Richness and Distribution of Zooplanktonic Crustacean Species in Chilean Andes Mountains and Southern Patagonia Shallow Ponds

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Abstract

The lacustrine ecosystems located in the Andes Mountains in the Atacama desert and in the Chilean Southern Patagonia are characterized by their high levels of salinity, the zooplankton in these sites are characterized by a marked predominance of calanoid copepods at low or intermediate salinity levels, and at high salinity levels pratically only the genus *Artemia* is dominant. Data on levels of salinity and zooplanktonic composition in both regions were collected in field work and from published data. Statistical analysis showed a marked inverse association between salinity and species richness that was notoriously significant for Andes Mountains ($R = -0.8193$; $p = 0.0037$), whereas for Southern Patagonia there were observed weakly similar results, caused by lack of data between 5.0-15.0 g/l. Both zones observed calanoid dominance at low and moderate salinity levels between 3-51 g/l and 1-16 g/l for Andes Mountains and Southern Patagonia, respectively, and *Artemia* genus was dominant at salinities above 100 g/l for Andes Mountains and 20 g/l for Southern Patagonia. Ecological and biogeographic effects, and comparison with zooplankton assemblages of Australian saline lakes are discussed in the present study.

Keywords: calanoid copepods, *Artemia*, salinity, zooplankton

Introduction

The lacustrine zooplankton in South America is characterized by a marked predominance of calanoid copepods [1, 2]. The species composition has been described in detailed biogeographic studies for Central and Central-South Chile [3, 4], and very basic studies for Andes Mountains and Southern Patagonia [5, 6, 7].

Salinity is important in the chemical composition and structuring of fauna and flora in saline lakes [8, 9], the salt sources in lakes can be natural by mineral composition of their basins or arid weather [8, 9], other cause of the increase of salts increasing in lakes is human intervention by industrial residuals [10, 11]. The exposition of live organisms to a wide salinity gradient implies important osmotic regulation adaptations [10, 12]. Also, the brine composition implies different dominant anions such as chloride, sulphate and carbonate, and each organism in species or populations within a same species will see optimal population development at specific concentrations of these anions [13]. The Chilean saline lakes are distributed mainly in the zone between 18 and 27°S [2, 8, 14], and between 51 and 53°S [15]. Lakes and ponds between 18 and 27°S are associated with highly sulphated saline volcanic deposits rather difficult to access and in warm desert zones [14], whereas between 51 and 53°S are exposed to strong winds, having periods without rains, could increase ionic concentration in the water – mainly chloride and sulphate [15].

Those sites with very high levels of salinity do not have zooplanktivorous fish [16, 17], and zooplankton predators are aquatic birds that use the sites for nesting and/or feeding [18, 19, 20, 21]. Dominant zooplanktivore groups are mainly calanoid copepods and the *Artemia*

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genus and both groups do not coexist [15, 16, 18]; their predominance is highly conditioned by the salinity levels and probably by the predation potential of calanoid copepods over nauplius and *Artemia* [18]. This study made a first comparison between the association between salinity levels and zooplankton assemblage in fishless ponds for the Andes Mountains and Southern Patagonia.

Materials and Methods

Saline (> 16.0 g/l) and subsaline (0.1-16.0 g/l), shallow (Zmax <10 m) fishles ponds located in the regions of Tarapacá, Antofagasta, Atacama (Andes Mountains, Table 1) and regions of Aysén y Magallanes (Southern Patagonian, Table 2), were studied first, and included published information of zooplankton and salinity of water bodies (mainly in the Andes) [2, 7, 15, 24, 25]. To this information was added information collected in field works during the periods of January, March and October 2000-01. Those periods corresponded to maximal zooplanktonic abundances observed [2]. Salinity and salinity using a YSI-30 sensor was measured and zooplankton samples were collected using an Apstein net of 100 µm mesh size and fixated in ethanol. Zooplankton species collected were counted and identified according to the

Table 1. Location, surface area and depth of studied sites in the present work.

Site	Location	Surface area (km^2)	Depth (m)	Reference
Andes Mountains				
Llamara	21°18’ 69°37’	< 1.0	< 0.5	[34]
Cejas	23°02’ 68°13’	< 1.0	14.0	[24, 34]
Tebenquiche	23°07’ 68°16’	< 1.0	10.0	[24, 34]
Chaxas	23°10’ 68°15’	< 1.0	< 0.5	Present study
Gemela Este	23°14’ 68°14’	< 1.0	< 7.0	[7]
Gemela Oeste	23°16’ 68°14’	< 1.0	< 7.0	[7]
Miscanti	23°43’ 67°48’	13.4	9.0	[7]
Miniques	23°43’ 67°48’	1.6	5.0	[7]
Capur	23°54’ 67°48’	0.9	1.5	[7]
Santa Rosa	27°05’ 69°10’	No data	< 1.5	[7]
Southern Patagonia				
Balmaceda	45°53’ 71°40’	< 0.1	< 1.5	Present study
Amarga	50°29’ 72°45’	6.0	3.0	[15]
Isidoro	50°57’ 72°53’	< 0.1	< 1.5	Present study
Cisnes	51°01’ 72°52’	< 0.1	1.0	[16]
Redonda	51°01’ 72°52’	< 0.1	< 3.0	[16]
Larga	51°01’ 72°52’	< 0.1	< 5.0	[16]
Don Alvaro	51°01’ 72°52’	< 0.1	< 2.0	Present study
Juncos	51°01’ 72°52’	< 0.1	< 3.0	[16]
Guanaco	51°01’ 72°50’	< 0.1	< 2.0	Present study
Paso	51°02’ 72°55’	< 0.1	< 3.0	[16]
Jovito	51°02’ 72°54’	< 0.1	< 3.0	[16]
Monserrat	51°07’ 72°47’	< 0.1	< 1.5	Present study
Vega del Toro	51°07’ 71°40’	< 0.1	< 1.5	Present study
Kon Aikén	52°50’ 71°10’	< 0.1	< 1.0	Present study
De los Cisnes	53°14’ 70°00’	6.0	< 3.0	Present study
Porvenir	53°17’ 70°19’	< 0.1	< 1.5	Present study

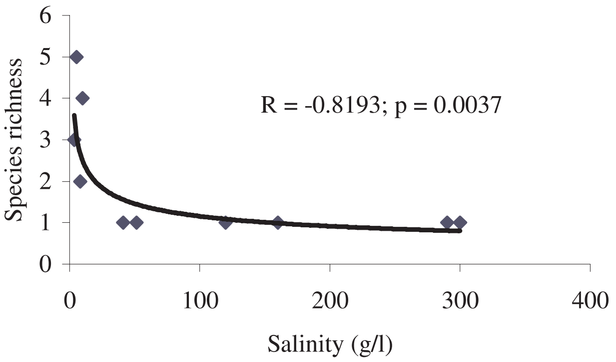

Fig 1. Correlation between species richness and salinity for ponds in the Andes Mountains.

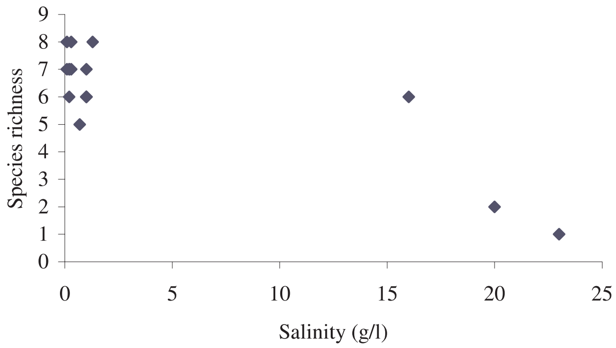

Fig 2. Correlation between species richness and salinity for ponds in Southern Patagonia.

Table 2. Average salinity, occurrence of crustacean zooplankton species and species richness for the sites in the Andes Mountains.

Site	Llamara	Cejas	Tebenquiche	Chaxas	Gemela Este	Gemela Oeste	Miscanti	Miniques	Capur	Santa Rosa
Cladocera										
Daphnia spp.							x	x		
Alona pulchella. (King, 1853)							x	x		
Chydoridae (unidentified)							x	x	x	x
Anostraca										
Artemia franciscana (Kellog, 1906)	x	x	x	x						
	Copepoda									
Boeckella poopoensis (Marsh, 1906)					x	x	x	x	x	x
Cyclopoida (unidentified)							x	x	x	
Salinity (ppt)	160	290	300	120	41	51.4	5.2	9.8	3.4	8
Reference	[34]	[25, 34]	[24,34]	*	[7]	[7]	[7]	[7]	[7]	[7]

Note: *data obtained in the present study.

descriptions of specialized literature [3, 5, 21, 22, 23]. In addition, data published for both regions [2, 15, 24, 25] was reviewed. Data of location, depth and surface of studied sites are specified in Table 1. Data was arranged in two groups: Andes Mountains and Southern Patagonia regions and Spearman non-parametric correlation analysis was applied to determine a possible degree of association between abundance of species and salinity. Statistical analysis was carried out using the Statistica 5.0 software.

Results and Discussion

There was an inverse relationship between salinity and species richness in the studied sites (Tables 2 and 3, Figs. 1 and 2), being more significant in the Andes Mountains R = -0.8193; p <0.0037; Fig. 1) than in Southern Patagonia (Fig. 2), for this last zone few data were observed at salinities between 5.0 to 15.0 g/l, and in this situation would not generate a strong result for statistical analysis, although the results of Southern Patagonia can denote a weak inverse relation between salinity and species richness (Fig. 2, Table 3). When considering zooplanktonic structuring in both zones, a marked predominance of calanoid copepods was found in sites with low to moderate salinity, 3.0-90.0 g/l for Andes Mountains [7, 18, 29] and 0.1 to 16.0 g/l for Southern Patagonia (Tables 2 and 3). Whereas in sites with salinity higher then 90.0 g/l for Andes Mountains [7,18,29] and > 16.0 g/l for Southern Patagonia [15], absolute predominance of *Artemia* spp. was observed (Tables 2 and 3). Although this pattern was common for both zones, the principal species were markedly different in both regions. When considering the levels of salinity where the species were observed, it was found that in the Andes the most representative species is *B. poopoensis,* which is highly halotolerant (5.0-90.0 g/l)[28]. The

Table 3. Average salinity, occurrence of zooplanktonic groups and species richness for the sites in Southern Patagonia.

Site	Balmaceda	Amarga	Isidoro	Cisnes	Redonda	Larga	Don Alvaro	Juncos	Guanaco	Paso	Jovito	Monserrat	Vega del Toro	Kon Aikén	De los Cisnes	Porvenir
Cladocera																
Daphnia commutata (Ekmann 1900)				x												
D. dadayana (Paggi 1999)	x		x				x					X	x	x		x
D. obtusa (Kurz 1874)					x	x		x	x	x	x					
D. pulex (Scourfield 1877)					x		x	x	x	x	x	X	x			
Chydorus sphaericus (Müller 1785)			x		x	x	x	x		x	x					
Neobosmina chilensis (Daday 1902).			x	x	x	x		x	x	x	x	X	x	x		x
Anostraca																
Branchinecta sp.	x												x	x		
Artemia persimilis (Piccinelli & Prosdocimi 1968)		x													x	
Copepoda																
Boeckella brasiliensis (Lubbock 1855)	x											x				
B. brevicaudata (Brady 1875)	x													x		
B. gracilipes (Daday 1902)	x				x		x		x	x						
B. meteoris (Kiefer 1928)				x												
B. michaelseni (Mrázek 1901)			x					x				x	x			
B. poopoensis (Marsh 1906)				?												
B. popei (Mrázek 1901)	x		x	x	x	x	x		x	x	x	x	x	x		x
Parabroteas sarsi (Daday 1901)	x			x	x	x	x		x				x	x		x
Harpacticoida (unidentified)															x	
Cyclopoida (unidentified)	x		x	x	x	x	x	x	x	x	x	x	x	x		x
Salinity (ppt)	0.1	23	0.2	16	0.3	1	0.1	1	0.3	1	1	0.2	1.3	0.2	20	0.7
Reference	*	[16]	*	**	**	**	*	**	*	**	**	*	*	*	*	*

Notes: *data obtained in the present study, **Soto & De los Ríos. Unpublished data [2].

other species observed at rather high levels of salinity was *A. franciscana* (Table 2).

When comparing data obtained in Southern Patagonia, it was found that calanoid copepods were the most dominant but not exclusive for all the sites, and it was also found that at higher salinity levels (> 17.0 g/l) the predominant species was *A. persimilis* (Table 3) [26, 27]. The sites studied showed an inverse relationship between salinity and species richness (Figures 1 and 2) and this pattern was common to most saline lakes [9, 29, 30]. This pattern was more significant in the Andes sites than in Southern Patagonia, probably due to the fact that calanoid copepods such as *B. poopoensis* from the Andes have a higher tolerance limit to salinity (5.0-90.0 g/l) this species is the most halotolerant species amongst the copepods from *Boeckella* genus, [7, 30, 31], showing even higher tolerance than other zooplanktonic groups such as Daphnidae cladocerans [20, 30]. This condition could mean that at relatively moderate levels of salinity this species would practically be the exclusive component of the crustaceans [7], whilst at higher levels of salinity (> 90.0 g/l), *A. franciscana* is the only successful species [24, 25]. On the other hand, in Southern Patagonia the levels of tolerance to salinity observed for calanoid copepods are markedly low (0.1-16.0 g/l; Table 3) in comparison to the levels observed in the Andes (0.1 – 90.0 g/l; Table 2), and in general this group does not coexist with *Artemia* genus populations (Table 3)[18, 28]. The same as for the Andes, it was observed that calanoid copepods did not coexist with *Artemia* sp.(Table 2). However, the levels of salinity for occurrence for both groups in Southern Patagonia were notoriously lower than those observed in the Andes Mountains (Tables 2 and 3). The role of salinity as a conditioning factor for structuring zooplankton assemblages was described in detail for New Zealand lakes and Australian lakes, including the population dynamics of the species *Daphnia carinata* and *Boeckella hamata* [30, 31, 32], although there are species of *Calamoecia* genus such as *C. clitellata* that have high salinity tolerance levels (7.0 – 195.0 g/l) in comparison to other halophilic species of genus *Boeckella* and *Daphnia* [28, 30]. Nevertheless, the salinity effects on zooplankton assemblage can be associated with variations in other factors such as trophic conditions or ionic composition, which would be important for determining biotic assemblages [32, 11].

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