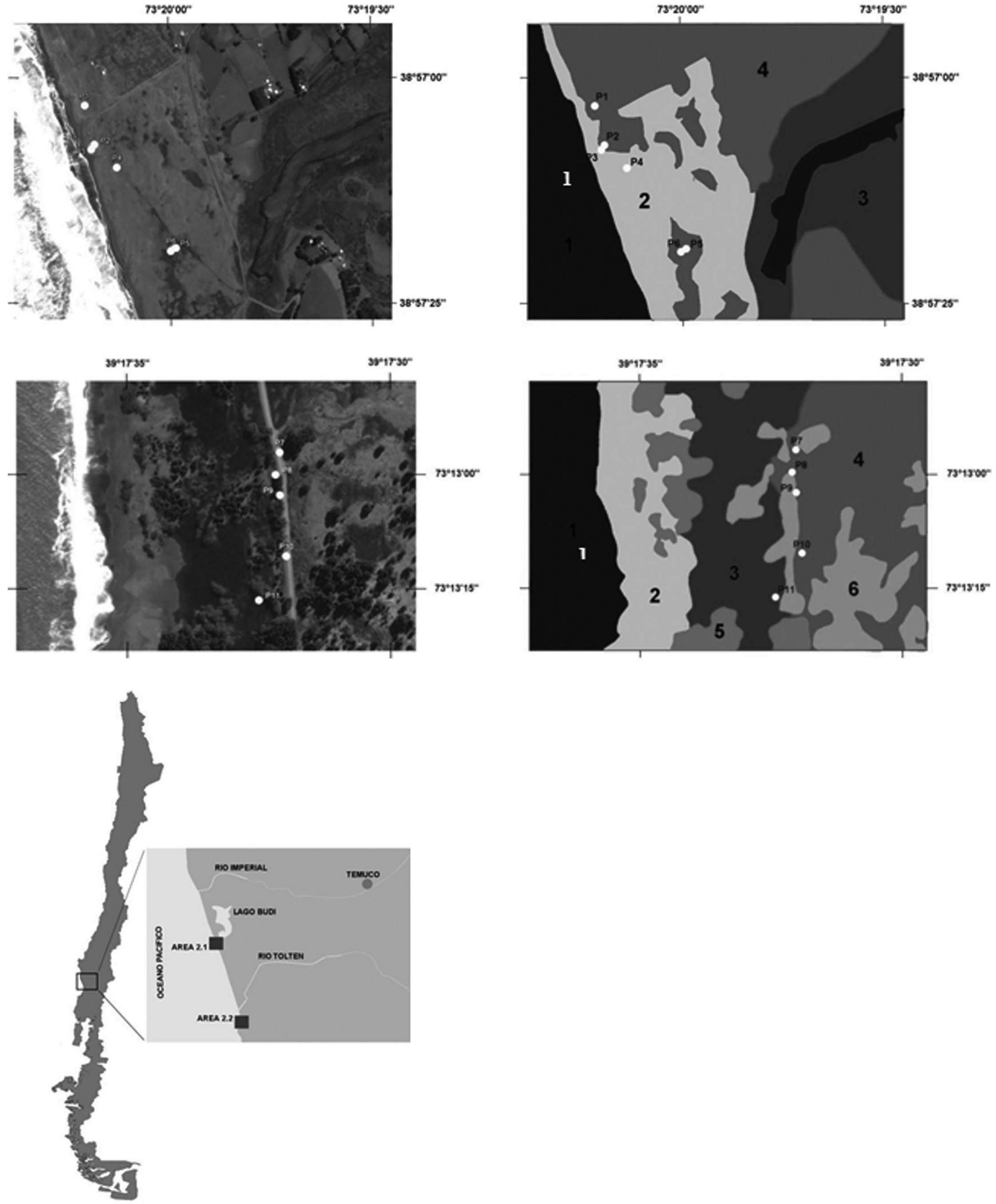

Figure 1. Map and description of the sites studied (Gray gradient denotes kind of surface: 1: water; 2: sand and dunes; 3: wetlands; 4: agricultural zones and prairies; 5: forestry areas; 6: scrub).

3. Results

The results revealed that the sites have a relatively neutral pH, low mineral content and low species number (Table 1); the species number is lower in the Nigue pools than the Puaucho pools (Table 1). The main species reported for the Puaucho pools were *Ceriodaphnia dubia* Richard, 1894, *Chydorus sphaericus* (O.F. Müller, 1785), *B. gracilis* (Daday, 1902), *Mesocyclops araucanus* (Pilati and Menu-Marque, 2003) and *Hyalella costera* (González and Wattling, 2001), whereas for the Nigue pools the main species reported were *D. ambigua* Scourfield, 1947, *C. sphaericus, C. dubia* and *Eucyclops macrurus* (Sars, 1863)(Table 1).

The correlation analysis of the total data revealed direct significant correlation of *C. dubia* with *M. araucanus*;

C. dubia with Harpacticoids; and *C. dubia* with *H. costera*. Similar results were also reported for *E. macrurus* with total dissolved solids and conductivity; *M. araucanus* with Harpacticoida and *H. costera*; and *P. fimbriatus chiltoni* with pH (Table 2). Significant inverse correlations were reported for *C. sphaericus* with conductivity; and *C. sphaericus* with total dissolved solids. Similar results were reported for *B. gracilis* with pH; and pH with *Cypris* sp. (Table 2).

About percentage of contribution for first axis the most important variables were total dissolved solids, conductivity and temperature (Table 3, Figure 2), whereas for second axis were *C. dubia, C. sphaericus, M. araucanus, Cypris* sp., Harpacticoida and *H. costera* (Table 3, Figure 2). The results of PCA revealed three main groups, a first group of Puaucho pools 1; 2; 3 and 4 with low TDS, conductivity and pH, high temperature and high abundance of *Ch. sphaericus, B. gracilis* and *Cypris* sp.; a second group with Puaucho pools 5 and 6 with relatively moderate to low TDS, conductivity and pH but high abundance of *C. dubia, M. araucanus, H. costera,* and Harpacticoida; and a third group with Nigue pools with high pH, TDS, conductivity, and temperature, but high abundance of *E. macrurus, D. ambigua,* and *P. fimbriatus chiltoni* (Figure 2).

The results of the co-occurrence null model analysis revealed the presence of regulator factors for total data, and for the data from each site (Table 4), that would agree with the results of PCA analysis of strong driving force for crustacean communities.

4. Discussion

The results revealed the presence of marked significant regulator factors in crustacean assemblages in both groups of habitats. The literature indicates that chlorophyll and conductivity would be the main regulator factors in crustacean assemblages in Chilean lakes and ponds (De los Ríos-Escalante, 2010), and similar results are found in Argentinean lakes (Quiros and Drago, 1999). Although the present results did not include chlorophyll concentration, the presence of daphnid cladocerans, such as *D. ambigua* and *C. dubia*, and cyclopoid copepods would indicate the presence of relatively moderate chlorophyll concentrations (Jeppesen et al., 1997, 2000; De los Ríos and Soto, 2009; De los Ríos-Escalante, 2010). These results would not be supported by the inverse relation between *C. dubia* and *B. gracilis*, since calanoid copepods are more dominant than daphnid cladocerans in markedly oligotrophic environments in southern Argentinean and Chilean lakes (Modenutti et al., 1998; De los Ríos and Soto, 2009; De los Ríos-Escalante, 2010), and likewise in New Zealand lakes (Jeppesen et al., 1997, 2000).

The presence of *H. costera* in ephemeral pools in Chile was not reported in previous studies, which described the presence of this species in permanent lakes, rivers and lagoons (De los Ríos-Escalante et al., 2012). The literature indicates that *Hyalella* genus inhabits zones with high organic matter (Vainola et al., 2008), and this would agree with the direct

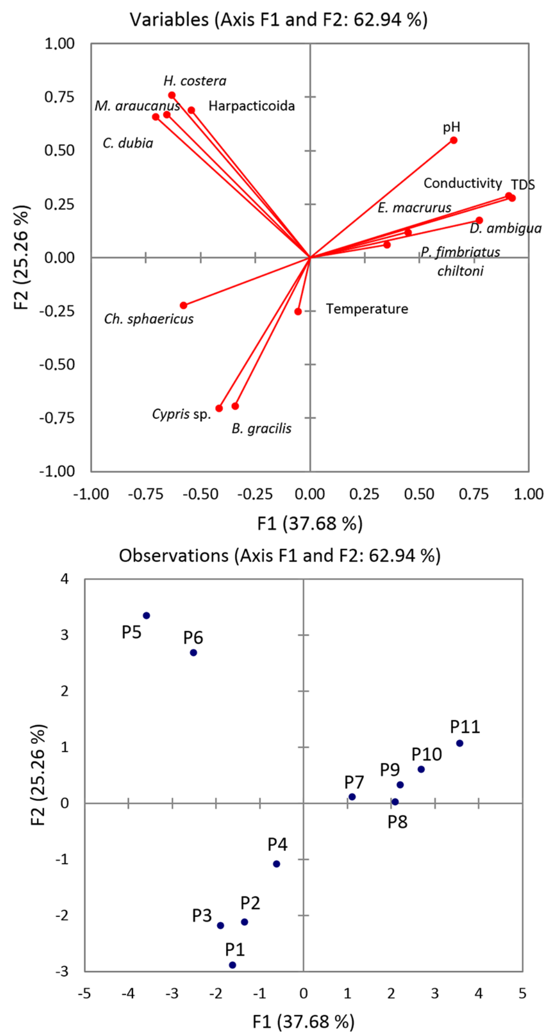

Figure 2. Results of PCA for studied sites.

association between *H. costera* and *C. dubia* obtained in the present study. These results would agree with similar observations for Andean ephemeral pools (De los Ríos and Roa, 2010) and southern Patagonian water bodies (De los Ríos-Escalante et al., 2010), where daphnid cladocerans can be found coexisting with species of the genus *Hyalella*. The presence of direct and indirect associations of some species with conductivity, total dissolved solids and pH would probably be due to the importance of calcium concentrations for crustaceans. Some of these groups have high calcium requirements for their shells, and are therefore not found under acid pH conditions (Bos et al., 1996; Alstad et al., 1999; Waervagen et al., 2002).

These temporary ponds are formed during the rainy season and disappear during the dry season, leading to local processes of species colonization and extinction (Keeley and Zedler, 1998; Eitam et al., 2004; Altermatt, 2008; Vignatti et al., 2012). In South America, seasonal ponds have been studied in central Argentina where they present

Table 1. Geographical location, conductivity, total dissolved solids (TDS), pH, temperature and species abundance (ind/L) for each site included in the present study.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
	38º 57'03.9"; 73º20'12.3"W	**38º57'08.5"S; 73º20'10.7"W**	**38º57'08.8"S; 73º20'10.9"W**	**38º57'11.0"S; 73º20'07.1"W**	**38º57'20.1"S; 73º19'58.3"W**	**38º57'20.4"S; 73º19'58.6"W**	**39º17'28.9"S; 73º13'06.5"W**	**39º17'29.9"S; 73º13'06.7"W**	**39º17'30.8"S; 73º13'06.4"W**	**39º17'33.5"S; 73º13'05.9"W**	**39º17'35.5"S; 73º13'07.4"W**
Temperature (°C)	17.8	15.9	14.6	16.3	15.1	15.5	16.7	21.0	17.6	14.5	10.9
Total disolved solids (mg/L)	0.19	0.14	0.18	0.22	0.35	0.32	1.40	2.63	2.57	3.09	4.30
Conductivity (mS/cm)	0.11	0.27	0.35	0.44	0.66	0.64	2.40	5.31	4.54	5.75	8.83
pH	7.22	6.95	7.51	7.62	7.63	7.86	8.22	8.00	8.24	8.03	8.03
Daphnia ambigua Scourfield, 1947	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.28	2.75	0.11
Ceriodaphnia dubia Richard, 1894	4.00	1.53	1.60	0.00	23.93	14.93	0.00	0.00	0.17	0.22	0.00
Chydorus sphaericus (O.F. Muller, 1785)	1.33	3.53	18.27	15.00	7.80	4.53	0.00	0.00	0.00	0.00	0.00
Boeckella gracilis (Daday, 1902)	13.60	7.20	22.93	1.13	0.07	0.00	0.07	0.00	0.00	0.00	0.08
Mesocyclops araucanus (Pilati & Menu-Marque, 2003)	0.00	0.00	0.33	0.00	2.13	0.87	0.00	0.00	0.00	0.00	0.00
Eucyclops macrurus (G.O. Sars, 1863)	0.00	0.00	0.00	1.27	0.00	0.00	0.00	3.22	1.19	1.75	5.28
Paracyclops fimbriatus chiltoni (Thomson, 1882)	0.00	0.00	0.00	0.00	0.00	0.00	2.27	0.00	3.00	0.00	0.00
Cypris sp.	98.33	43.40	16.53	7.13	0.00	0.00	0.07	0.03	0.39	0.25	0.03
Harpacticoida indet.	0.00	0.00	0.00	0.00	12.80	26.27	0.27	0.00	0.00	0.00	0.00
Hyalella costera (Gonzalez & Watling, 2001)	0.00	0.00	0.00	0.00	3.87	2.73	0.00	0.00	0.00	0.00	0.00

Table 2. Results of correlation analysis for each species reported in the present study (values in bold revealed significant correlation: $p < 0.05$).

	Total data									
	D. ambigua	***C. dubia***	***Ch. sphaericus***	***B. gracilis***	***M. araucanus***	***E. macrurus***	***P. fimbriatus chiltoni***	***Cypris* sp**	**Harpacticoida**	***H. costera***
pH	0.2	–0.1	–0.3	**–0.6**	–0.1	0.4	**0.6**	**–0.7**	0.0	–0.0
Conductivity	0.4	–0.4	**–0.6**	–0.5	–0.3	**0.9**	0.2	–0.5	–0.3	–0.3
TDS	0.4	–0.4	**–0.6**	–0.5	–0.4	**0.9**	0.2	–0.4	–0.3	–0.3
Temperature	–0.1	–0.1	–0.2	–0.0	–0.2	–0.3	0.2	0.2	–0.1	–0.1
H. costera	–0.1	**0.9**	0.1	–0.3	**0.9**	–0.3	–0.2	–0.2	0.8	
Harpacticoida	–0.1	**0.8**	0.1	–0.2	**0.7**	–0.3	–0.2	–0.2		
Cypris sp	–0.1	–0.1	–0.0	0.6	–0.2	–0.3	–0.2			
P. fimbriatus chiltoni	–0.1	–0.2	–0.3	–0.3	–0.2	–0.1				
E. macrurus	0.1	–0.3	–0.3	–0.3	–0.4					
M. araucanus	–0.1	**0.9**	0.2	–0.1						
B. gracilis	–0.2	–0.1	0.5							
Ch. sphaericus	–0.2	0.1								
C. dubia	–0.2									

Table 3. Percentaje of contribution for PCA for studied variables.

	F1	F2
Temperature	0.1	1.7
TDS	16.2	2.2
Conductivity	15.6	2.3
pH	8.1	8.6
D. ambigua	3.8	0.4
C. dubia	9.5	12.3
Ch. sphaericus	6.5	1.4
B. gracilis	3.3	13.9
M. araucanus	8.1	12.8
E. macrurus	11.3	0.9
P. fimbriatus chiltoni	2.3	0.1
Cypris sp.	2.2	13.6
Harpacticoida	5.6	13.5
H. costera	7.6	16.3

Table 4. Results of null model co-occurrence species for data included in the present study ("p" values lower than 0.05 denotes the existence of regulator factors in species associations).

Total data				
Model	**Observed index**	**Mean index**	**Standard effect size**	**P**
Fixe-fixed	7.6	6.7	5.7	< 0.01
Fixed-proportional	7.6	5.5	3.1	< 0.01
Fixed-equiprobable	7.6	5.7	3.0	< 0.01

a strong salinity gradient as a function of the rainy season. During the rainy season there is a high species richness; whereas during the dry period, the species richness decreases and halophilic species predominate (Vignatti et al., 2012). There are no data on the temporal gradient in Chilean ephemeral ponds, nevertheless, preliminary descriptions for ephemeral ponds in coastal and mountain zones in the Araucanía region would indicate that they are present in early spring, and disappear by mid or late spring (De los Ríos-Escalante et al., 2010).

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