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Morphological variations in *Boeckella poopoensis* (Marsh, 1906) (Copepoda, Calanoida) in two shallow saline ponds (Chile) and potential relation to salinity gradient

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Abstract

The calanoid copepod *Boeckella poopoensis* (Marsh, 1906) is a widespread species inhabiting South American inland saline waters with gradient of salinity between 5-90 g/dm^3 and it can be practically considered as obligate component of zooplankton of saline lakes. The aim of the present study is to analyze and compare morphometrically two populations of this species collected during two seasons in two small saline ponds with different salinity levels, located in northern Chile. The results of PCA revealed that the salinity would be weakly inversely associated with morphometric parameters, whereas many morphometric parameters are significantly directly associated. The results revealed that the salinity would not generate significant morphometric alterations in adults of *B. poopoensis*.

Key words: *Boeckella poopoensis*, morphometry, saline lakes, Chile

Introduction

The calanoid copepods are abundant in zooplankton of Chilean inland waters (Soto & Zúñiga, 1991), and the main causes of this pattern are the oligotrophy and high conductivity of water bodies (Soto & De los Ríos, 2006). In South America, there are calanoids species that can inhabit at different salinity gradient, and one of these species is *Boeckella poopoensis*, frequent in waters with gradient of salinity between 5-90 g/dm^3 (Bayly, 1993, 1995; De los Ríos & Crespo, 2004; De los Ríos & Contreras, 2005). The species is widespread in tropical, temperate and subpolar zones in South America (Menu-Marque *et al.*, 2000). The studies about this species concern mainly its occurrence in species communities in South American Altiplano (Hurlbert *et al.*, 1984, 1986; Williams *et al.*, 1995; De los Ríos & Crespo, 2004).

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Because *B. poopoensis* inhabits water bodies with wide salinity gradient, different altitude, temperature and UV radiation exposure, it is possible to find morphological variations in different populations due to environmental heterogeneity. Such morphometric variations in function to water salinity are observed for brine shrimps (Branchiopoda, Anostraca) (Amat, 1980; Zúñiga et al., 1994; Zúñiga & Wilson, 1996; De los Ríos & Asem, 2008). The aim of the present study is to analyze and compare morphometrically two populations of *B. poopoensis* collected during two seasons in two small saline ponds with different salinity levels, located in northern Chile.

Material and Methods

The material was collected from two small shallow saline ponds with surface lower than 1 km^2 and maximum depth of 7 m, called "Gemela Este" and "Gemela Oeste" (23º 30' S; 68º 14' W; 2400 m a.s.l). Both sites are 500 meters separated and their *B. poopoensis* communities could be considered as different separate populations (De los Rios & Crespo, 2004). Both shallow ponds are located in the "Salar de Atacama", a saline deposit with hyper saline water bodies inhabited mainly with brine shrimp *Artemia* populations (Zúñiga et al., 1991, 1994; Gajardo et al. 1992) and few sites with *B. poopoensis* (De los Ríos, 2005). The sites were visited in May and September 2000. Conductivity, temperature and salinity were measured using an YSI-30 sensor. The zooplankton samples were collected using qualitative plankton net of 20 cm diameter and 50 ・m mesh size, specimens were fixed in absolute ethanol and identified according to Bayly (1992). For the morphological analysis we considered the following copepod body morphometric parameters and features: cephalic length (CL), abdominal length (AL), cephalothorax wide (CW), abdominal wide (AW), adapted from Villalobos & Zúñiga (1991), and furcae wide (FW), furcae length (FL), terminal external setae length (TEL), terminal median external setae length (TMEL), terminal median internal setae length (TMIL), terminal internal length (TIL) (Einsle, 1988, Wyngaard, 2000), and setae number. These parameters were measured for 20 specimens (males and females). The obtained morphomertric data and salinity concentration values were treated by PCA analysis using the software Xlstat 5.0.

Results

The results of morphometry, revealed that this species has an important morphometric plasticity (Table 1).

Table 1: Morphometric parameters (average in mm ± standard deviation) for studied populations of *B. poopoensis* and salinity (g/dm^3).

Site	date	g/dm^3	CL	AL	TW	AW	FW	FL	TIL	TMIL	TMEL	TEL	NS
Gemela	May	21.1	1.35	0.336	0.058	0.019	0.039	0.131	0.152	0.171	0.181	0.165	10.1
Oeste	2000		±0.11	±0.007	±0.008	±0.003	±0.006	±0.012	±0.025	±0.029	±0.031	±0.026	±0.5
Gemela	May	15.7	1.18	0.265	0.052	0.018	0.035	0.109	0.130	0.163	0.168	0.137	10.0
Este	2000		±0.18	±0.006	±0.009	±0.004	±0.006	±0.015	±0.031	±0.029	±0.030	±0.027	±0.0
Gemela	Sept.	64.9	1.05	0.241	0.043	0.016	0.032	0.097	0.121	0.153	0.150	0.116	10.0
Este	2000		±0.21	±0.007	±0.010	±0.003	±0.005	±0.023	±0.036	±0.030	±0.029	±0.041	±0.0
Gemela	Sept.	77.3	1.14	0.289	0.049	0.018	0.035	0.0105	0.139	0.168	0.175	0.138	10.0
Oeste	2000		±0.15	±0.007	±0.006	±0.003	±0.005	±0.011	±0.037	±0.037	±0.034	±0.037	±0.0

The correlation analysis shows a weak inverse association between salinity and all morphometric parameters (Table 2). There are significant direct associations of CL with TW, FW, FL and TEL; Al with FL, TIL and LTE; TW with AW, FW, FL, and TEL; AW with FL, TMEL and TEL; FW with FL and TEL; FL with TEL; TIL with TMIL and TEL; and TMIL with TMEL (Table 2).

Table 2: Correlation matrix of salinity and studied parameters for *B. poopoensis* considered (values in bold, denoted significant correlation).

	CL	AL	TW	AW	FW	FL	LTI	LTMI	LTME	LTE
g/L	-0.659	-0.366	-0.734	-0.604	-0.663	-0.618	-0.323	-0.308	-0.356	-0.571
CL		0.941	**0.983**	0.944	**0.996**	**0.994**	0.918	0.839	0.852	**0.990**
AL			0.891	0.908	0.932	**0.956**	**0.994**	0.915	0.909	**0.971**
TW				**0.973**	**0.968**	**0.985**	0.878	0.851	0.871	**0.974**
AW					0.913	**0.970**	0.919	0.943	**0.958**	**0.968**
FW						**0.983**	0.900	0.797	0.808	**0.977**
FL							0.943	0.891	0.902	**0.998**
LTI								**0.950**	0.943	**0.961**
LTMI									**0.998**	0.907
LTME										0.915

The results of PCA analysis revealed that the studied variables contribute with 97.60 %, and for the first axis, the LF and TE contributes and the remaining morphometric variables with a 9.31 %, whereas for second axis with a contribution of 88.39% the main contributor variable was the salinity (Table 3; Figure 1). These results revealed that the salinity has a weak inverse relation in all morphometric differences of studied populations. The PCA analysis denoted that Gemela Oeste collected in May is the most large size population, whereas the most small size population corresponded to the specimens collected for Gemela Este lagoon at September, an intermediate situation was observed for populations of Gemela Oeste collected in September, and Gemela Este collected in May (Figure 1).

Table 3: Percentage of contributions for PCA for considered variables in the present study

	F1	F2
g/L	3.477	62.901
LC	9.951	1.664
LA	9.503	4.229
AT	9.873	3.818
AA	9.947	0.009
LF	9.595	2.537
AF	10.233	0.320
TIL	9.423	7.314
TMIL	8.783	10.017
TMEL	8.965	7.189
TEL	10.249	0.000

Discussion

The results denoted that the morphometric parameters are similar with descriptions for south American centropagid species, this is a total length approximately of 1.0 mm, in genera it is possible found differences in morphometric parameters, with exception to setae number, that are practically constant with 10 setae by specimens (Table 1).

The results of morphometry, revealed that this species has an important morphometric plasticity (Table 1). This condition would be normal for other widespread similar species with heterogeneity in its habitats such as *B. gracilipes* (Villalobos & Zúñiga, 1991). The role of salinity in morphometry was originally described for European brine shrimps populations (Amat, 1980), to these populations were described that the salinity is inversely related with salinity variations, and these

results were confirmed for Chilean populations on the basis of field observations (Zúñiga et al., 1994) and data obtained from culture experiences (Zúñiga & Wilson, 1996). In according to Amat (1980), it is possible found variations in seteae numbers and/or length in according to the salinity variations, because at high salinity it is possible found smaller setae as an adaptation to the hydraulic properties of their brines. The results observed denoted that the setae length is weakly inversely related with salinity, that would agree with Amat (1980).

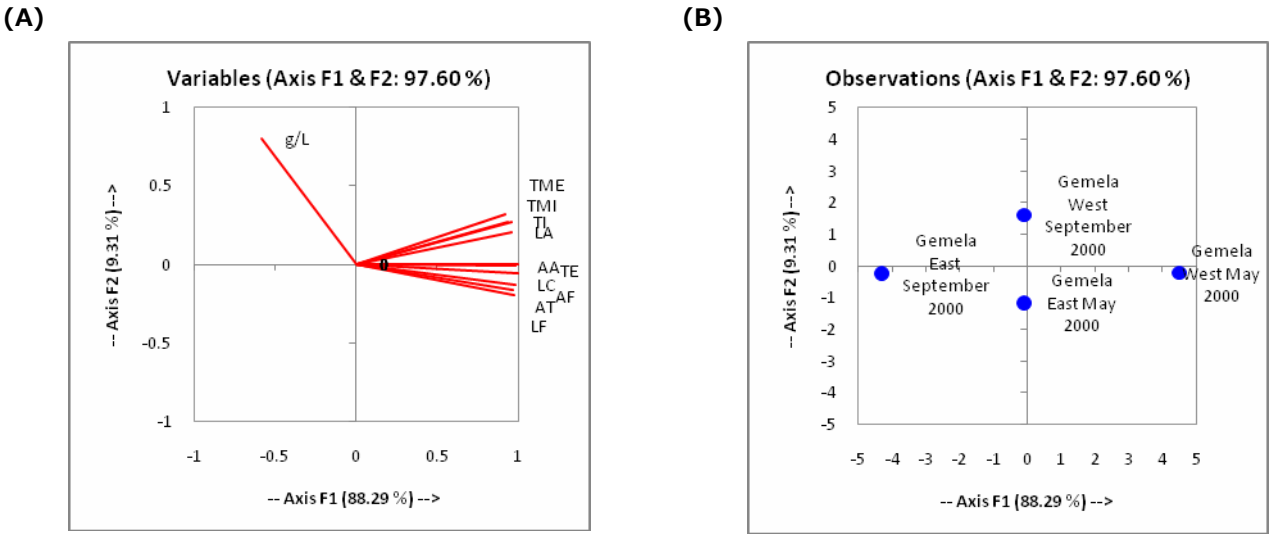

Figure 1: Results of PCA analysis, with variable contribution (A), and studied sites (B)

If we considered that the salinity is an important factor as accelerator of genetic changes and mutations in halophilic crustaceans (Hebert et al., 2002), these results agree with the observations of the present study that denote a weak inverse relation of salinity with morphometric parameters. In according to Hebert et al., (2002), the halophilic crustaceans many sometimes are exposed to another extreme environment that is exposute to natural ultraviolet radiations, with the consequences in genetic variations, and in consequence in other parameters such as morphology. The effects stressors of agents such as ultraviolet radiation, was described on the basis of morphometric evidence, for populations from polar and subpolar environments such as *Boeckella poppei* and *Eurytemora velox* (Pandourski & Evtimova, 2009). Similar variations at morphological level was described for copepods populations from habitats with

geothermal activity (Pandourski & Evtimova, 2005), and of brackish environments (Pandourski & Evtimova, 2006), nevertheless these variations was described at level of thoracopods not for whole body. These variations were described also for subpolar populations of *B.poppei* from Tierra del Fuego island (Adamowicz et al., 2007, Menu-Marque, 2003). In this scenario, it is possible that the salinity variation is an important factor regulator of morphometric variation in *B. poopoensis.*

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