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Environmental Factors and the Succession of Aquatic Insects in a Shallow Chinese Lake

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Lake Donghu, a medium-sized lake along the middle reaches of the Changjiang River (the Yangtze River), situated in the northeastern part of Wuhan City, Hubei Province, China, has a surface area of 27.9 km^2 with a mean depth of 2.2 m. It is composed of several lake regions (Shuiguohu, Tanglinhu, Guozhenghu and Houhu etc.) which are connected by small channels. Before the 1970s, there were abundant aquatic plants, and the coverage rate reached as high as 40-80% of the sediment surface. The bottom of the lake was flat with mud and could be seen in most area from the water surface in the 1960s. Afterwards, aquatic plants decreased gradually and became very scarce in the 1995-1996 (Chen, 1990; Ni, 1996).

Aquatic insects had thrived in the lake with many species and high biodiversity during the 1960s (Wang, 1963; 1977; Chen and Wu, 1990). Because the untreated domestic wastewater along the shore was discharged directly into the lake, Lake Donghu has suffered increasing eutrophication year by year. Our research shows that the biodiversity of aquatic insects has decreased prominently, and many species that cannot tolerate the pollution have gradually disappeared.

From 1962 to 1996, a total of 91 species of aquatic insects were found on the quantitative and qualitative bases. However, only 33 species appeared and about 3-4 dominant species were present since the 1980s, and in particular, the Trichoptera and Chironomidae changed greatly. This paper documents the succession of aquatic insects over more than 30 years and discusses the relationship between the biodiversity of aquatic insects and environmental factors in the lake.

MATERIALS AND METHODS

Field samplings were carried out since the early 1960s, and several transections and many stations were set up in Lake Donghu for regular sampling of aquatic insects in different years (Chen and Wu, 1990). Selection of these sections depended on the environmental conditions in Lake Donghu. The sections and stations chosen for sampling in 1995-1996 were similar to the previous ones. There were 10

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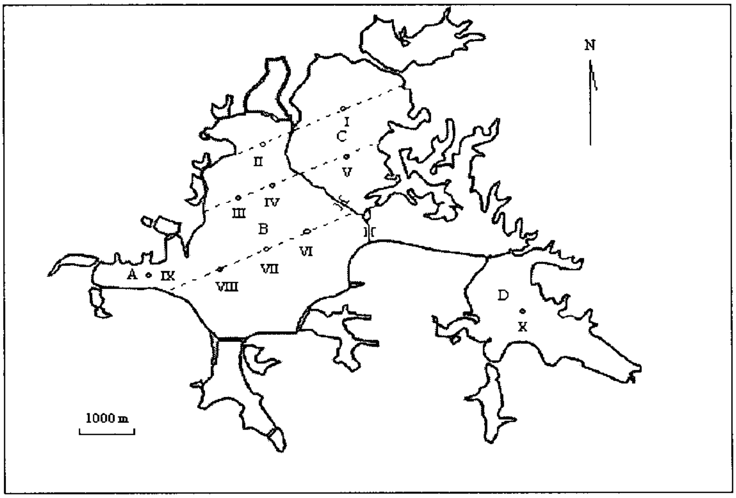

Figure 1. Sampling sites of Lake Donghu. (A. Shuiguohu; B.Tanglinhu; C. Guozhenghu; D. Houhu)

sites in total: 8 sites through 3 sections, which crossed the main part of Tanglinhu and Guozhenghu, 1 site in both Shuiguohu and Houhu (Figure 1). We therefore had a unique opportunity to continuously analyze and compare the materials from the 60s to **90s.**

Because species identification of aquatic insects depends mainly on the adults, lamp-trap method was used to collect adult specimens of aquatic insects, especially, Trichoptera and Chironomidae. Qualitative samplings were also performed by hand-net along lake shore. In the lake areas, quantitative specimens of aquatic insects were collected using a modified Petersen dredge ($0.0625m^2$), sampling 1 or 2 hauls every sites, and washing through a 40 pore/inch of screen, then putting the collected material into the plastic bags. The samples were poured into dissecting dishes, and the aquatic insects were picked out alive, then fixed in 70% alcohol. After identifying species, individual number of every species per square meter was calculated. To analyze succession of aquatic insect, some physical and chemical factors, e.g., the annual mean data of nitrogen and phosphorus were utilized.

RESULTS AND DISCUSSION

Aquatic insects in Lake Donghu were investigated many times from 1962 to 1996, among which there were four large-scale investigations. During the 35 years, a total of 91 species of aquatic insects were found. The species number of aquatic insects changed greatly among these years. In 1962 to 1963, there were 74 species of aquatic insects, including 37 species of Chironomidae, 13 Trichoptera, 11 Odonata, 5 Hemiptera, 3 Coleoptera, 1 Ephemeroptera and 4 other Diptera. Data from 1962-1963 were regarded as the basis of species number, and results from the following years were compared with these data.

Table 1. The succession of aquatic insects in Lake Donghu

	1962-63	1973-75	1979-81	1995-96
EPHEMEROPTERA				
1. *Caenis* sp.	+	+		+
ODONATA				
2. *Coenagrion* sp.	+		+	+
3. *Ichnura* sp.	+			
4. *Lestes* sp.	+	+	+	+
5. *Calopteryx* sp	+	+	+	
6.*Aeschna* sp.	+	+	+	
7. *Anax* sp.	+	+		
8. *Orthetrum* sp.	+			
9. *Libellula* sp.	+	+	+	+
10. *Pantala* sp.	+	+	+	
11. *Sympetrum* sp.	+			
12. *Gomphidia* sp.	+	+	+	+
HEMIPTERA				
13. *Notonecta chinensis* Fallon	+			
14. *Micronecta* sp.	+	+	+	
15. *Corixa* sp.	+	+		
16. *Kirkaldyia* sp.		+	+	+
17. *Sphaerodema* sp.	+	+	+	
18. *Nepa* sp.		+	+	+
19. *Ranatra chinensis* Mayr	+	+	+	
20. *R. unicolor* Scott		+	+	
21. *Gigantometra gigas* (China)		+		
LEPIDOPTERA				
22. *Nymphula* sp.		+		
NEUROPTERA				
23. *Osmylus* sp.			+	
COLEOPTARA				
24. *Gyrinus* sp.	+	+		
25. *Donacia* sp.		+		
26. *Haemonia* sp.		+		
27. *Haliplus* sp.		+		
28. *Psephenus* sp.		+	+	+
29. *Hydrophilus* sp.		+	+	
30. *Enochrus* sp.	+	+	+	+
31. *Cybister japonicus* Sharp		+		
32. *Dytiscus* sp.		+		+
33. *Eretes sticticus* Linne	+			
34. *Rhantus punctatus* Fourcroy			+	+
TRICHOPTERA				
35. *Dipseudopsis stellata* Mclachlan	+	+		
36. *Kyosyche japonica* Tsuda	+	+		
37. *Ecnomus tenellus* Ramber	+	+	+	+
38. *Hydroptila wuchangensis* Wang	+			
39. *Orthotrichia tetensii* Kolbe	+	+	+	
40. *O. tragetti* Mosely	+			
41.*Triaenodes unanimis* f. recta Martynov	+			
42. *Mystacides sibiricus* Martynov	+			
43. *Triplectides magna* (Walker)	+			
44. *Leptocerus biwae* (Tsuda)	+	+		
45. *L. dicopennis* (Hwang)	+	+	+	
46. *Oecetis palidipunctata* Martynov	+			
47. *Oecetinella morii* (Tsuda)	+			

Table 1. continued

DIPTERA				
Chironomidae				
48. *Tanypus chinensis* Wang			+	+
49. T. *punctipennis* (Fabricius)	+	+	+	+
50. *T. monilis* (Linne)	+			
51. *Procladius choreus* (Meigen)	+	+	+	+
52. *P. lugens* Kieffer	+			
53. *Clinotanypus sugiyamai* Tokunaga	+	+	+	+
54. *Cricotopus. bicinctus* (Meigen)	+			+
55. *C. sylvestris* (Fabricius)	+			+
56. *C. trifasciatus* (Panger)	+	+	+	+
57.*Tokunagayusurika akamusi* (Tokunaga)	+	+	+	+
58. *Smittia aterrima* (Meigen)	+			
59. *S. cheethami* Edwards	+			
60. *Cryptochironomus arcuatus* Goetg	+	+		
61. *C. chlorostolus* (Kieffer)	+	+	+	
62. *C. detectus* Kieffer	+			
63. *C. primitivus* Johannden	+			
64. *C. tener* Kieffer	+			+
65. *Harnischia fuscimanus* Kieffer	+			
66. *H. pseudosimplex* Goetg	+			
67. *H. virescens* Meigen	+			
68. *Glyptotendipes gripekoveni* Kieffer	+	+	+	+
69. *G. severini* Goetghebuer	+			
70. *Polypedilum convictum* Walker	+	+		+
71. *P. masudai* Tokunaga	+			
72. *Lauterborniela marmorata* (V. D.Wulp)	+			
73. *Dicrotendipes flexus* Jonannsen	+			
74. *Pentapedilum sordens* V. D. Wulp	+			
75. *Chironomus pallidivittatus* Malloch	+			
76. *C. tentans* Fabricius	+	+		+
77. *C. dorsalis* Meigen	+	+		+
78. *C. dystenus* Kieffer	+			
79. *C. hirtitarsis* Johannsen	+			
80. *C. honi* Kieffer	+			
81. *C. plumosus* (Linne)	+	+	+	+
82. *C. thummi* Kieffer	+			+
83. *Cladopelma* sp.				+
84. *Tanytarsus ejuncides* Walker	+	+		
85. *T. formosanus* Kieffer	+		+	
Other Diptera				
87. *Bezzia* sp.				+
88. *Culicoides* sp.			+	
89. *Palpomyia* sp.	+			
90. *Chaoborus* sp.	+	+		+
91. *Chrysops* sp.	+	+	+	+
Total number	74	47	33	31

Trichoptera and Chironomidae were common in the Lake in the 1960s (Wang, 1963; 1977), and their species number covered 68% of total aquatic insects. Trichoptera larvae were widely distributed among the aquatic plants. Most caddisfly larvae are phytophagous, clambering and swimming among the high plants. *Triaenodes unanimisrecta, Mystacides sibiricus* and *Triplectides magna* make cases from stems and leaves, e.g., *Ecnomus tenellus* makes cases using gland silk and the leaves of *Potamogeton crispus* and *Vallisneria spiralis*, etc. However, after the 1960s, species number of Trichoptera larvae decreased greatly, and only one species was found in the samples in 1995 -1996. The species richness decreased more than 90%. Chironomidae was represented by 37 species in the 1960s, living in all kinds of substrata of the lake, but only 21 species persisted into the 1990s. Other aquatic insects also decreased to some extent. Only 31 species of aquatic insects were found in the 1990s.

Species succession of aquatic insects was closely related to the changes in environmental conditions in Lake Donghu. These changes included separation of Lake Donghu from the Changjiang River, eutrophication, and disappearance of aquatic plants. The two latter aspects were more important than the former.

In the early 1960s, Lake Donghu was connected with the Changjiang River through some channels. In flood months, as the river water flowed into the lake, some aquatic insects in the river can enter the lake, which compensated the source of aquatic insects and increase biodiversity. But since the 1970s, Lake Donghu was separated from the river by dams. Some species in the river disappeared gradually in the lake, e.g., *Tanytarsus* spp. and *Orthotrichia* spp.

In the 1960s-1970s, the aquatic plants of the lake were distributed widely in the lake, and there were 83 species (Chen, 1990). The dominant species were *Potamogeton maackianus, P. crispus, P. malainus, Vallisneria spiralis, Najas major,* and *Nalumbo nucifera*. Owing to the presence aquatic plants and little domestic wastewater charged into the lake, organic matter was low in the water. The Secchi disk transparency was more than 2 m, and aquatic insects could be seen among the aquatic plants, such as *Leptocerus dicopnnis* clambering between them, and *Tokunagayusurila akamusi* on the mud of the bottom. However, after late 1970s, aquatic plants deceased gradually, meanwhile algae density increased and transparency decreased greatly to 30-50 cm. Eutrophication and overstocking of grass carp are the main reasons for the disappearance of aquatic plants in the lake (Ni, 1996). The importance of aquatic plants in supporting species richness of aquatic insects is probably because that the plants provide aquatic insects with a lot of food (including periphyton on it), and that their stems and leaves, widely extending into water, provide substrata for the living, feeding and reproducing of aquatic insects, and that plants are also shelters to prevent aquatic insects from predation by other animals. So the disappearance of aquatic plants will lead directly to decrease or absence of some species concerned. For example, many Trichoptera larvae not only make cases using stems and leaves for protection but also eat them as food. There were 13 species of Trichoptera larva in 1963, however, in 1995-1996, species numbers of Trichoptera larvae were reduced sharply and only one species, *Economus tenellus,* was found.

Along with above stated, another more serious problem is that nitrogen and phosphorus in the lake increased greatly due mainly to human activities, such as the discharge of untreated domestic wastewater into the lake and overstocking of fish since the 1970s. The lake became more and more eutrophic (Liu, 1990). The changes in TDN and TDP just reflected that tendency. At Station IX, TDN was ca. 0.6mg/l in 1964. It increased greatly in the following years, reaching to 3.07 mg/l in 1985 and 4.24 mg/l in 1995. TDP also increased during 1980-1995. At the same station, TDP was 0.116 mg/l in 1980, but in 1995, it increased to 0.354 mg/l (Liu, et al., 1990; Xie and Takamura, 1996). Eutrophication has great negative effect on aquatic insects, one of which is to lower dissolved oxygen concentration of water to restrain or kill aquatic insects. Studies that eutrophication led to simple community and low biodiversity of plankton have been stated by Dodson (1990) (Xie and Chen, 1999).

Gyorgy (1983) found that species composition of Chironomidae is closely correlated to the trophic gradient in Balon Lake of Hungary, i.e., the higher the trophic level of the lake was, the less the species number of Chironomidae was. A similar phenomenon was found in Lake Donghu during the investigation in 1995. At Station IX with the highest trophic level among the ten sampling stations, none of aquatic insects existed. 14 species were found at Station I, V and X, where trophic level was the lowest. Other stations with the trophic level between above two types of stations, only 6 species occurred. Lake eutrophication can be indicated by some indicator species, e.g., *Chironomus plumosus, Tokunagayuaurika akamusi* and *Tanypus punctipennis* (Gyorgy, 1983; Iwakuma and Yasuno, 1983; Armitage, 1995). In Lake Donghu, these three species all existed in the samples of 1995, and their density accounted for 70% of the total density of aquatic insects, which showed that Lake Donghu has become a highly eutrophic lake.

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