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A quantitative method of palaeolake-level reconstruction using ostracod assemblages: an example from the Bolivian Altiplano

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Abstract

This paper provides quantitative information concerning the response of ostracods to environmental variability in order to reconstruct past environments. Ostracod faunas from modern sediments of Bolivian lakes and swamps were studied. Ostracod distribution is controlled by several ecological characteristics such as lake-level and water chemistry. Statistical results indicate that three transfer functions (on water depth, Total dissolved Salts and water in Mg/Ca ratio) can be developed, from ostracod species frequencies in lacustrine sediments, with some restrictions for the two last ones.

Introduction

Lake-level fluctuations are used as an indicator of climatic change especially when considering the Evaporation/Precipitation ratio (Street-Perrott & Harrison, 1984, 1985). In most cases, past lake-levels are recognized through lacustrine shorelines or terraces. Recently, diatom remains have been used to provide quantitative records of past hydrochemical variations (Roux *et al.*, 1991, and publications mentioned in this paper).

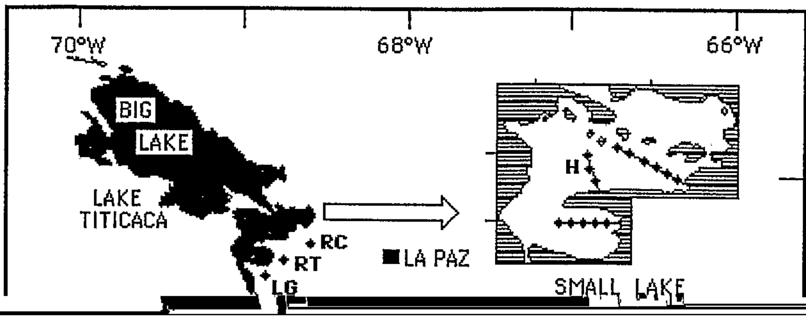
In the present paper, we use ostracod assemblages to reconstruct past limnological conditions. This study site is situated on the Altiplano in Bolivia where a large spectrum of lakes occurs. Ostracods were chosen because of their ecological diversity and abundance in lacustrine sediments. Salinity and water depth are recognized as having an important effect on ostracod distribution (Neale, 1990; Cohen, 1984). The role of particular aspects of water chemistry has recently received attention as well (Delorme, 1969; Forester, 1983, 1985, 1986; De Deckker, 1988; De Deckker & Forester, 1990), and thus we studied the relation between these different variables (water depth, TDS and major ions) and the ostracod assemblages in Altiplano lakes.

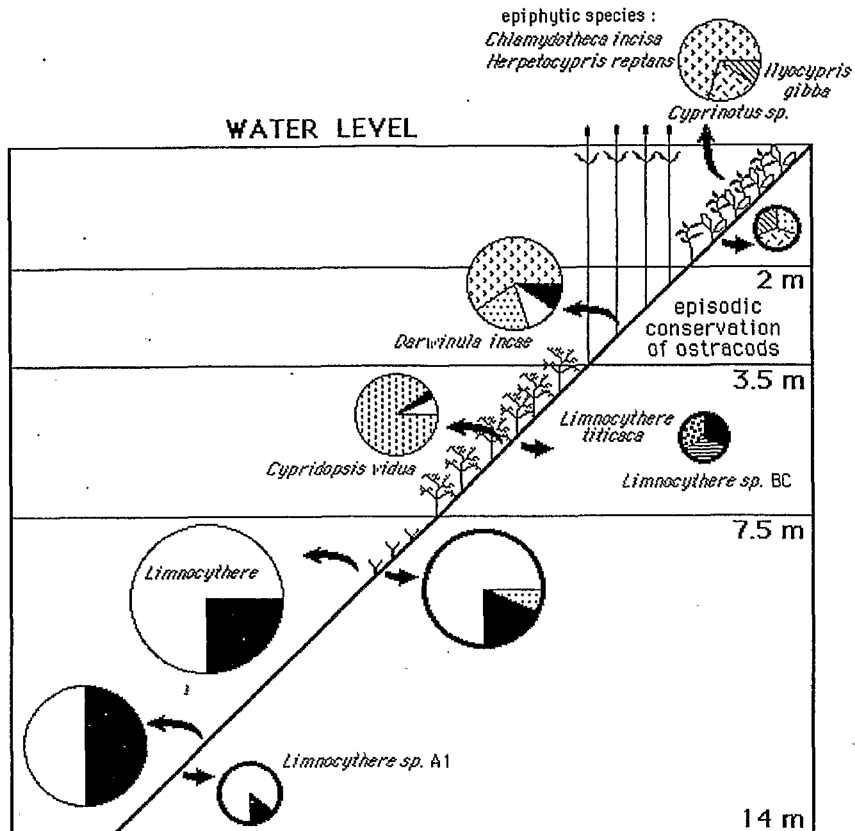
In order to infer past lake-levels or lake water chemistry, the most important step is to develop transfer functions (Roux, 1985) using modern ostracod assemblages and pertinent environmental parameters. In the present paper, calibration models which were developed by using factorial analysis of correspondance (FAC) applied to ostracod assemblages, ostracod species and environmental classes are reported, and then, multiple linear regressions (MLR) were used. The quality of equations obtained permit us to predict (1) water depth, (2) total salinity and (3) Mg/Ca ratio.

Study area and study lakes

The Bolivian Altiplano is an endorheic basin which extends between 15 to 22°S latitude and from 65 to 69°W longitude, around 4000–4500 meters a.s.l., over an area of ≈200 000 km^2. From north to south, four main lake systems occur on the plateau (Fig. 1):

- Lake Titicaca, a deep, freshwater lake at 3809 m a.s.l., with a surface of ≈8500 km^2;
- Lake Poopó, an instable shallow meso- to hyperhaline lake at 3686 m a.s.l.;


70°W
68°W
66°W
BIG
LAKE
LAKE
TITICACA
RC
RT
LG
LA PAZ
H
SMALL LAKE



epiphytic species :
Chlamydotheca incisa
Herpetocypris reptans
Ilyocypris gibba
Cyprinotus sp.
WATER LEVEL
2 m
episodic conservation of ostracods
Darwinula incae
3.5 m
Limnocythere titicaca
Cypridopsis vidua
Limnocythere sp. BC
7.5 m
Limnocythere
Limnocythere sp. A1
14 m

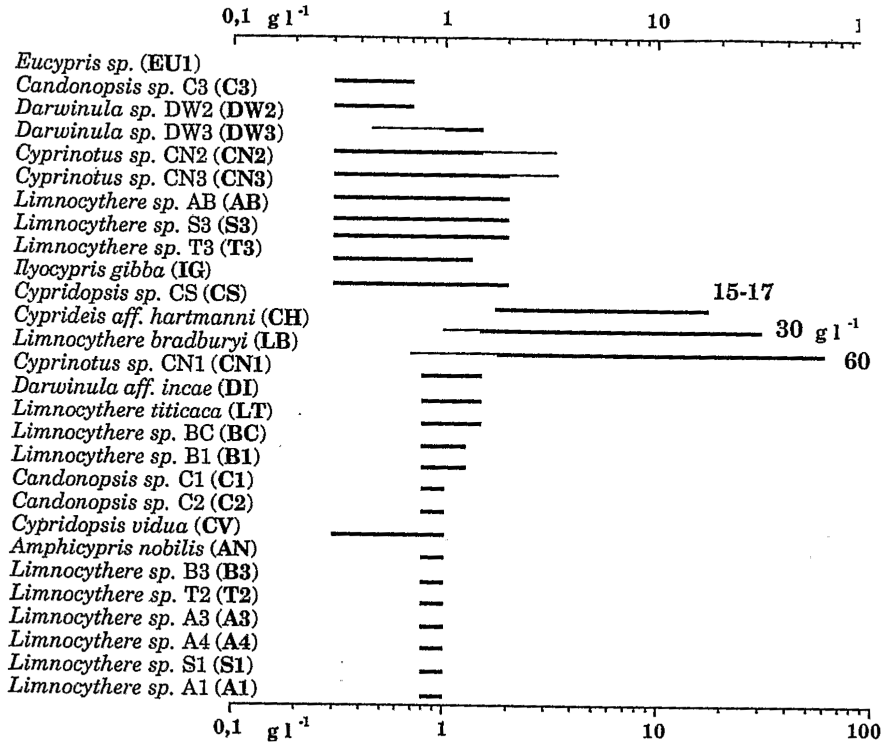
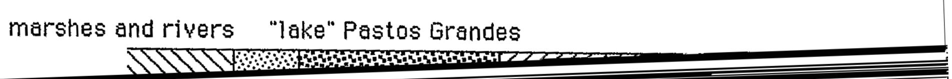
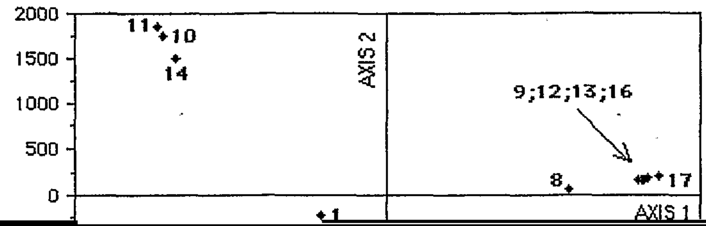


Fig. 3. Salinity ranges of the 28 living ostracod species integrated in the FAC.




1500
1000
"Poopó"
samples


2000
1500
1000
500
0
AXIS 2
AXIS 1
11
10
14
9;12;13;16
8
17
1

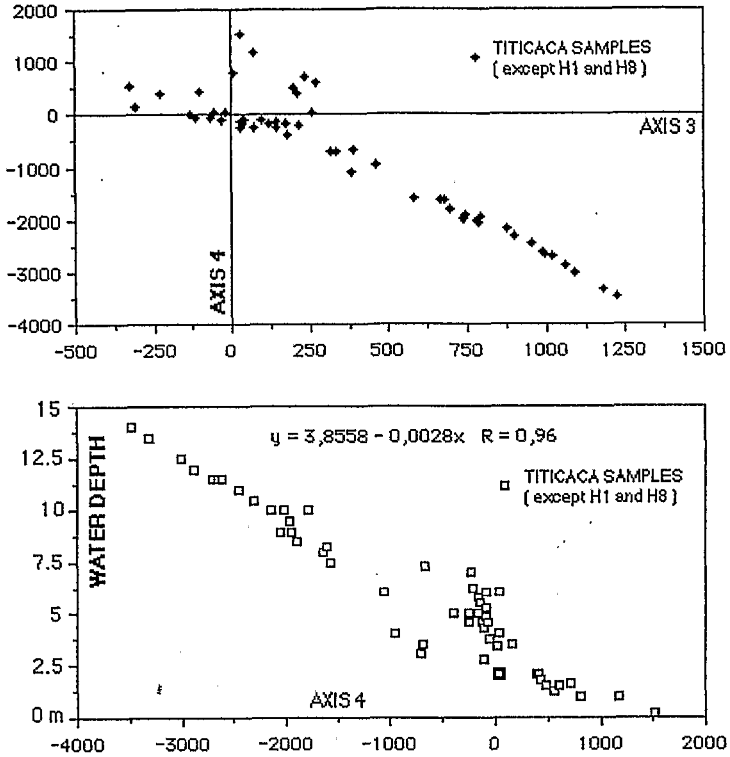


Fig. 9. 1. Axis 4 (12.41% of variance) versus axis 3 (13.82% of variance) 2. Water depth versus axis 4 of the FAC (only classes are active elements) and corresponding correlation coefficient.

Table 1. Factor analysis of correspondances of data, inertia values. 1. Modern samples are active elements. 2. Ecological classes are active elements (*).

Axis	Eigenvalues	Inertia	Cumulate inertia
1	0.9894702	14.15%	14.15
2	0.9802653	14.02	28.17
3	0.8112326	11.60	39.77
4	0.6850839	9.80	49.57
5	0.5550738	7.94	57.51
6	0.5147444	7.36	64.87%
1*	0.9727050	21.69%	21.69
2*	0.9293810	20.72	42.41
3*	0.6198077	13.82	56.23
4*	0.5565896	12.41	68.64
5*	0.4376901	9.76	78.40
6*	0.3676360	8.20	86.60%

-*sensu* Benzecri, 1973) are obtained (Fig. 6). Factors 1 and 2 represent 42.41% of the total information (Table 1). According to these 2 factors, the same groups as in the precedent FAC are individualized (Figs 7 and 8). Group T is characterized by living lake Titicaca species with water depth (1–14 m) and salinity (0.8–1.4 g l^{-1}) ranges (see Table 2). Group P and PG are characterized by *Limnocythere bradburyi* and *Cyprideis aff. hartmanni* respectively. Physico-chemical ranges are:

– 0.15–2.75 m and 2.5–60 g l^{-1} for group P;
– 0–0.1 m and 1.2–30 g l^{-1} for group PG.

Others samples correspond to group MR (see above for details on group signification). The results on fossil samples will be discussed in a future publication.

The patterns support the qualitative observations based on ostracod ecology that the Mg/Ca ratio is the principal control over their presence-absence, and the water levels and salinity the major controls over their distribution in each lacustrine system (Fig. 9).

Therefore a multiple linear regression (MLR) including the 3 environmental controls (a, b and c) is obtained. The MLR results are given in plots between observed and estimated variates (Figs 10, 11 and 12). Plots of residuals show that the estimates are

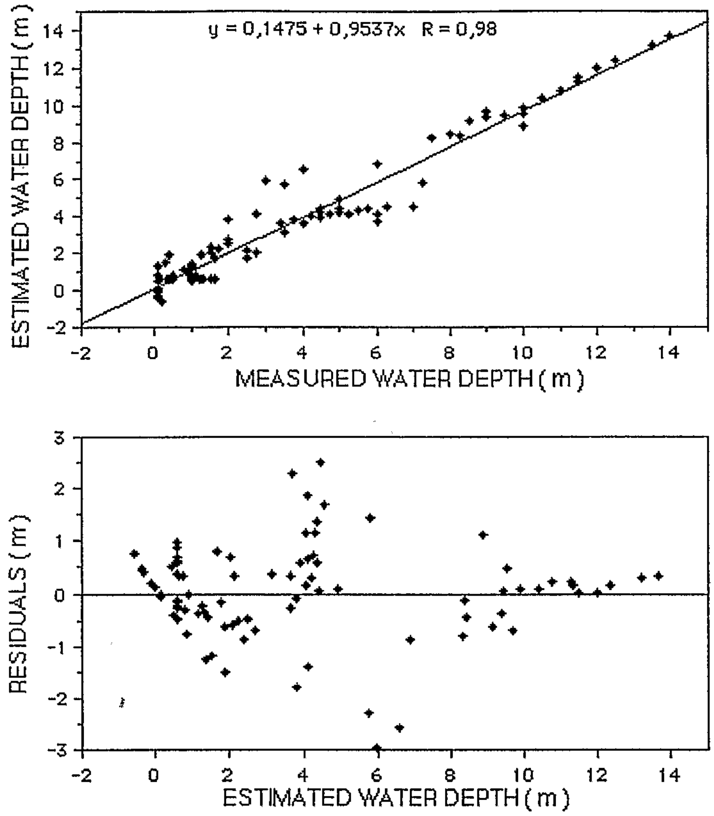


Fig. 10. Estimated versus measured water depth for the 115 samples and plot of the MLR residuals.

within±0.82 m of the observed water depths with a corresponding correlation coefficient of 0.9766, ±6.83 g l^{-1} of the observed salinities with a correlation coefficient of 0.8627 and ±0.062 of the observed Mg/Ca ratios with a correlation coefficient of 0.9645. Salinity plots (Fig. 11) show (1) a lack of values witin the range 1,5–15 g l^{-1} and (2) incorrect estimations above 17 g l^{-1} salinity. These samples are caused by monospecific occurrence of ostracods (*e.g. Limnocythere bradburyi or Cyprideis aff. hartmanni*) in lakes.

Conclusion

The data indicate that ostracod assemblages can be used to quantitatively reconstruct several ecological variables by using transfer functions. There are strong correlations between ostracod faunas and water depth. Nevertheless, it seems that transfer functions may be developed between ostracods and (a) Mg/Ca ratio and (b) water salinities in the 0–15 g l^{-1} range using more samples and better chemical analyses. It is possible that other chemical variables may have an important rôle on ostracod distribution, and consequently other transfer functions ought to be developed. With this statistical analysis in hand, model applications to Holocene ostracode palaeoassemblages will become possible.

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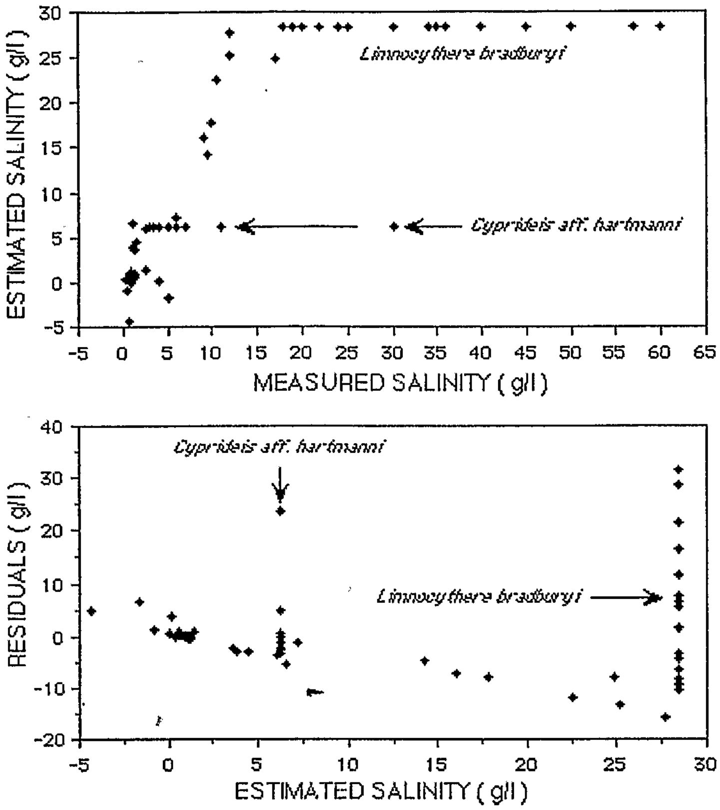

Fig. 11. Estimated versus measured water salinity for the 115 samples and plot of the MLR residuals.

Table 2. Ecological class combinations and codes used in the FAC.

Depth ranges (m)	Salinity ranges (g/l)	Mg/Ca ratio ranges	Code

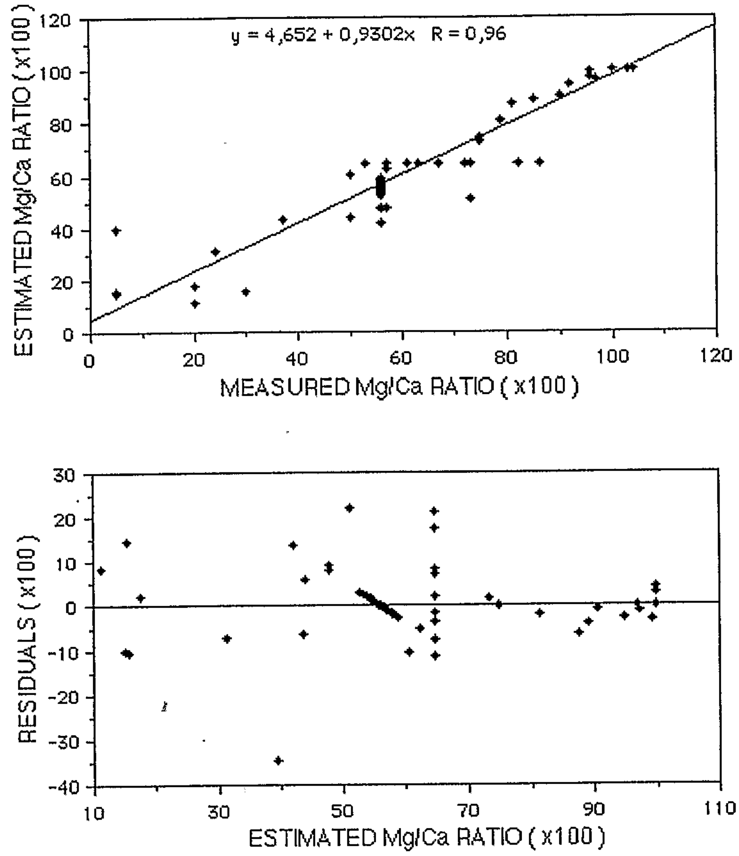

Fig. 12. Estimated versus measured water Mg/Ca ratio for the 115 samples and plot of the MLR residuals.

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