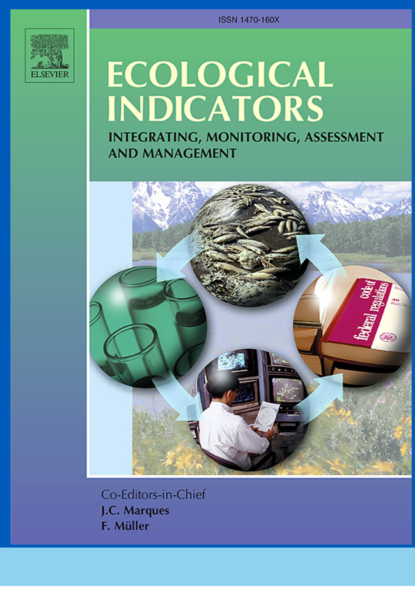

Depth distribution of ostracods in Lake Ngoring on the Tibetan Plateau and its ecological and palaeolimnological significance

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Abstract

Abstract: 31 surface-sediment samples were analyzed from the large fresh-water Lake Ngoring with water depth from two to 31 m on the northeastern Tibet-Qinghai Plateau to provide depth-preference information of ostracods valuable for palaeobathymetric reconstruction. Among the nine species discovered, Tonnacypris estonica and Ilyocypris echinate show clear preferences to shallow waters while Leucocythere sp. 1 and Cytherissa lacustris are confined to depths exceeding 22 m. Ilyocypris sp., Candoninae sp. [what is this? indet. Candonids? > Candoninae indet.), and Leucocythere sp. 2 are slightly more abundant in deeper parts of the lake, while Candona candida and Fabaeformiscandona sp. tend to be more abundant in the shallow area. Such information can be used to reconstruct qualitatively lake level change. Meanwhile, based on 23 samples with over 200 valve counts, three water-depth transfer functions are established, which have generally good and comparable performances judged from their determination coefficients and predictive errors. We propose that future studies should endeavor to investigate the distribution of more ostracod species across wider depth ranges from various lakes to encompass the large changes in ostracod assemblage and depth in the geologic past, and that datasets from different lakes can be synthesized into 'mega-transfer functions' to improve palaeolimnological reconstruction.

Study site

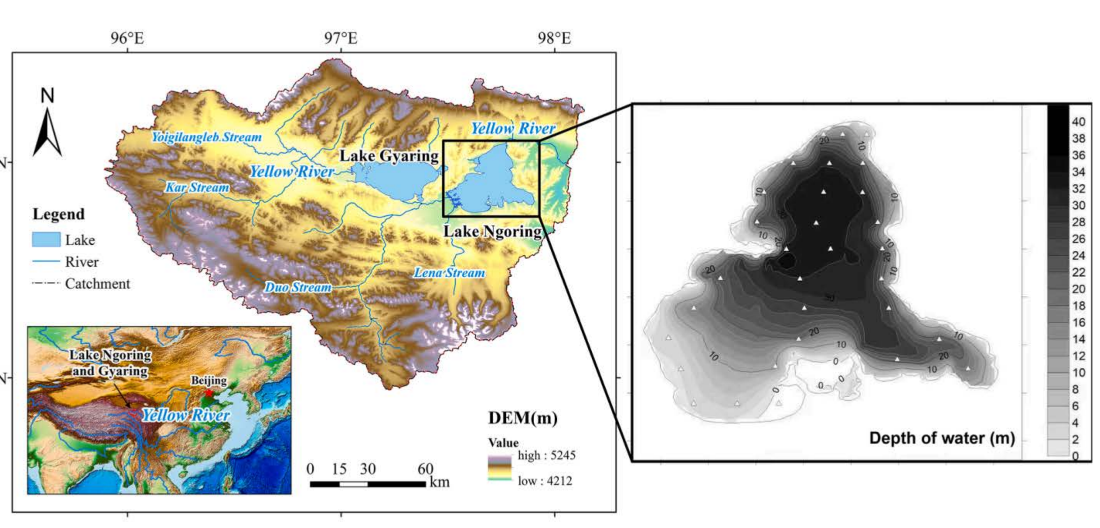

Fig. 1. Map showing the location of Lake Ngoring and the geographical settings of the catchment area. Positions of sampling sites are indicated in the bathy metric map.

Materials and methods

1. Field survey and sample analyses: In August 2015, 31 sites in Lake Ngoring were sampled for surface sediment and surface water (Fig. 1; Table 1). Ostracod valves were extracted from sub-sample sizes of 8–65 g (dry weight), averaging 22 g, with larger sub-sample sizes analyzed for samples with less abundant ostracods (Supplementary Material : Table S1).

2.Numerical analyses: Canonical corre-spond analysis (CCA) was chosen for the ordination of the ostracod abundance and the water depth (Ter Braak and Šmilauer, 2002). we used both Partial Least Squares (PLS, linear response model) and Weighted Averaging Partial Least Squares (WAPLS, unimodal response model) regressions to recover the quantitative relation between the ostracods and the water depth.

Results and discussion

1. Ostracod species and their within-lake distribution

- A total of 10,730 ostracod valves are recovered from the 31 sediment samples (Supplementary material: Table S1).

Table 1 .General state of the surface-water chemistry in Lake Ngoring, represented by average values and standard deviation (STD) of the 31 sampling sites. See text for detail.

	Average	STD
K^+ (mg l^{-1})	3.2	0.2
Na^+ (mg l^{-1})	50.5	4.1
Ca^{2+} (mg l^{-1})	34.4	1.3
Mg^{2+} (mg l^{-1})	26.3	1.1
Cl^- (mg l^{-1})	69.9	8.6
SO_4^{2-} (mg l^{-1})	18.5	2.1
CO_3^{2-} (mg l^{-1})	23.1	10.1
HCO_3^- (mg l^{-1})	222.1	29.9
Salinity (mg l^{-1})	448.1	26.6
pH	7.68	0.25

The total valve count in each sample ranges from 33 to 1,123 valves, averaging 346 valves. Valve count exceeds 200 in 23 of the 31 samples, whereas in the other eight samples valve counts are lower despite larger sub-sample sizes (aver-aging 33 g). Nine ostracod species from five families, namely, Cando-nidae, Cyprinidae, Cytherideidae, Ilyocyprididae, and Limnocytherideidae are recognized (Figs. 2–4), whose total abundance varies from 5 two 9,571 valves per 10 g, averaging 217 valves per 10 g (Fig. 5).

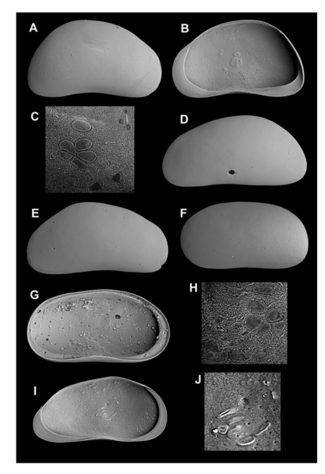

Fig. 2. Ostracods in the surface sediments of Lake Ngoring.
(A) Candona candida (O.F. Müller, 1776).
(B) C. candida.
(C) Muscle scars in the central area of (A),
(D) Fabaeformiscandona sp..
(E) Fabaeformiscandona sp..
(F) Candoninae sp..
(G) Candoninae sp..
(H) Muscle scars in the central area of (F).
(I) Tonnacypris estonica (Jüarvekülg, 1960).
(J) Muscle scars in the central area of (I).

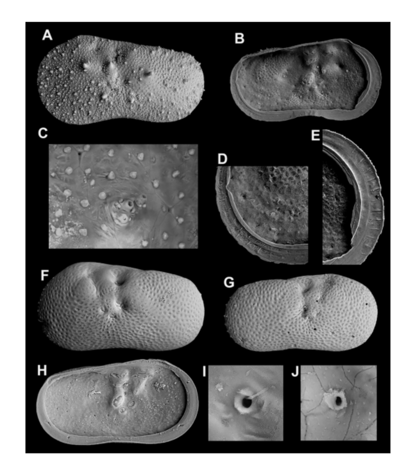

Fig. 3. Ostracods in the surface sediment of Lake Ngoring.
(A) Ilyocypris echinata Huang, 1979.
(B) I. echinata Huang, 1979.
(C) Details of the valve surface of (A),
(D) Detail of the postero-ventral part of (B).
(E) Detail of the anterior part of (B).
(F) Ilyocypris sp..
(G) Ilyocypris sp..
(I) A normal pore with seta preserved on the surface of (F).
(J) A normal pore on the surface of (G),

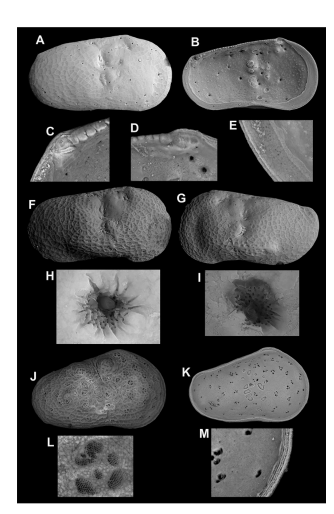

Fig. 4. Ostracods in the surface sediment of Lake Ngoring.
(A) Leucocythere sp. 1.
(B) Leucocythere sp. 1.
(C) Posterior hinge area of (B).
(D) Anterior hinge area of (B).
(E) Posterior valve margin of (B).
(F) Leucocythere sp. 2, phenotype 1.
(G) Leucocythere sp. 2.
(H) A sieve pore on the valve surface of (F).
(I) A sieve pore on the valve surface of (G).
(J) Cytherissa lacustris (Sars, 1863).
(K) C. lacustris.
(L) A sieve-pore complex on the valve surface of (J).
(M) Details of antero-ventral part of (K).

- Depth-constrained cluster analysis distinguishes three ostracod assemblage zones, namely, the shallow-water Zone 1 (2.1–4.5 m), the intermediate Zone 2 (6.0–22.0 m), and the deep-water Zone 3 (23.0–33.3 m) (Figs. 5, 6). The ercentage diagram (Fig. 6) shows the change in the portion of each ostracod element within the total ostracod fauna.

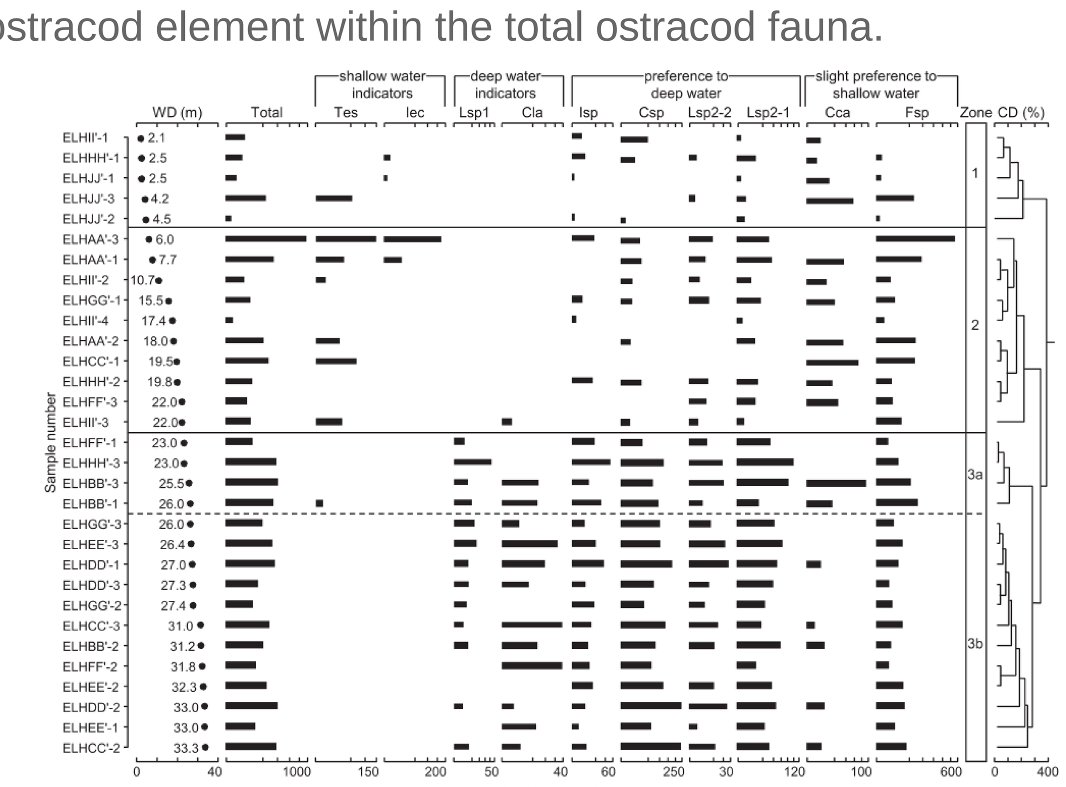

Fig. 5. Ostracod abundances (valves per10g dried sediment, expressed on square-root scale) in 31 surface-sediment samples from Lake Ngoring.

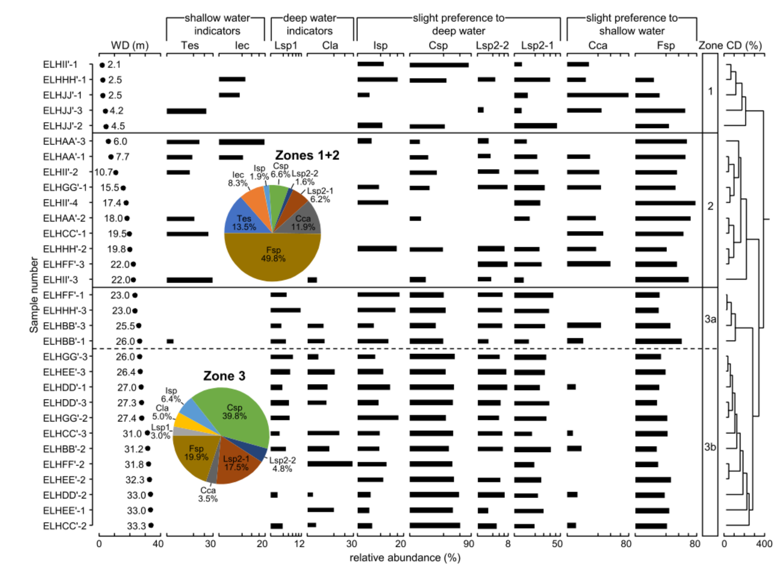

Fig. 6. Relative abundances (%, expressed on square-root scale) of ostracods in 31 surface-sediment samples from Lake Ngoring. The pie charts show the overall percentage compositions of the ostracods in Zones 1+2 and Zone 3, respectively.

2.Results of CCA and transfer function

- CCA analysis shows a strong dependence of the ostracod abundance on the water depth (Fig. 7).

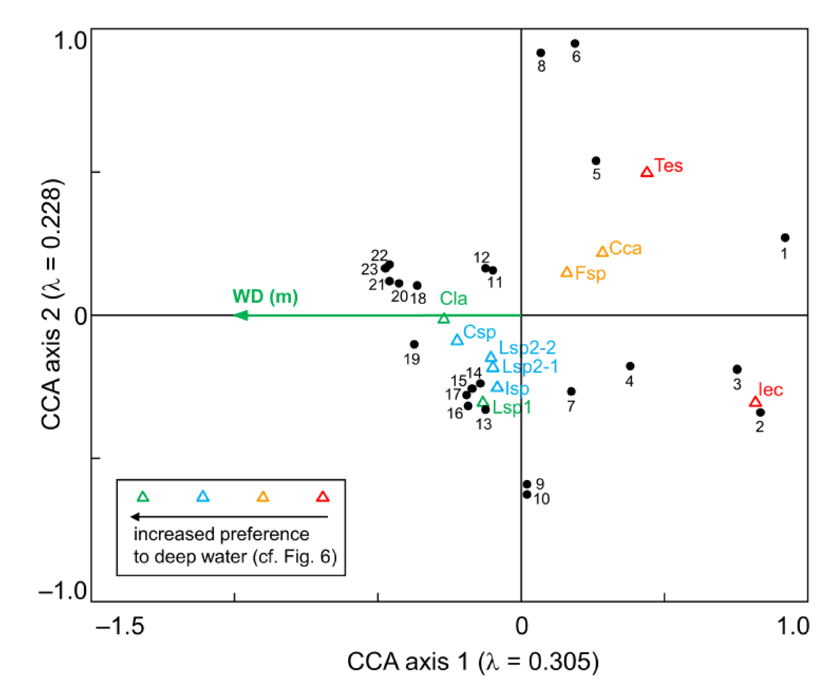

Fig. 7. CCA (canonical correspondence analysis) ordination showing the relationship between the water depth and the ostracod distribution in Lake Ngoring. Black dots represent the 23 samples with ostracod valve count exceeding 200. Colored triangles indicate ten ostracod groups, with colorations highlighting different preferences to water depth.

- Transfer functions based on Partial Least Squares (PLS) and Weighted Averaging Partial Least Squares (WAPLS) regressions were established (Fig. 8).

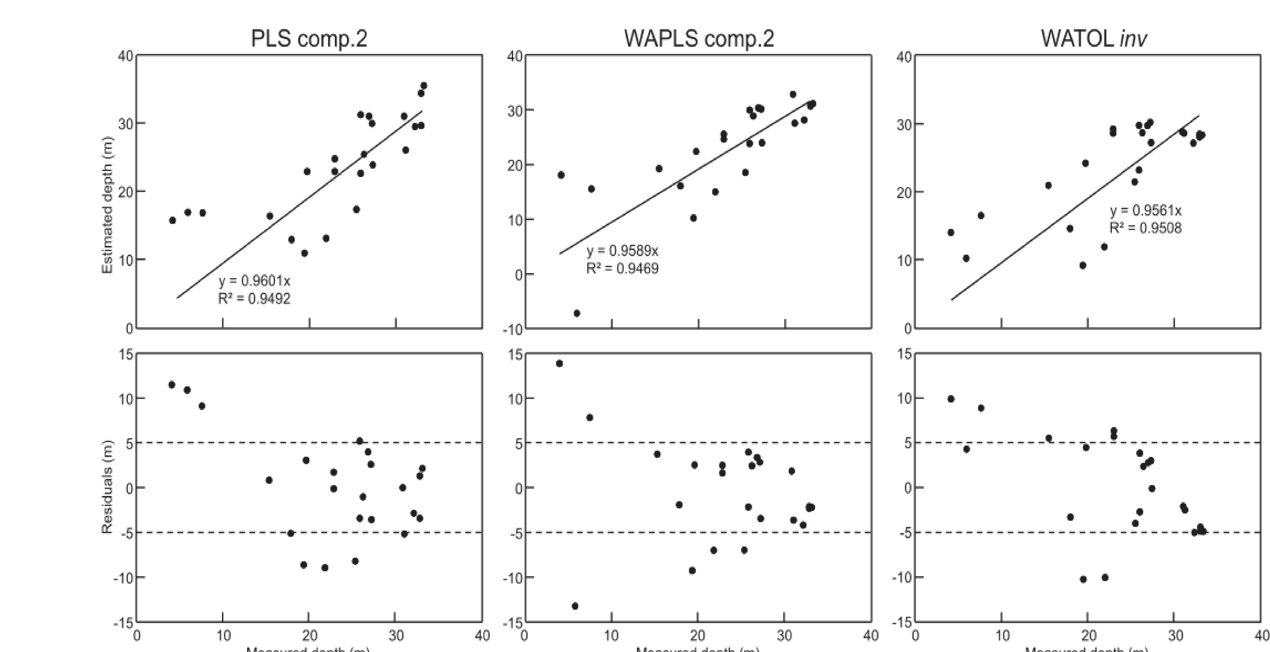

Fig. 8. Upper panels: the relationship between the measured water depth and the estimated water depth in Lake Ngoring using three ostracod-based transfer functions (PLS, WA-PLS, WA). Regressions are based on compelled linear models with an intercept at (0, 0). Lower panels: the residuals (measured minus estimated depth) of the three transfer functions. Horizontal dashed lines represent the residual range of ± 5 m. This figure shows that the performances of the three models are generally good and comparable (see also Table 3).

3.Prospects in the application of the ostracod-based transfer function

- The modern ostracod assemblages of various habitats across different geographical conditions need to be studied, to include more species, more environmental variables, and a wider range of each variable.
- For quantitative water-depth reconstruction, the ostracod datasets from different lakes should be synthesized into more comprehensive, more relevant transfer functions that contain more species and wider depth ranges to better capture the assemblage and depth variations in the geologic past.

Conclusion

Analysis of the surface-sediment samples from Lake Ngoring yields mathematically good and testable relation between the ostracod assemblage and the water depth, in the form of several transfer functions with comparable predictive results. These transfer functions have the potential to be applied to the ostracod-assemblage data in the sediment core from this lake and from lakes with similar faunal compositions and hydrological settings to quantitatively reconstruct the water depths in the past. However, such an attempt should take into consideration the various environmental factors besides water depth that can affect the ostracod assemblage, as well as the probable large shifts in the ostracod assemblage and water depth in the past that might go beyond the ranges represented by the training dataset. In the future, if possible, ostracod datasets from different lakes should be synthesized together to build up 'mega-transfer functions' that cover more diverse assemblages and wider ranges of water-depth changes to improve the quantitative reconstructions of palaeolimnological conditions.

Acknowledgments

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