ISSN 1009 - 3095 *Journal of Zhejiang University SCIENCE* V.3, No.1, P.118 - 124, Jan. - Mar., 2002
http://www.periodicals.com.cn; http://www.zju.edu.cn/depart/zdxb
http://lib.zju.edu.cn/eindex.htm; http://www.zjupress.com; jzu_s@mail.hz.zj.cn

Studies on the changes of West Lake's zoobenthic communites after Qiantang River water was pumped into it*

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Received Dec.26, 2000; revision accepted Mar.18, 2001

Abstract: During Jan.1995 to Dec.1996, monthly investigations on the zoobenthic communities of West Lake, samples were collected from six sampling stations. A total of 26 species of macrozoobenthos were identified. The seasonal changes in density and biomass of zoobenthos in this lake were analyzed. The annual mean densities were 980 ~ 2751 ind/m^2 and mean biomass was 19.69 - 122.80 g/m^2. The densities in winter and early spring were higher than those in summer and autumn. Comparative study of theprevious data (1982 to 1983) collected by the authors, showed that the succession of zoobenthic communities, dominated by *Procludius choreus* in density and *Bellamya purificata* in biomass, had been occurred in Xiaonan sub-lake after Qiantang River water was drawn into it; and that the species and biomass of zoobenthos were then increased and the density was decreased. In other sub-lakes, the dominant species were *Limnodrilus hoffmeisteri* and *Tokunagayusurika akamusi* in density and *Branchiura sowerbyi* and *Tokunagayusurika akamusi* in biomass. The water quality was bad in these sub-lakes because these dominant species are indicators of eutrophication. According to the Margalef index and Goodnight index, West Lake is still an eutrophic lake. Only the water quality of Xiaonan sub-lake was improved after water drawn from the Qiantang River was introduced into it.

Key words: zoobenthos, eutrophication, water pumped, West Lake, environmental engineering
Document code: A　　**CLC number:** Q178.11

INTRODUCTION

West Lake, a famous scenic spot for tourists in China, is a small shallow eutrophic lake. However, the lake has been suffering from eutrophication from year to year and its beauty is marred by the low transparency of the water. The eutro-phication of West Lake studied in the 1970s by many scientists. In order to improve the water quality, wastewater from households was greatly reduced and Qiantang River fresh water was pumped into the lake during 1980s. It was the first time in China that the river water was pumped into the eutrophic lake in order to improve the water quality. So, many scientists were interested in the ecological effect of pumping Qiangtang River water into West Lake.

Because the habitats of zoobenthos are limited, they are good indicators of the lake environment. The zoobenthic fauna of West Lake was investigated during 1982 to 1983 (Yu et al., 1991) before Qiantang River water was pumped into the lake. This Jan. 1995 to Dec.1996 study was aimed to identify and compare; to determine the communities of zoobenthos then with those in 1982 to 1983; to determine the ecological effect of drawing Qiantang River water into the lake; and to evaluate the lake's present trophic state.

STUDY SITES AND METHODS

West Lake (120°16′E, 30°15′N; surface area 5.6 km^2; mean depth 1.8 m) is divided into five sub-lakes, i.e, Outer lake (4.40 km^2), Xiaonan sub-lake (0.09 km^2), Xili sub-lake (0.76 km^2), Yue sub-lake (0.07 km^2), Beili sub-lake (0.34 km^2). Fig.1 shows the distribu-

* Project supported by the Evironmental Protection Bureau of Hangzhou, China.

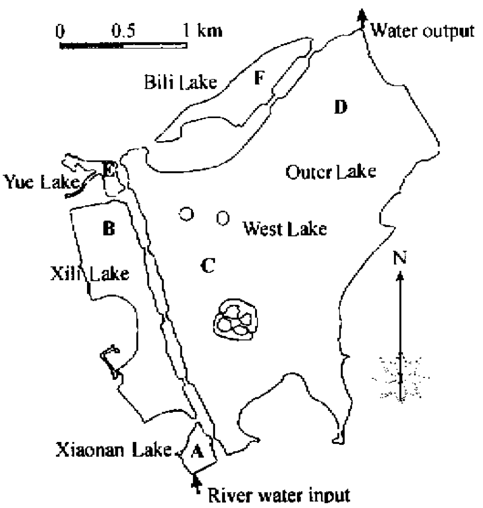

Fig.1 Sampling stations in West Lake

tion of six sampling stations. Large scale dredging at stations E and F during the investigation, the complete quantitative data had been really yielded from stations A, B, C and D. Three replicate sediment samples were taken monthly from Jan. 1995 to Nov. 1996 with a Peterson Grab (1/16 m^2) at each sampling site. Each sediment sample was washed in laboratory with a stainless bolting net (0.45 mm opening) containg zoobenthos after the washing. After wet weight of each species was obtained with electronic balance (0.1 mg accuracy) and after water on their surface had been absorbed with papers, they were preserved in 70% ethanol solution.

RESULTS AND DISCUSSION

1. Species composition and distribution

Table 1 shows the 26 zoobenthos taxa recorded, consisting of six Oligochaeta, seven Chironomidae, six Mollusca, two Odonata, one of Ceratopogonidae, Poly-chaeta, Hirudinea, Turbellaria and Nematoda. Among these taxa, *Branchiura sowerbyi* and *Limnodrilus hoffmeisteri* are the species surviving in heavy organic pollution (Brinkhurst, 1974). *Chironomus plumosus* and *Tokunagayusurika akamusi* are indicators of eutrophic lake (Iwakwma, 1988).

The finding of the above taxa was related to the drawing water from the Qiantang River. The euryhaline species (*Nephthys oligobranchia Southern*. *Mytilus* sp.) found existing in Xiaonan sub-lake because two taxa were also found in the sediment samples from the Qiantang River at one time.

The zoobenthos of the lake relatively long generation time; some of them had several generations in a year and appeared in all seasons, except *T. akamusi*, a 2-year life cycle univoltine species that emerges once in autumn during Oct. to Dec of every year. Two generations were overlapped in winter and disappeared in May to Oct. because the species burrowed to depths of 40–80 cm in the sediment (Iwakuma, 1987).

Compared with our 1982 to 1983 results, the species number of zoobenthos were increased from 12 taxa to 25 taxa in Xiaonan sub-lake, but in other sub-lakes were decreased from 18 taxa to 13 taxa. The increasing diversity of species indicated that the zoobenthic community had a qualitative change in Xiaonan sub-lake.

2. The standing crop of zoobenthos

The average density was 2751 ind/m^2 at Station B (Xili sub-lake), > 2514 ind/m^2 at Station D (Outer lake), > 1376 ind/m^2 at Station A (Xiaonan sub-lake), > 980 ind/m^2 at Station C (Outer lake).

The seasonal density fluctuations in four stations of West Lake are shown in Fig. 2. The peaks of density occurred in the winter and the early-spring and lower density emerged in summer. This phenomenon was closely related to the lower predatory pressure of fish and to the life history of the dominant fauna populations, and especially related to the life history of Chironomidae. In winter, there was higher density in the over-wintering generation of *T. punctipennis*, *P. choreus* and *C. plumosus*. The population of *T. akamusi* emerged once in autumn from Oct. to Dec.; its reproduction and growth occurred in Oct. to Apr. of next year. Two generations overlapped in winter, when there was a higher density of zoobenthos. The lowest density of Oligochaeta in summer was related to the following reasons: first, Chironomidae emergence; second, *T. akamusi* burrowed deep into the sediment; third, the predatory pressure in summer from fish was higher than that in winter.

The seasonal trend of zoobenthic density in West Lake corresponded roughly with trend in

Table 1 Zoobenthos found in West Lake during the January 1995 to November 1996 survey

Species	Outer lake	Beili lake	Yue lake	Xili lake	Xiaonan lake
Oligochaeta					
Branchiura sowerbyi	* +	* +	* +	* +	* +
Limnodrilus hoffmeisteri	* +	* +	* +	* +	* +
L. grandisetosus	*		+	* +	* +
L. udekemianus	*	*	*	*	*
Aulodrilus pluriseta	* +	* +	* +	* +	* +
A. prothecatus	*	*	*	*	*
Tubifex sp.	* +	* +	* +	* +	* +
Dero digitata	*				+
Specaria josinae				*	
Stephensoniana trivandrana	*		*	*	
Amphichaeta asiatica				*	
Chironomidae					
Tanypus punctipennis	* +	* +	* +	* +	* +
Procladius choreus	* +	* +	* +	* +	* +
Tokunagayusurika akamusi	* +	* +	* +	* +	+
Chironomus plumosus	* +	+	* +	* +	* +
Microchironomus sp.	+		+	+	+
Cryptochironomus conjugens	*			*	*
Einfeldia sp.					+
Tanytarsus sp.				*	
Orthocladius sp.					+
Other Insecta					
Ceratopogonidae			* +	* +	+
Epitheca sp.					+
Mollusca					
Bellamya purificata					+
Bellamya sp	* +	* +	* +	* +	* +
Gyraulus sp.					+
Radix swinhoei	* +	* +	* +	* +	* +
Semisulcospira sp.	+	+	+	+	+
Parafossarulus striatulus			*		
Hyriopsis cumingii				+	+
Mytilus sp.					+
Polychaeta					
Nephthys oligobranchia southern					+
Hirudinea					
Helobdella nuda			+	+	+
Turbellaria					
Probescis worme					+
Other groups					
Nematoda				+	

Note: * Species that appeared before the drawing of Qiantang River water into West Lake (1982 to 1983)
+ Species that appeared after the drawing of Qiantang River water into West Lake. (1995 to 1996)
Gastropoda appeared in stone that lie in the bank of the lakes except Xiaonan sub-lake

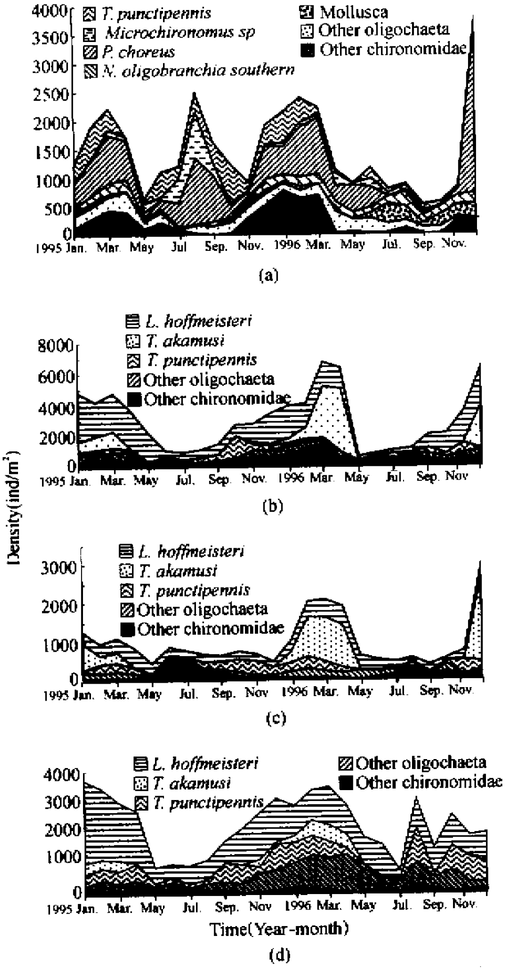

Fig.2 Seasonal density fluctuations at 4 stations
(a)Station A in Xiaonan sub-lake;
(b)Station B in Xili sub-lake;
(c)Station C in Outer lake;
(d)Station D in Outer lake

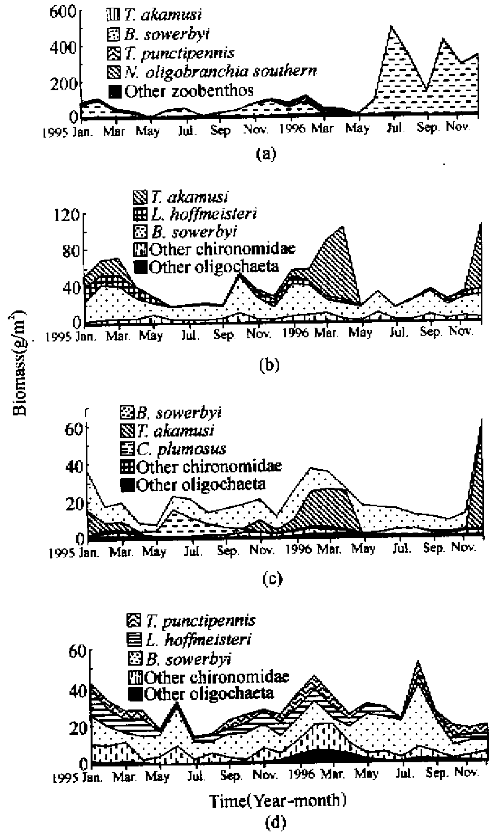

Fig.3 Seasonal biomass fluctuations at 4 stations
(a) Station A in Xiaonan sub-lake;
(b) Station B in Xili sub-lake;
(c) Station C in Outer lake;
(d) Station D in Outer lake

previous results (1982 to 1983), and respectively with the trend in of Donghu Lake (Cheng, 1990), Honghu Lake (Wang, 1995) and Taipinghu Lake (Lui, 1997).

Fig.3 shows the seasonal fluctuations of the biomass in four stations. Because the zoobenthos were much different in size and weight, the variations of the biomass did not correspond with the density. Except at Station A (Xiaonan sub-lake), where the peaks of the biomass were related to the dominant chironomidae. *T. punctipennis*, *P. choreus* and *C. plumosus* were important populations in biomass. *T. akamusi* made specially contributed to the biomass in winter because of its overlapping generations. *Bellamya purificate*' s appearance in Xiaonan sub-lake caused the biomass at Station A to be the highest among the four stations. The ranges of the average biomass in four stations were: 122.80 g/m^2 at Station A (Xiaonan sub-lake); > 41.05 g/m^2 at Station B (Xili sub-lake); > 27.09 g/m^2 at Station D (Outer lake); > 19.69 g/m^2 at Station C (Outer lake) The biomass in Xiaonan lake was dominated by Mollusca, biomass at Station B (Xili sub-lake) and Station D

(Outer lake) was dominated by Oligochaeta; and the biomass of Oligochaeta and of Chironomidae were equal at Station C (Outer lake).

1982 to 1983 data collected by the authors showed that the annual mean density and biomass were respectively 322 ind/m^2, 1.08 g/m^2 in Outer lake; 1121 ind/m^2, 3.80 g/m^2 in Xili sub-lake; 1757 ind/m^2, 3.59 g/m^2 in Xiaonan sub-lake. Compared with the above data, the density and biomass of Outer lake and Xili sub-lake had increased, but the density was decreased and the biomass was increased in Xiaonan sub-lake. The reasons for the above results were as follows. The weight of individuals was increased because the dominant species changed and the succession of zoobenthic fauna occurred in Xiaonan sub-lake after the drawing of Qiantang River water into it. But the water of Qiantang Rive into the other sub-lakes did not decrease their eutrophication, which is still progressing.

3. Dominant population

Table 2 shows the dominant populations in the density. *Limnodrilus hoffmeisteri*, *Tanypus punctipennis*, *Tokunagayusurika akamusi* were dominant species at Station B (Xili sub-lake), Station C and Station D (Outer lake). If *Tokunagayusurika akamusi* burrowed deep into sediment in summer, its position in the dominant species should be go up. The dominant populations in Xiaonan sub-lake were different from those in other sub-lakes. Oligochaeta disappeared while Polychaeta became dominant.

Table 2 Dominant populations in density(ind/m^2)

Sampling station	Year	Dominant populations		
		First	Second	Third
Station A	1995	*P. choreus* 512	*T. punctipennis* 283	*Microchironomus sp.* 160
	1996	*P. choreus* 329	*N. oligobranchia southern* 153	*T. punctipennis* 140
Station B	1995	*L. hoffmeisteri* 1516	*T. punctipennis* 349	*T. akamusi* 241
	1996	*L. hoffmeisteri* 1175	*T. akamusi* 946	*T. punctipennis* 196
Station C	1995	*L. hoffmeisteri* 248	*T. punctipennis* 192	*T. akamusi* 127
	1996	*T. akamusi* 483	*L. hoffmeisteri* 283	*T. punctipennis* 146
Station D	1995	*L. hoffmeisteri* 1458	*T. punctipennis* 452	*T. akamusi* 125
	1996	*L. hoffmeisteri* 1013	*T. punctipennis* 532	*T. akamusi* 148

Because the zoobenthos were much different in size and weight, the dominant populations in the density differed from the dominant species in biomass. Table 3 shows the dominant populations in biomass. In Xiaonan sub-lake, *Bellamya purificata* and *Nephthys oligobranchia southern* became the dominant species in biomass, and because their individual weight was more than that of other taxa, their biomass was the highest in the sub-lakes.

Compared with the results of the 1982 to 1983 survey, i.e, *B. sowerbyi*, *L. hoffmeisteri*, *A. pluriseta*, *T. punctipennis*, *C. plumosus* and *P. choreus* were the dominant species, *A. pluriseta* disappeared as the dominant species and *P. choreus* was replaced by *T. akamusi* as dominant in density. In the Xiaonan sub-lake, *B. sowerbyi* and *L. hoffmeisteri* were replaced by *T. punctipennis* and *P. choreus* as dominant in density and were replaced by *Bellamya purificata* and *Nephthys oligobranchia* southern as dominant in biomass.

Table 3 Dominant populations in biomss(g/m^2)

Sampling station	Year	Dominant populations		
		First	Second	Third
Station A	1995	*Bellamya purificata* 39.44	*N. oligobranchia southern* 2.66	*B. sowerbyi* 2.17
	1996	*Bellamya purificata* 173.64	*N. oligobranchia southern* 7.11	*T. akamusi* 2.70
Station B	1995	*B. sowerbyi* 19.47	*L. hoffmeisteri* 6.6	*T. akamusi* 4.50
	1996	*B. sowerbyi* 21.06	*T. akamusi* 18.98	*L. hoffmeisteri* 3.45
Station C	1995	*B. sowerbyi* 9.37	*C. plumosus* 3.48	*T. akamusi* 2.50
	1996	*T. akamusi* 9.91	*B. sowerbyi* 7.92	*C. plumosus* 1.25
Station D	1995	*B. sowerbyi* 11.26	*L. hoffmeisteri* 5.80	*T. punctipennis* 2.77
	1996	*B. sowerbyi* 13.42	*L. hoffmeisteri* 4.17	*T. punctipennis* 3.79

4. The ecological effect of drawing water from Qiangtang River into West Lake

The above analysis of the zoobenthic fauna in West Lake before and after Qiangtang River water was introduced into West Lake showed that the zoobenthic fauna in Xiaonan sub-lake were obviously different from those of the other sub-lakes; which indicated difference in habitat environment caused by the introduction of Qiangtang River water into them. The surface of Xiaonan sub-lake (0.09 m^2) comprises 1.6% of West Lake. Introduction of Qiangtang River water through this sub-lake into West Lake resulted in: 1) Increased transparency of the sub-lake as the water carried out a lot of plankton (Wei, 1989; Li, 1994; Li, 1997[①]); 2) Introduction of *Nephthys oligobranchia southern* and *Mytilus* sp. The latter feeds on algae by filtering and therefore the algae density was decreased; 3) Removal of bottom mud by the river water and the consequent reduction of organic material on the bottom caused the bottom to be hardened and be favorable to Gastropoda and unfavorable to Oligochaeta. Because the transparency of the water was increased, macrophytes such as *Vallisneria spiralis*, *Ceratophyllum demersum* and *Myriophyllum spicatam* etc could grow in the Xiaonan sub-lake. These macrophytes covered 0.03 km^2 and competed with algae for nutriments and space, so that the algae density was further decreased. Because the macrophytes were also favorable to Gastropoda (Cheng, 1990), *Bellamya purificata* became the dominant species. The succession of zoobenthos resulted from the change in habitat environment.

Compared with the Xiaonan sub-lake zoobenthic community, the zoobenthic communities in the other sub-lakes had higher density, lower biomass and greater species simplicity. The dominant species were eutrophic indicators tolerating anoxic conditions and organic wastes. The characters of zoobenthic fauna in these communities were not varied. The introduction of Qiantang River water had apparently not affected the other sub-lakes whose eutrophication is still ongoing.

5. Evaluation of present trophic state in West Lake

The history of trophic lake type systems was summarized by Brundin (1949) and Brikhurst (1974). The predominance of chironomids in the profundal zone of lakes and their responses to trophic conditions make them useful for classifying lakes. A number of lake types were characterized by their chironomid assemblages (Brundin, 1949, 1958; Saether, 1975).

① Li, M., 1997. Evaluation of the water quality of West Lake after drawing of water from the Qiangtang River into it. Administrative Office of West Lake in Hangzhou (in Chinese).

C. plumosus, *T. akamusi*, *T. punctipennis* and *P. choreus* were distributed in the eutrophic lakes. *C. plumosus* appeared in strongly eutrophic lake and the lake was named *C. plumosus* type (Wielderholm, 1980;). In twenty-one lakes of Japan, *T. akamusi* was distributed in the lake where trophic state index (TSI) was 40 to 89 and *C. plumosus* was distributed in the lake where TSI was 54 to 89 (Iwakwma, T., 1988). The TSI in West Lake was more than 60 during the last decade. *B. sowerbyi* and *L. hoffmeisteri* are species surviving in heavy organic pollution (Brinkhurst, 1974). The characters of the dominant species indicated that except Xiaonan sub-lake the eutrophic state had not changed in West Lake.

Table 4 **Margalef index and Goodnight index of West Lake compared with those of other lakes in China**

Lake	Donghu Lake	Honghu Lake	Chaohu Lake	Taihu Lake	Xuanwuhu Lake	West Lake 1	West Lake 2	West Lake 3
Margalef index	7.30	22.1	19.6	10.0	3.95	6.80	4.32	7.23
Goodnight index(%)	63.0	19.3	14.2	38.1	28.9	80.1	58.4	15.5

West Lake 1: before introduction of river water; West Lake 2: the sub-lakes after introduction of water Xiaonan sub-lake excluded; West Lake 3: Xiaonan sub-lake after introduction of water. The data of the other lakes were collected from "The Lake of China"(Jing, 1995).

Table 4 shows the Margalef species diversity index and Goodnight biological index of zoobenthic fauna in West Lake. The study results showed that the above two indexes of Xiaonan sub-lake were better than those of the other sub-lakes, which indicated the difference in the quality of water. In the other lakes, Goodnight indexes were better before the introduction of river water into them while the Margalef indexes were worse. The decrease in Margalef index values was due to the decrease of species and the change of the Goodnight index was due to the increasing individual number of Chironomidae. Both indexes indicated that the zoobenthic fauna of Xiaonan sub-lake had been greatly influenced by the introduction of Qiangtang River water into the sub-lake although the other sub-lakes were seemingly not influenced. Compared with other lakes of China, West Lake is still considered to be in the range of eutrophic lake.

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