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Short research contribution

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SALINITY LEVEL AND OCCURRENCE OF CENTROPAGID COPEPODS (CRUSTACEA, COPEPODA, CALANOIDA) IN SHALLOW LAKES IN ANDES MOUNTAINS AND PATAGONIAN PLAINS, CHILE

ABSTRACT: In Andes Mountains (14–27°S) and Patagonian plains (45–53°S) in Chile, there are numerous shallow saline and sub-saline lakes. These water bodies have important temporal and spatial variation of their salinity caused by mineral composition of their watershed or exposition to arid weather. In this study we compared the salinity level and the occurrence of centropagid copepods (Crustacea, Copepoda, Calanoida) in water bodies of both regions. In the Andes Mts the calanoids inhabit water bodies of salinity lower than 90 g l^{-1}, and the representative species was *Boeckella poopoensis* (Marsh 1906), that occurs between 5.0 to 90.0 g l^{-1}. In Patagonian plains, the copepods occur at salinity level between 0.1 to 16.0 g l^{-1}, and within these values most frequent are *B. popei* (Mrázek 1901) and *Parabroteas sarsi* (Mrázek 1901). Both species can coexist with other calanoid species.

KEY WORDS: saline lakes, salinity, zooplankton, copepods, *Boeckella*

The zooplankton in inland waters from South America is characterised by the frequent occurrence and higher abundance of centropagid copepods (Soto and Zúñiga 1991, Modenutti *et al.* 1998a, b). Some of these ecosystems are characterised by relatively moderate to high levels of salinity, and are localised mainly in tropical and subtropical latitudes in Andes Mountains (Hurlbert *et al.* 1986, Williams *et al.* 1995, De los Ríos and Crespo 2004), plains in central Argentina (Pilati 1998), and Patagonian plains (Soto *et al.* 1994, Campos *et al.* 1996). The diversity of zooplankton assemblages in these ecosystems are regulated generally by salinity level, and at relative low and intermediate salinity the centropagids predominate (Hurlbert *et al.* 1986, Williams *et al.* 1995, De los Ríos and Crespo 2004,), whereas at relative high salinity the anostracan *Artemia* sp., is the dominant genus (Hurlbert *et al.* 1986, Williams *et al.* 1995, Campos *et al.* 1996). The representative species of halophilic copepod is *Boeckella poopoensis*, that tolerates salinities from 5 to 90 g l^{-1} (Hurlbert *et al.* 1986, Bayly 1993). This species is distributed mainly in shallow lakes in the Andes Mountains (Hurlbert *et al.* 1986, Bayly 1993, De los Ríos and Crespo 2004), and central Argentina (Menu-Marque *et al.* 2000). Some recent studies described the presence of saline and sub-saline shallow lakes in southern Patagonia (Soto *et al.* 1994, Campos *et al.* 1996, De los Ríos 2003). Therefore potential similarities in zooplankton assemblages

Table 1. Location, geographical parameters and salinity level of water bodies of Andes Mountains analysed in the present study.

Site (local name)	Location S.latitude W.longitude	Maximum depth (m)	Area (km^2)	Salinity ($g\ l^{-1}$)	Elevation above sea level (m)	Centropagid species
Pampamarca	14°08' 71°29'	> 16	6.7	0.90	3788	*Boekella occidentalis*
Collpacocha	15°15' 70°03'	< 1	39.0	38.60	3825	*B. poopoensis*
Parinacochas	15°17' 73°42'	< 3	67.0	5.60	3273	*B. poopoensis*
Colorada II	15°22' 70°21'	< 1	2.5	0.27	3845	*B. gracilipes, B.occidentalis*
Saracocha	15°47' 70°38'	75.00	14.8	0.90	4145	*B. occidentalis*
Loripongo	16°50' 69°13'	< 2	0.6	0.54	4555	*B. gracilipes, B.palustris*
Loriscota	16°52' 70°02'	2.60	33.0	11.10	4552	*B. poopoensis*
Viscacha	16°53' 71°29'	1.00	8.4	0.90	4575	*B. gracilipes*
Suches	16°56' 70°24'	to 12	15.0	0.26	4452	*B. occidentalis*
Huancaroma	17°40' 67°30'	No data	No data	3.50	No data	*B. gracilipes, B.occidentalis*
Soledad	17°44' 67°22'	No data	No data	11.00	No data	*B. poopoensis*
Cotacotani	18°14' 69°13'	No data	6.0	0.60	4495	*B. gracilipes, B.occidentalis*
Chungará	18°15' 69°09'	13.20	34.0	1.00	4530	*B. gracilipes, B.occidentalis*
Salar de Surire	18°51 69°07'	< 1	5 to 14	1.00	4270	*B. gracilipes, B. calcaris*
Chulluncani	21°32' 67°52'	No data	1.4	64.50	4450	*B. poopoensis*
Ramaditas	21°38' 68°05'	0.25	4.0	30.70	4117	*B. poopoensis*
Khara	21°54' 67°52'	No data	No data	8.70	No data	*B. poopoensis*
Conchostraca	22°18' 67°14'	No data	No data	0.69	No data	*B. gracilipes, B. calcaris, B. palustris*
Penitas Blancas	22°25' 67°15'	No data	No data	3.70	No data	*B. gracilipes*
Este	22°31' 67°29'	No data	No data	86.00	No data	*B. poopoensis*
Puripica Chico	22°31' 67°30'	1.00	No data	8.20	4393	*B. poopoensis*
Polques	22°32' 67°37'	12.00	No data	12.00	4393	*B. poopoensis*
Totoral	22°32' 67°17'	1.00	No data	0.65	No data	*B. gracilipes*
Guacha	22°33' 67°31'	No data	No data	36.00	No data	*B. poopoensis*
Campo Grande	22°33' 67°12	No data	No data	3.40	No data	*B. gracilipes*
Verde II	22°48' 67°48'	10.00	No data	57.10	4315	*B. poopoensis*
Capur	23°00' 67°43'	< 1	0.9	9.99	3950	*B. poopoensis*
Calientes I	23°08' 67°24'	No data	2 to 3	47.00	4280	*B. poopoensis*
Calientes II	23°31' 67°34'	No data	9.0	10.00	4200	*B. poopoensis*
Calientes III	25°30' 68°38'	No data	2 to 3	24.20	3950	*B. poopoensis*
Gemela Oeste	23°30' 68°14'	<7	<1	46.50	2400	*B. poopoensis*
Gemela Este	23°30' 68°14'	<7	<1	54.10	2400	*B. poopoensis*
Catalcito	23°31' 67°15'	No data	No data	8.10	No data	*B. poopoensis*
Miscanti	23°44' 67°46'	9.00	13.4	8.98	4140	*B. poopoensis*
Miniques	23°45' 67°46'	5.00	1.6	9.79	4120	*B. poopoensis*
Hombre Merto	25°30' 66°51'	No data	No data	21.00	No data	*B. poopoensis*
Santa Rosa	27°46' 69°10'	<1	0.1	8.00	3760	*B. poopoensis*

between these ecosystems and their counterparts in Andes Mts may exist (Campos *et al.* 1996).

The aim of this study was to compare the salinity level and the occurrence of centropagid copepods in shallow saline lakes in Andes Mountains and Southern Patagonia. The studied sites are difficult to access for human activities such as the research due to geographic or climatic reasons (Soto *et al.* 1994, De los Ríos and Crespo 2004). Therefore, this brief study would contribute to the knowledge of the aquatic fauna of these habitats.

The published data on salinity levels and occurrence of centropagid copepods in saline shallow lakes in Andes Mts (Argentina, Bolivia, Chile, Perú, 14–27°S, 67–71°W) were included (Bayly 1993, De los Ríos and Crespo 2004) as well as for South Patagonia (Chile 51°S, 70–73°W; De los Ríos 2003, Soto unpublished data). The geographical data of 37 studies sites located in Andes Mts (Hurlbert and Keith 1979, Hurlbert *et al.* 1986, 1984, Bayly 1993, Williams *et al.* 1995, De los Rios and Crespo 2004) and 15 sites located in Southern Patagonia (45; 51–53°S, 70–73°W) are specified in tables 1 and 2 respectively. The Southern Patagonian data were obtained from published (Soto *et al.* 1994, De los Ríos 2003) and unpublished information obtained during a field work in September and October of 2001. For this last field work, the salinity was measured with an YSI-30 sensor, and the zooplankton was collected in vertical hauls taken with an Apstein net of 80 μm of pore size. The collected zooplankters, specifically the centropagid copepods, were determined according to Bayly (1992).

The data on copepods occurrence obtained for Andes Mts and Southern Patagonia were compared using a non-parametric Mann-Whitney test. The data on the salinity level related to the occurrence of each species were taken as the number of sites with the presence of given species. The comparison between data obtained for Andes Mts and Southern Patagonia was done using a non-parametric Kruskall-Wallis test and Tukey non-parametric comparison test. The first two statistical analysis were applied using the software Statistica 5.0 whereas the last statistical analysis were applied in according to the description of Zar (1999).

The species reported for studied sites in Andes Mts water bodies were following: (Tables 1 and 3): *Boeckella calcaris* (Harding

Table 2. Location, geographical parametres and salinity level of water bodies in Southern Patagonia analysed in the study.

Site (local name)	Location (S. latitude W. longitude)	Maximum depth (m)	Area (km^2)	Salinity ($g\ l^{-1}$)	Centropagid species
Balmaceda I	45°53' 71°40'	<1.5	<0.1	0.10	*B.brasiliensis, B. brevicaudata, B. popei, P. sarsi*
Balmaceda II	45°53' 71°40'	<1.5	<0.1	0.10	*B.brasiliensis, B. brevicaudata, B. popei, P. sarsi*
Isidoro	50°57' 72°53'	<1.5	<0.1	0.20	*B.michaelseni, B. popei*
Guanaco	51°01' 72°50'	<2	<0.1	0.30	*B.gracilipes, B. popei, P. sarsi*
Don Alvaro	51°01' 72°52'	<2	<0.1	0.10	*B.gracilipes, B. popei, P. sarsi*
Larga	51°01' 72°52'	<5	<0.1	0.10	*B.popei, P. sarsi*
Redonda	51°01' 72°52'	<3	<0.1	0.3	*B.gracilipes, B. popei, P. sarsi*
Juncos	51°01' 72°52'	<3	<0.1	1.00	*B.michaelseni*
Cisnes	51°01' 72°52'	1.0	<0.1	16.00	*B.meteoris, B. popei, P. sarsi*
Jovito	51°02' 72°54'	<3	<0.1	1.00	*B.popei*
Paso de la Muerte	51°02' 72°55'	<3	<0.1	1.00	*B.gracilipes, B. popei*
Vega del Toro	51°07' 71°40'	<1.5	<0.1	1.30	*B.michaelseni, B. popei, P. sarsi*
Monserrat	51°07' 72°47'	<1.5	<0.1	0.20	*B.brasiliensis, B. michaelseni*
Kon Aikén	52°50' 70°00	<1	<0.1	0.10	*B.brevicaudata, B. popei*
Porvenir	53°17' 70°19'	<1.5	<0.1	0.7	*B.popei, P. sarsi*

Table 3. Average and range of salinity (g l^{-1}) and occurrence of centropagid species in lakes in Andes Mts and Southern Patagonia (Chile) n – number of sites (see Tables 1 and 2).

Centropagid species in	Average	Range	n
Andes Mts			
Boeckella calcaris (Harding, 1955)	0.85	0.69–1.00	2
Boeckella gracilipes (Daday, 1902)	1.50	0.27–3.70	11
Boeckella occidentalis (Marsh 1906)	1.09	0.26–3.50	7
Boeckella palustris (Harding 1955)	0.62	0.54–0.69	2
Boeckella poopoensis (Marsh 1906)	26.80	5.60–86.00	23
Southern Patagonia			
Boeckella brasiliensis (Lubbock 1855)	0.13	0.10–0.20	3
Boeckella brevicaudata (Brady 1875)	0.10	0.10–0.10	2
Boeckella gracilipes (Daday 1902)	0.32	0.10–1.00	6
Boeckella meteoris (Kiefer 1928)	16.00	–	1
Boeckella michaelseni (Mrázek 1901)	0.56	0.10–1.03	4
Boeckella popei (Mrázek 1901)	1.98	0.10–16.00	13
Parabroteas sarsi (Daday 1901)	2.21	0.10–16.00	9

Table 4. Results of Tukey multiple comparison test for salinity level and occurrence of species of centropagid copepods in Andes Mts water bodies. * – "Q" values higher than 2.639 indicate significant differences.

	"Q" observed
B. gracilipes <B. poopoensis	4.406 (*)
B. gracilipes – B. occidentalis	0.295
B. poopoensis> B. occidentalis	4.073 (*)

1955), *Boeckella gracilipes* (Daday 1902), *Boeckella occidentalis* (Marsh 1906), *Boeckella palustris* (Harding 1955) and *Boeckella poopoensis* (Marsh 1906). Whereas for Southern Patagonian water bodies the presence of the following species were reported (Tables 2 and 3): *Boeckella brasiliensis* (Lubbock 1855), *Boeckella brevicaudata* (Brady 1875), *Boeckella gracilipes* (Daday 1902), *Boeckella meteoris* (Kiefer 1928), *Boeckella michaelseni* (Mrázek 1901), *Boeckella popei* (Mrázek 1901) and *Parabroteas sarsi* (Daday 1901). The results for Southern Patagonia are similar to the preliminary ones described by Soto (1990) who studied small shallow lakes in Chilean Patagonia distributed at 51° and 52°S.

If we include all centropagid species reported and their respective salinity level it becomes clear that in Andes Mts water bodies the copepods occur at salinity level notoriously higher in comparison to the species observed for Southern Patagonia lakes (P <0.001;Table 3). The principal reason for this difference is that in Andes Mts water bodies the halophilic copepod *Boeckella poopoensis* occurs and this species requires the salinities higher in comparison to the other species reported (Tables 3 and 4, P <0.05). This observation was supported with the results of multiple comparison analysis (P <0.05; Table 4). In Southern Patagonia water bodies the high salinity level was reported for the occurrence of *Boeckella meteoris* (Table 3). But this species was found only in one site, and its presence in this isolated situation would not be relevant for the statistical analysis. Finally, the statistical differences between the salinity level for the copepods of Southern Patagonia water bodies were not stated (Table 3; P = 0.26).

The results of salinity level for halophilic copepods, mainly *B. poopoensis* in lakes in Andes Mts agree with the literature data (Hurlbert *et al.* 1986, Bayly 1993, Williams *et al.* 1995, De los Rios and Cre-

spo 2004). Similar results were observed for saline lakes in plains of central Argentina (Pilati 1997, Menu-Marque *et al.* 2000). *Boeckella poopoensis* was predominant in Andes Mts water bodies (Williams *et al.*1995, De los Rios and Crespo 2004), because it can tolerate a relative wide range of salinity level (5–90 g l^{-1}; Bayly 1993).

A different situation occurs in saline lakes of Southern Patagonia; in these water bodies at least three species can tolerate a salinity range from 0.1 to 16 g l^{-1} (Table 1). Although the few available data revealed that at salinity around 16 g l^{-1} *B. meteoris* can predominate and coexist with *B. popei* and *P. sarsi* (De los Rios 2003, Soto unpublished data). Probably the centropagid copepods would not inhabit the water bodies with salinity level higher than 17 g l^{-1} (Campos *et al.*1996). Our results for shallow lakes in Northern Patagonia in Argentina indicate that large centropagid copepods occur permanently in greater abundance in zooplankton assemblage (Modenutti *et al.* 1998a, De los Rios 2005). Also, in these water bodies the species richness of zooplankton community is relatively high (6 to 8 species), with two or three species of centropagid copepods. If we consider that some shallow lakes in Southern Patagonia are ephemeral (Balmaceda I and II, Table 2), these results agree with the findings of Blaustein and Schwatz (2001) and Eitam *et al.* (2004).

Our results agree with the reports for other species of halophilic copepods of shallow water bodies of central Argentina, such as *B. gracilis* (Daday 1902) and *Notodiaptomus incompositus* (Brian 1925). These species were reported for salinity levels between 0.20–7.36 g l^{-1} (Pilati 1997). The occurrence of halophilic copepods of family Centropagidae was reported for Australian inland water bodies. These habitats are characterised by the presence of *B. triarticulata* (Thomson 1883), *Calamoecia salina* (Nicholls 1944) and *Calamoecia clitellata* (Bayly 1962) which can live at salinity levels between 1–22 g l^{-1}; 7–195 g l^{-1} and 6–132 g l^{-1}, respectively (Bayly 1992, 1993). The salinity level tolerance for the studied species and other similar species from Australian and New Zealand water bodies are permanently higher in comparison to other planktonic crustaceans such as daphnids (Hurlbert *et al.* 1986, Bayly 1993).

For both studied regions of Andes Mts and Southern Patagonia, the copepods occur at relatively moderate salinity, at high salinity level – the genus *Artemia* is dominanting (Hurlbert *et al.* 1986, Williams *et al.*1995). In Andes Mts, at salinity higher than 90 g l^{-1} *Artemia franciscana* was dominating (Hurlbert *et al.* 1986, Williams *et al.* 1995). In Southern Patagonia, the salinity limit for copepods could be of 16 g l^{-1}, because *Artemia persimilis* is dominating at salinity level upper than 17 g l^{-1} (Campos *et al.* 1996, Gajardo *et al.* 1998).

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