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Ecology of macrozoobenthic communities in two plateau lakes of Southwest China*

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Abstract Ecological studies on macrozoobenthos were conducted in two small plateau lakes in the Yunnan-Guizhou Plateau, Southwest China: Xingyun Lake (XL), a eutrophic lake whose main source of primary production was phytoplankton (Chl a=99.76±24.01 μg/L), and Yangzong Lake (YL), a mesotrophic lake. Sampling was carried out from October 2002 to May 2004. Altogether 23 benthic taxa were identified in XL and 21 taxa in YL. The density of benthos in XL was much lower than that in YL, but the biomass was about equal in the two lakes, being 1 423 ind/m^2 and 8.71 g/m^2 in XL and 4 249 ind/m^2 and 8.60 g/m^2 in YL. The dominant species were *Limnodrilus hoffmeisteri*, *Branchiura sowerbyi*, *Aulodrilus pluriseta* and *Chironomus* sp. in XL and *Limnodrilus hoffmeisteri*, *Aulodrilus pluriseta* and *Bellamya* sp. in YL. Seasonal fluctuation occurred, showing richer species in summer and winter, but the density and biomass varied in different ways in the two lakes. Analyses on functional feeding groups indicate that collector-gatherers were predominant, but the relative abundances of other groups were different. Stepwise multiple regression analysis demonstrated that the water depth, conductivity and chlorophyll a were the key factors affecting macrozoobenthic abundance in the lakes.

Keyword: plateau lakes; macrozoobenthos; taxonomic composition; standing crop; functional feeding group; environmental analysis

1 INTRODUCTION

Macrozoobenthic communities play important role in nutrient cycling and are very useful as biological monitor to environmental health of lakes (Brinkhurst, 1974; Hanson and Peters, 1984; Rosenberg and Resh, 1993; Pinel-Alloul et al., 1996). Despite many studies on macrozoobenthos undertaken in lakes of other countries (Brinkhurst, 1974; Timm et al., 1996a, 1996b; Martin et al., 1999; Ohtaka and Nishino, 1999; Nalepa et al., 2003) and in Chinese shallow lakes along the middle and lower reaches of the Changjiang (Yangtze) River (Chen et al., 1980; Liang and Liu, 1995; Xu et al., 2003; Wang et al., 2005; Jiang et al., 2006), little attention has been paid to Chinese plateau lakes so far. On the Yunnan-Guizhou Plateau, there are many deep lakes, mostly 10–80 m in depth, playing as invaluable pools of aquatic organisms. However, due to increasing human activities in recent years, these lakes are suffering from water deterioration and species invasion. As a result, the diversity and population sizes of some endemic exotic species in these lakes were decreasing continuously (Qin, 2005; Cui et al., 2008). For the program of lake conservation, comprehensive studies on macrozoobenthos should be carried out.

In 2002–2004, an investigation of macrozoobenthos was carried out as a part of a project on biological limnology of plateau lakes in Yunnan Province, China, such as Fuxian Lake, Xingyun Lake, and Yangzong Lake. This study is to compare the community structure, characteristics of the macrofauna, and seasonal changes in eutrophic Xingyun Lake and mesotrophic Yangzong Lake, and environmental analyzing were also included. The two lakes are different mainly in their trophic level and water depth and similar in other characteristics, such as geographic locality, surface area and sediment structure.

2 STUDY AREA AND METHODS

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The study sites were two small tectonic lakes: Xingyun Lake (24º17′–24º23′N, 102º45′–102º48′E) and Yangzong Lake (24º51′N–24º58′102º58′–103º01′E) (Fig.1) on the Yunnan-Guizhou Plateau. Xingyun Lake receives surface runoff from the catchments (378 km^2) through many small rivers, and the water is discharged into Fuxian Lake through a river to the northeast. Yangzong Lake receives the water from three small rivers and some temporal stream, and the water is discharged into Nanpan River through Baiyi River to the northeast (Wang and Dou, 1998). Major physico-chemical parameters of the lakes are given in Table 1.

Samplings were carried out bimonthly from October 2002 to August 2003 in Xingyun Lake, and quarterly from August 2003 to May 2004 in Yangzong Lake. Benthic samples were collected by a weighted Peterson sampler (1/16 m^2), and cleaned gently with a 420 µm sieve. Animals were manually sorted out from sediment with a white porcelain plate and preserved in 10% formalin.

Animals were mainly identified to species and genera. All taxa were assigned to functional feeding groups (shredders, collector-gatherers, collector-filterers, scrapers and predators) according to Morse et al. (1994) and Liang and Wang (1999), or by direct examination of their gut contents. When a taxon has several possible feeding activities, its functional designations were equally proportioned. Wet biomass of larger animals was determined with an electronic scale after being blotted (molluscan shells retained).

STATISTIC 6.0 was used for one-way ANOVA and stepwise multiple regression analyses. The standing crops were compared among zones using Unequal N HSD Test after one-way ANOVA. Environmental factors and macrozoobenthic abundance were analyzed using stepwise multiple regressions. Some parameters were log-transformed to obtain normal-distributed data. Species number and density were transformed to $\log(x+1)$ and biomass to $\log(x+0.01)$ because of the presence of zero in original data set.

Jaccard Coefficient (S_j) was applied for the similarity comparison of benthos communities between the lakes (Wu and Liang, 1999):

$$S_j = c/(a+b-c),$$

where a is the number of species in community A; b is the number of species in community B; and c is the number of species common to both communities.

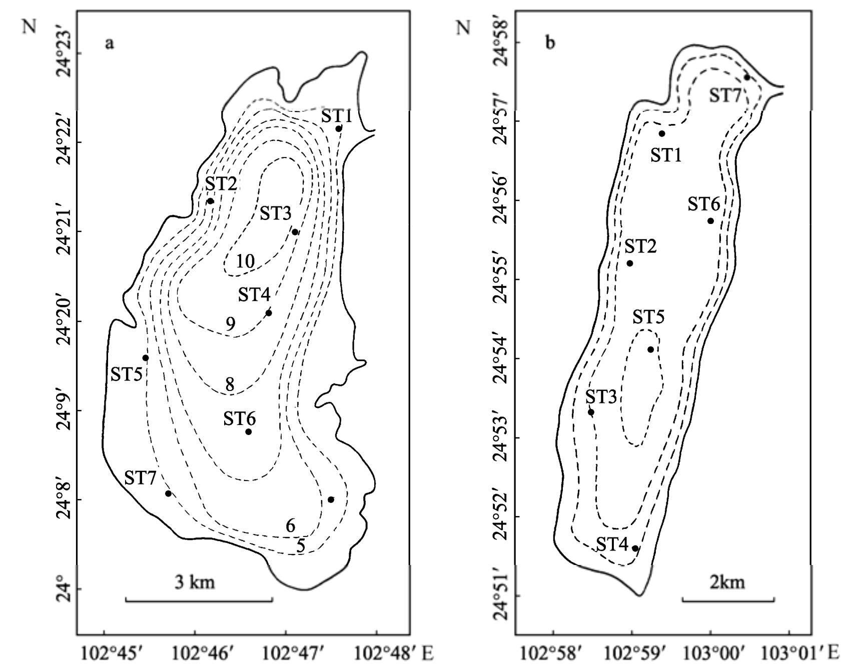

Fig. 1 Sampling stations in the two lakes

a. Xingyun Lake; b. Yangzong Lake; Dashed lines showing isobaths

Table 1 Major physico-chemical characteristics of Xingyun Lake and Yangzong Lake (mean±SE**)**

Parameter	Xingyun Lake (Lei et al., 1963; Wang and Dou, 1998)	Yangzong Lake (Lei et al., 1963; Wang and Dou, 1998)
Surface area (km^2)	35	32
Water level (m)	1722	1771
Maximum length (km)	10.5	12
Maximum width (km)	5.8	3.1
Maximum depth (m)	11	30
Mean depth (m)	7.8	19.5
Shore development (D_L)	1.64	1.64
Air temperature (°C)	15.0	14.5
Mean precipitation (mm)	947	964
Mean evaporation (mm)	1192	1337
Catchments area (km^2)	378	192
Water temperature (°C)	19.0	17.7
Secchi depth (m)	1.23±0.09	4.95±0.72
Conductivity (µm/cm)	332±9.8	29.8±11.2
pH	8.85±0.27	9.15±0.94
Chlorophyll *a* (µg/L)	99.76±24.01	3.96±0.38
Total nitrogen (mg/L)	3.922±0.47	0.270±0.06
Total phosphorus (mg/L)	0.310±0.036	0.022±0.001
Trophic level	Eutrophic	Mesotrophic
Type of sediment	Fine silt	Fine silt
Number of sediment samples taken	8	7

3 RESULTS

3.1 Community structure

3.1.1 Species composition

Altogether 23 taxa in Xingyun Lake belonging to 7 families and 16 genera were identified. Among them were 14 species of oligochaetes, 4 species of molluscs and 4 species of aquatic insects. A total of 21 taxa belonging to 6 families and 16 genera were found in Yangzong Lake. Among them were 11 species of oligochaetes, 4 species of molluscs and 6 species of aquatic insects (Table 2).

3.1.2 Standing crop

The standing crop of zoobenthos in the Xingyun Lake was 1 423 ind/m^2 in density and 8.71 g/m^2 in wet biomass. Oligochaetes were the most abundant group, comprising 95.0% in density and 82.9% in biomass. Insects comprised 4.3% in density and 16.8% in biomass, respectively. Molluscs were found only in littoral regions. Although the density of zoobenthos in Yangzong Lake (4 249 ind/m^2) was much higher than that in Xingyun Lake, their biomass was almost equal. This is mainly due to the different species composition in the lakes, i.e. large worm, *Branchiura sowerbyi*, is the predominant taxa in Xingyun Lake. And the oligochaetes were also the most predominant group, comprising 99.4% in density and 54.3% in biomass (Fig.2, Table 2).

3.1.3 Predominant species

Quantitative aspects of taxa are given in Table 2. According to the abundance, *Limnodrilus hoffmeisteri*, *Branchiura sowerbyi*, *Aulodrilus pluriseta* and *Chironomus* sp. were predominant in Xingyun Lake; they comprised 75.1%, 2.7%, 12.4% and 3.8% in density, and 54.0%, 27.2%, 1.5%, and 16.2% in biomass, respectively. The predominant forms in Yangzong Lake were *Limnodrilus hoffmeisteri*, *Aulodrilus pluriseta* and *Bellamya* sp., comprising 91.1%, 4.7% and 0.1% in density, and 51.8%, 0.6%, and 43.7% in biomass, respectively.

Table 2 Density (D, ind/m^2**), biomass (**B, g/m^2, wet weight**) and percentage of taxa in Xingyun Lake and Yangzong Lake**

Species	Xingyun Lake				Yangzong Lake			
	Density	%	Biomass	%	Density	%	Biomass	%
Nematoda	9	0.6	0.02	0.2	–	–	–	–
Annelida								
Oligochaeta								
Naididae								
Dero digitata	5	0.3	0.00	0.0	–	–	–	–
Dero obtusa	3	0.2	0.00	0.0	–	–	–	–
Paranais frici	–	–	–	–	1	0.0	0.00	0.0
Tubificidae								
Aulodrilus limnobius	2	0.1	0.00	0.0	1	0.0	0.00	0.0
A. japonicus	3	0.2	0.00	0.0	–	–	–	–
A. pectinatus	–	–	–	–	**47**	**1.1**	0.02	0.2
A. pluriseta	**207**	**12.4**	**0.13**	**1.5**	**202**	**4.7**	0.05	0.6
Limnodrilus hoffmeisteri	**1260**	**75.1**	**4.70**	**54.0**	**3870**	**91.1**	**4.45**	**51.8**
L. claparedeianus	4	0.3	0.00	0.0	1	0.0	0.00	0.1
L. grandisetosus	1	0.0	0.00	0.0	11	0.3	0.08	1.0
L. udekemianus	1	0.0	0.00	0.0	–	–	–	–
Branchiura sowerbyi	**45**	**2.7**	**2.37**	**27.2**	3	0.1	0.02	0.2
Ilyodrilus templetoni	**17**	**1.0**	0.01	0.1	–	–	–	–
Potamothrix sp1	2	0.1	0.00	0.0	5	0.1	0.01	0.1
Potamothrix sp2	10	0.6	0.01	0.0	2	0.0	0.00	0.0
Tubifex tubifex	**34**	**2.0**	**0.01**	**0.1**	**85**	**2.0**	0.03	0.3
Mollusca								
Gastropoda								
Viviparidae								
Bellamya sp.	—	–	–	–	3	0.1	**3.75**	**43.7**
Cipangopaludina chinensis	+	–	–	–	–	–	–	–
Margarya sp.	+	–	–	–	+	–	–	–
Planorbidae								
Hippeutis sp.	+	–	–	–	+	–	–	–
Lymmaeidae								
Radix sp.	+	–	–	–	1	0.0	**0.12**	**1.3**
Insecta								
Chironomidae								
Chironomus sp.	**64**	**3.8**	**1.41**	**16.2**	12	0.3	0.05	0.6
Dicrotendipes sp.	1	0.0	0.01	0.1	–	–	–	–
Djalmabatista sp.	–	–	–	–	1	0.0	0.00	0.0
Micopsetra sp.	–	–	–	–	1	0.0	0.00	0.0
Microchironomus sp.	8	0.5	0.02	0.3	1	0.0	0.00	0.0
Procladius sp.	1	0.0	0.01	0.1	3	0.1	0.00	0.0
Tanytarsus sp.	–	–	–	–	1	0.0	0.00	0.0
Total	1 423	100.0	8.71	100.0	4 249	100.0	8.60	100.0

Bold letters denote relative abundance >1%; + denote only occurrence in littoral region; - denote no occurrence

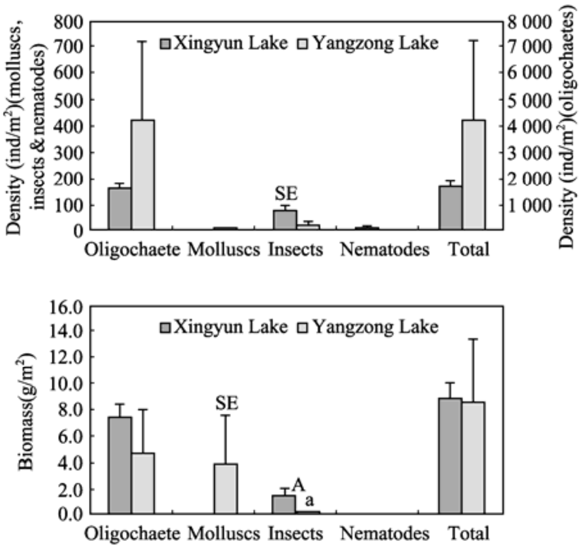

Fig. 2 Density and biomass (wet weight**) of macrozoobenthos in Xingyun Lake and Yangzong Lake**

Different letters above the bars indicate significant difference (p<0.01) between two lakes among each taxonomic group

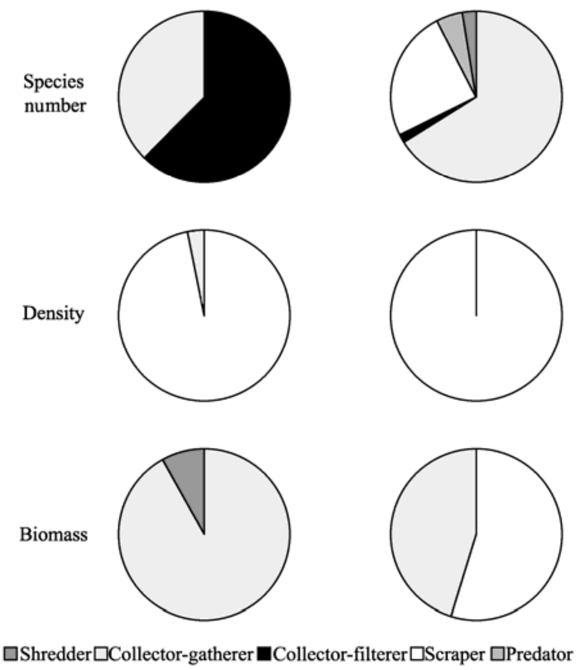

Fig.3 Relative abundances of functional feeding groups in Xingyun Lake and Yangzong Lake

3.2 Functional structure

The relative abundance of five functional feeding groups in the lakes (Fig.3) shows, the collector-gatherers were predominant in Xingyun Lake and Yangzong Lake, comprising 62.3% and 65.9% in species number, 97.0% and 99.7% in density, and 91.5% and 54.6% in biomass, respectively. Both the relative abundances of collector-filterers and predator are much lower in the two lakes, comprising 2.2%–6.5% in species number, and much less than 1% in density and biomass. The relative abundances of scrapers and shredders were different in two lakes. The biomass of scrapers in Yangzong Lake was much higher than that in Xingyun Lake. Both relative and absolute abundances of shredders in Xingyun Lake were higher than those in Yangzong Lake, although the species numbers in the lakes were almost equal. This is mainly due to *Chironomus* sp. as the predominate taxa in Xingyun Lake.

3.3 Seasonal dynamics

The seasonal changes of taxa number and standing crops (Fig.4) show that, in Xingyun Lake, the benthic taxa were richer in winter, e.g. 15 species were observed in winter, but only 7 species in summer. However, higher density and greater biomass were observed in spring and summer, with the maximum density (2 809 ind/m^2) and biomass (14.84 g/m^2) in summer. The minimum density (327 ind/m^2) and biomass (1.48 g/m^2) were present in fall. In Yangzong Lake, the benthic taxa were richer in summer, e.g. 15 species were observed in summer, but only 2 species in fall. Higher density was observed in summer and greater biomass was present in summer and winter.

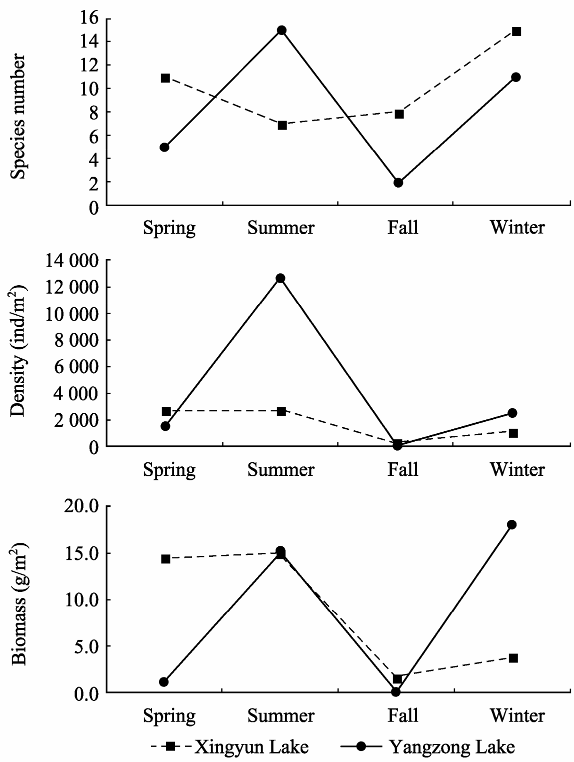

Fig.4 Annual changes of species number, density and biomass (wet weight**) of macrozoobenthos in Xingyun Lake and Yangzong Lake**

3.4 Environmental analysis

The results of stepwise multiple regression analysis (Table 3) shows that water depth contributed greatly to the variations in species number, and macrozoobenthic, oligochaete and collector-gatherer standing crop, so did the conductivity to the variations of insects and shredder, and chlorophyll *a* to the variations of predator. It demonstrates that water depth, conductivity and chlorophyll *a* were the key factors affecting macrozoobenthic community structure in the lakes.

4 DISCUSSION

Based on present and previous researches (Wang, 1988), 28 taxa in total have been reported from Xingyun Lake and 24 taxa in Yangzong Lake. The species compositions were similar in the lakes, and the similarity index (S_j**)** was 40.5%. The characteristics of the macrofauna in the lakes are mainly as follows: 1) the taxa were common species except *Potamothrix* and *Margarya*, the former distributed mainly in Holarctic region (Cui and Wang, 2005), and the latter were an endemic genus in Yunnan Province (Liu et al., 1993); 2) nearly half of the entire taxa were Oligochaeta, and *Limnodrilus hoffmeisteri* was the most predominant species; 3) molluscs occurred only in littoral regions. Compared with other plateau lakes of various trophic levels, sizes and depths, the macrozoobenthic diversity of Xingyun Lake and Yangzong Lake was poorer than those in Fuxian Lake, Dianchi Lake and Erhai Lake. Macrozoobenthos of Fuxian Lake was special compared to other lakes (Table 4, Fig. 5). Although the predominant taxa of the plateau lakes are different, *Limnodrilus hoffmeisteri* and *Branchiura sowerbyi* are always predominant taxa in trophic lakes (Table 4).

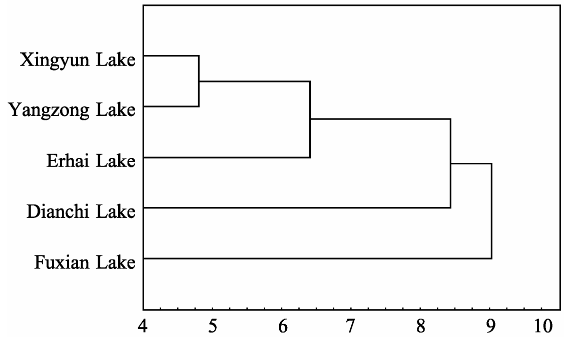

Fig. 5 Similarity of species compositions of macrozoobenthos in different plateau lakes

Significant seasonal changes were found in macrozoobenthic diversity and abundance in Xingyun Lake and Yangzong Lake. Including the seasonal changes of macrozoobenthos in Fuxian Lake, the benthic taxa of plateau lakes were richer in summer and winter, while those of Changjiang shallow lakes were richer in spring and autumn (Liang et al., 1995). In the lakes, the density and biomass varied in different ways, greater biomass of Yangzong Lake was observed in summer and winter, because of the occurrence of *Bellamya* sp. Due to the fact that oligochaetes comprised 95.0%–99.4% in total density of the lakes, the seasonal change of benthic density was governed by oligochaetes, while those of Changjiang shallow lakes were governed by molluscs (Liang *et al*., 1995).

Table 3 Stepwise multiple regression analyses using environmental factors and macrozoobenthic abundance in Xingyun Lake and Yangzong Lake (Equation: $y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$, n=75, F to enter is 4)

y	b_0	x_1=*DEP*		x_2=*COND*		x_3=*Chl a*		x_4=*SD*		x_5=*TP*		r^2	p
		b_1	F	b_2	F	b_3	F	b_4	F	b_5	F		
lg(*SN*+1)	0.96	0.03	59.66	–	–	–	–	–	–	–	–	0.45	0.000
lg (D_O+1)	4.07	-0.13	71.01	–	–	–	–	–	–	–	–	0.49	0.000
lg (D_I+1)	0.26	–	–	0.002	24.14	0.002	15.16	–	–	–	–	0.30	0.000
lg (D_T+1)	4.04	-0.13	66.6	–	–	–	–	–	–	–	–	0.48	0.000
lg (D_{SH}+1)	0.10	–	–	0.002	26.13	0.002	17.49	–	–	–	–	0.33	0.000
lg (D_{CG}+1)	4.04	-0.13	68.97	–	–	–	–	–	–	–	–	0.49	0.000
lg (D_{SC}+1)	0.16	–	–	–	–	0.001	4.30	–	–	–	–	0.06	0.042
lg (D_{PR}+1)	0.21	–	–	–	–	0.002	5.35	–	–	-0.77	5.05	0.12	0.009
lg (B_O+0.01)	-0.87	-0.10	81.82	0.05	45.44	–	–	0.33	33.60	–	–	0.59	0.000
lg (B_I+0.01)	-1.91	–	–	0.03	36.03	0.002	21.51	–	–	–	–	0.37	0.000
lg (B_T+0.01)	0.33	-0.06	53.62	0.003	30.09	–	–	–	–	–	–	0.46	0.000
lg (B_{SH}+0.01)	-1.98	–	–	0.003	32.53	0.002	20.78	–	–	–	–	0.37	0.000
lg (B_{CG}+0.01)	0.44	-0.08	83.28	0.002	46.34	–	–	–	–	–	–	0.56	0.000
lg (B_{PR}+0.01)	-1.93	–	–	–	–	0.001	4.55	–	–	–	–	0.06	0.036

Abbreviations: *SN*, species number; *D*, density (ind/m^2); *B*, biomass(g/m^2); *O*, oligochaete; *I*, insect; *GA*, gastropod; *T*, Total; *SH*, shredder; *CF*, collector-filterer; *CG*, collector-gatherer; *SC*, scraper; *PR*, predator; *DEP*, water depth (m); *SD*, Secchi depth (m); *COND*, conductivity (μm/cm); *Chl a*, Chlorophyll *a* (μg/L); *TP*, Total phosphorus (mg/L)

Table 4 Comparison of environmental parameters, taxa number and abundance of macrozoobenthos among plateau lakes

Water bodies	Location	Environmental parameter				Species number			Density (ind/m^2)	Biomass (g/m^2)	Predominate species	Reference
		Area (km^2)	Mean depth (m)	TN (mg/L)	TP (mg/L)	Oligochaetes	Molluscs	Chironomids				
Xingyun Lake	24º17´–24º23´N 102º45´–102º48´E	35	7.8	3.922±0.47	0.270±0.06	14	9	4	1 423	8.71	*L. hoffmeisteri*, *B. sowerbyi*, *A. pluriseta*, *Chironomus* sp.	This study; Wang, 1988
Yangzong Lake	24º51´–24º58´N 102º58´–103º01´E	32	19.5	0.310±0.04	0.022±0.00	11	7	6	4 249	8.60	*L. hoffmeisteri*, *A.pluriseta*, *Bellamya* sp.	This study; Wang, 1988
Fuxian Lake	24º17´–24º37 N´ 102º49´–102º57´E	211	89	0.198±0.00	0.021±0.00	24	50	22	327	1.72	*Potamothrix* sp., *Procladius* sp., *Paraprososthenia* sp.	Wang, 1988; Nanjing Institute of Geography and Limnology, 1990; Cui et al, 2008
Dianchi Lake	24º40´–25º02´N 102º36´–102º47´E	306	4.4	2.62	0.20	8	76	8	11 089	58.95	*B. sowerbyi*, *L. claparedeianus*, *C. plumosus*	Wang, 1985; Wang, 1988; Wang et al, 2002
Erhai Lake	25º36´–25º58´N 100º05´–100º18´E	249	10.2	0.436±0.01	0.040±0.00	9	25	3	1 219	82.72	*M. melanoides*, *C. fluminea*, *B. sowerbyi*	Wang, 1988; Wu and Wang, 1999

Our analyses show that the factors governing the benthic community of Fuxian Lake were water depth, conductivity, chlorophyll *a*, Secchi depth and total phosphorus. Among them, water depth and conductivity are key factors affecting most the species number and standing crops of macrozoobenthos. Similar results have also been reported from Euro-American deep lakes (Brinkhurst, 1974; Dermott, 1978; Rasmussen and Kalff, 1987). Chlorophyll *a* was another key factor affecting standing crops of macrozoobenthos in the trophic plateau lakes

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References

Brinkhurst, R. O., 1974. The Benthos of Lakes. The Macmillan Press Ltd, London.

Chen, Q. Y., Y. L. Liang and T. H. Wu. 1980. Studies on community structure and dynamics of zoobenthos in Lake Donghu, Wuhan. *Acta. Hydrobiol. Sin.* **7**: 41-56.

Cui, Y. D. and H. Z. Wang, 2005. *Potamothrix scleropenis* sp. nov. (Oligochaeta: Tubificidae) from Fuxian Lake, the deepest lake in southwest China. *Zool. Sci*. **22**: 1 353-1 357.

Cui, Y. D., X. Q. Liu and H. Z. Wang, 2008. Macrozoobenthic community of Fuxian Lake, the deepest lake of southwest China. *Limnologica* **38**: 116-125

Dermott, R., 1978. Benthic diversity and substrate-fauna associations in Lake Superior. *J. Great. Lakes Res.* 4: 505-512.

Hanson, J. M. and R. H. Peters, 1984. Empirical prediction of crustacean zooplankton biomass and profundal macrobenthos biomass in lakes. *Can. J. Fish. Aquat. Sci.* **41**: 439-445.

Jiang, P. H., X. M. Liang, F. Chen, Y. Y. Zhou and H. Z. Wang, 2006. Indication of macrophytes-restorable area by spatial pattern of macrobenthos in a eutrophic Yangtze Lake. *Resource and Environment in the Yangtze Basin* **4**: 439-445.

Ley, S. H., M. K. Yu, K. C. Li, C. M. Tseng, C. Y. Chen, P. Y. Kao and F. C. Huang, 1963. Limnological survey of the lakes of Yunnan Plateau, *Oceanol. Limnolo. Sin.* **5**: 87-114. (in Chinese with English abstract)

Liang, Y. L. and H. Q. Liu, 1995. Resources, Environment and Fishery Ecological Management of Macrophytic Lake (No. 1). Science Press, Beijing. (in Chinese with English abstract)

Liang, Y. L. and H. Z. Wang, 1999. Zoobenthos. *In*: Liu, J. K. ed. Advanced hydrobiology. Science Press, Beijing, p. 241-259. (in Chinese)

Liu, Y. Y., W. Z. Zhang and Y. X. Wang, 1993. Medical Malacology. Ocean Press, Beijing. (in Chinese)

Martin, P., K. Martens and B. Goddeeris, 1999. Oligochaeta from the abyssal zone of Lake Baikal (Siberia, Russia). *Hydrobiologia* **406**: 165-174.

Morse, J. C., L. F. Yang and L. X. Tian, 1994. Aquatic Insects of China Useful for Monitoring Water Quality. Hohai Univ. Press, Nanjing.

Nalepa, T. F., D. L. Fanslow, M. B. Lansing and G. A. Lang, 2003. Trends in the benthic macroinvertebrate community of Saginaw Bay, Lake Huron, 1987 to 1996: response to phosphorus abatement and the zebra mussel, *Dreissena polymorpha*. *J. Great Lakes Res.* **19**: 14-33.

Nanjing Institute of Geography and Limnology (CAS), 1990. The Fuxian Lake. Ocean Press, Beijing. (in Chinese)

Ohtaka, A. and M. Nishino, 1999. Studies on the aquatic oligochaete fauna in Lake Biwa, central Japan. II. Records and taxonomic remarks of nine species. *Hydrobiologia* **406**: 33-47.

Pinel-Alloul, B., G. Méthot, L. Lapierre and A. Willsie, 1996. Macroinvertebrate community as a biological indicator of ecological and toxicological factors in Lake Saint-François (Québec). *Environ. Pollu.* **91**: 65-87.

Qin, J. H., 2005. Ecological Effects of the Invasive Icefish *Neosalanx taihuensis* in a deep oligotrophic plateau lake, Lake Fuxian. Ph.D. Thesis. Chinese Academy of Sciences, China.

Rasmussen, J. B. and J. Kalff, 1987. Empirical models for zoobenthic biomass in lakes. *Can. J. Fish. Aquat. Sci.* **44**: 990-1 001.

Rosenberg, D. M. and V. H. Resh. 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York, p. 488.

Timm, T., K. Kangur, H. Timm and V. Timm, 1996a. Macrozoobenthos of Lake Peipsi-Pihkva: taxonomical composition, abundance, biomass, and their relations to some ecological parameters. *Hydrobiologia* **338**: 139-154.

Timm, T., K. Kangur, H. Timm and V. Timm, 1996b. Macrozoobenthos of Lake Peipsi-Pihkva: long-term biomass changes. *Hydrobiologia* 338: 155-162.

Wang, L. Z., 1985. Macroinvertebrates of Dianchi Lake, Yunnan. *J. Yunnan Univ.* (Suppl) **7**: 73-83. (in Chinese with English abstract)

Wang, L. Z., 1988. An ecological study on Mollusca population in plateau lakes of Yunnan. *J. Yunnan Univ.* (Suppl) **10**: 37-43. (in Chinese with English abstract)

Wang, L. Z., X. Q. Xu, W. B. Zhou and H. Xiao, 2002. A study on the zoobenthos in Macunwan and Haidongwan Region of Dianchi Lake, Yunnan. *J. Yunnan Univ.* **24**: 134-139. (in Chinese with English abstract).

Wang, H. Z., Q. Q. Xu, Z. C. Xie and Y. L. Liang, 2005. Chapter 2. Resource and environmental characters of small and medium lake, zoobenthos. *In*: Cui, Y. B & Li, Z. J. (eds), Fishery Resources and Conservation of Environment in Lakes of the Changjiang River Basin. Science Press, Beijing, p. 52-89. (in Chinese with English abstract)

Wang, S. M. and H. S. Dou, 1998. Lakes of China, Science Press, Beijing. (in Chinese)

Wu, J. H. and Y. L. Liang, 1999. A comparative study of benthic nematodes in two Chinese lakes with contrasting sources of primary production. *Hydrobiologia* **411**: 31-37.

Xu, Q. Q., H. Z. Wang and S. P. Zhang, 2003. The impact of overstocking of mitten crab, Eriocheir sinensis, on lacustrine zoobenthic community. *Acta Hydrobiol. Sin.* **27**: 41-46. (in Chinese with English abstract)