CHANGE OF CHIRONOMID FAUNA (DIPTERA: CHIRONOMIDAE) IN EUTROPHIC LAKE KAWAGUCHI, JAPAN

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With 3 tables and 2 figures

ABSTRACT: Lake Kawaguchi is a eutrophic lake in central Japan. Results of a 22 sites survey carried out in March 2006 showed average benthic community for the entire lake was 1609 ind./m^2, comprising mainly oligochaetes (70.5%) and chironomids (29.5%). Chironominae (*Chironomus plumosus* (Linnaeus, 1758)), Orthocladiinae (*Propsilocerus akamusi* (Tokunaga, 1938)) and Tanypodinae were the dominant chironomid taxa. Oligochaetes and *P. akamusi* inhabited the entire lake bottom but *C. plumosus* occurred only in western parts and the lake centre. The maximum number of oligochaetes, *P. akamusi* and *C. plumosus* larvae differed significantly between sites. *C. plumosus* density was closely related to the density of Tanypodinae and oligochaetes. The density of Tanypodinae versus water depth showed negative correlations. Recently, numbers of *C. plumosus* and *P. akamusi* larvae in Lake Kawaguchi have decreased but the percentage of *P. akamusi* larvae in the chironomid communities has increased. Together with increased levels of organic content in upper sediment these results indicate increasingly eutrophic conditions in the lake.

RESUMO: O lago Kawaguchi é um lago eutrofico, situado no Japão central. Os resultados dum programa de amostragem de 22 sítios efectuado em Março de 2006 revelam uma comunidade bêntica média de 1609 ind./m^2, sendo principalmente As oligoquetas (70,5%) e os quironomídeos (29.5%). Chironominae (*Chironomus plumosus* (Linnaeus, 1758)), Orthocladiinae (*Propsilocerus akamusi* (Tokunaga,

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1938)) e Tanypodinae foram os taxones dominantes desta família. As oligoquetas e *P. akamusi* occupam todo o fundo do lago mas o *C. plumosus* occurred occoreu somente nas zona oeste e o centro do lago. Houve uma diferença significativa entre o número máximo de oligoquetas e larvas de *P. akamusi* e *C. plumosus* entre os locais de amostragem. A densidade de *C. plumosus* estava associada com as densidades dos Tanypodinae e das oligoquetas. A densidade dos Tanypodinae com a profundidade da água demonstrou uma correlação negativa. Recentmente tem havido uma diminuição nos números de larvas *C. plumosus* and *P. akamusi* larvae no Lago Kawaguchi mas a percentagem das larvas de *P. akamusi* aumentou. Junto com o aumento de matéria orgânica nos sedimentos do fundo, os resultados deste estudo indicam um aumento no estado eutrófico do lago.

INTRODUCTION

Lake Kawaguchi is one of the Fuji Five Lakes (Kawaguchiko, Motosuko, Saiko, Shojiko and Yamanakako), which are especially familiar to the Japanese for their beautiful landscapes. Over 22,000,000 tourists visit these lakes and Mt. Fuji annually.

Studies on the limnological conditions of this lake mention long-term change in water quality (YAMANASHI PREFECTURE, 1980; 1993). The lake's biota has been studied by several researchers since TERAO (1912) but there are relatively few studies on the lake's macrobenthic fauna (MIYADI, 1932; KITAGAWA, 1973; HIRABAYASHI *et al*., 1995). Since the mid-1990s, biotic and environmental conditions of the lake have been changing (YAMANASHI PREFECTURE, 2003) affecting the bottom fauna, especially dominant chironomids. This study on the horizontal distribution of benthic macroinvertebrates in Lake Kawaguchi compares chironomid fauna and density between the present and previous studies and discusses chironomid community change in relation to the lake's trophic status

STUDY SITE

Lake Kawaguchi (surface area 5.96 km^2, maximum depth 16.1 m; mean depth 9.3 m; 832 m asl) is located at the northern foot of Mt. Fuji. It is volcanically derived with a small inflowing stream, River Terakawa, but no outflowing rivers. Runoff drainage is mostly subterranean via porous volcanic deposits. The eastern shore of the lake is partly surrounded by cultivated land and some towns and villages are found on northeastern and southeastern shores. This lake is ice-covered from January to February and stratifies in the summer. Based on a modified Carlson's trophic state index (chlorophyll-a, total phosphorus, and transparency) the lake is ranked as eutrophic - mesotrophic (AIZAKI *et al*. 1981),

MATERIAL AND METHODS

On 7 March 2006, a multi-point sampling survey was carried out using a standard Ekman-Birge grab (15×15 cm, three replicate samples) at 22 locations (coordinates were taken with a global positioning system) between 5.4 and 13.2 m depth in a 800×800 m grid (Fig. 1). Sampling corresponded to times before the emergence periods of most chironomid species in the lake. After sieving the sediment through a Surber net (NGG 42; 418µm mesh size), chironomid larvae and oligochaetes were removed and counted in the laboratory. Small first and second instar chironomid larvae were not retained by the 418µm mesh sieve. To aid identification, some chironomid larvae were soaked in a 10% KOH solution, slide mounted with gum-chloral solution, and identified under a microscope to generic level (WIEDERHOLM, 1983, CRANSTON, 1982 and SASA & KIKUCHI, 1995).

A single sediment sample was taken with a core sampler (3 cm inner diameter) at each station to analyze organic content. Mud in the upper 3 cm layer of each core was oven-dried (110 ºC for two days) and ignited in a muffle furnace (550 ºC for three hours) to determine ignition loss (IL) values. Dissolved oxygen concentrations (DO; Winkler method with azide modification) in the water at the mud-water interface were assessed by carefully siphoning water near the mud surface in the core sampler into a glass bottlee. Mud temperatures (MT) in core samples were measured with a thermistor thermometer. Correlations of environmental variables (depth, IL, MT and DO) benthic macroinvertebrate densities were examined by the Kendal rank correlation test with the aid of a computer program package (SPSS).

Fig. 1. Location of Lake Kawaguchi, isopleths of depth (m), and sampling stations in the lake.

RESULTS

Table 1 summarises environmental and biological data from the present study. Figure 2 shows the horizontal distributions of ignition loss of sediment and some benthic macroinvertebrates. Sediment IL values ranged from 4.2 % (sand) to 19.8 % (mud). The lake basin mainly consisted of soft bottom with organic matter contents above 14 %. Sediment at site 3 contained the highest levels of organic matter. At depths above 6m, (i.e., site 6, southern part of lake), the sediment was generally sand and gravel with low IL values. Below 10m depth, the bottom sediment consisted mainly of mud with relatively high values of IL (12.0 -19.8%) (Fig 2). DO and MT ranged from 9.6 (site 10) to 11.6 (site 13) mg/L and 5.1 (site 19) to 6.9ºC (site 12), respectively. Values varied little between stations, since sampling occurred during the spring overturn (Table 1).

Average benthic community density was 1,609 ind./m^2, comprising mainly oligochaetes (70.5%) and chironomids (29.5%). Chironomid species belonging to three subfamilies were found, i.e., Chironominae (*Chironomus plumosus* Linnaeus, 1758), Orthocladiinae (*P. akamusi* (Tokunaga, 1938)) and Tanypodinae (2 species included). The larvae were mature fourth instar larvae of *P. akamusi* and *C. plumosus*. Larval density of *P. akamusi* was 3.5 times higher than that of *C. plumosus* and *P. akamusi* biomass was 2.4 times greater than that of *C. plumosus*. *P. akamusi* and *C. plumosus* larvae formed 70.7 % and 20.5 % of the chironomid communities respectively (Table 1).

TABLE 1. Mean values and SDs of the environmental factors and zoobenthos data

Environmental factors		
Number of sampling points	22	
Depth (m)	9,9 ± 2,2	
Mud temperature (ºC)	5,9 ± 0,5	
Ignition loss (%)	15,8 ± 3,2	
Dissolved oxygen (mg/L)	10,2 ± 0,5	
Zoobenthos	Ind. No. / m^2	W. W. g / m^2
Oligochaete	1135 ± 717	2,7 ± 1,6
Chironomidae	474 ± 418	-
Chironomus plumosus	97 ± 96	1,9 ± 1,7
Propsilocerus akamusi	335 ± 257	4,5 ± 3,3
Tanypodinae	43 ± 109	-
Others	2 ± 7	-

TABLE 2. Correlation matrix for environmental variables and densities of benthic macroinvertebrates in March 2006

	Depth	D.O.	M.T.	I.L.	C.P.	P.A.	Tanyp.	Oli.
Depth	-	0,02	-0,68 **	0,09	0,15	-0,25	-0,58 **	0,02
D.O.		-	-0,05	-0,12	0,11	-0,32	0,05	0,08
M.T.			-	0,07	-0,40	0,35	0,05	-0,24
I.L.				-	0,01	-0,04	0,00	-0,24
C.P.					-	-0,32	0,52 *	0,45*
P.A.						-	-0,30	0,13
Tanyp.							-	0,06
Oli.								-

Key:DO; dissolved oxygen concentration, M.T.; mud temperature, I.L.; ignition loss, C.P.; *Chironomus plumosus*, P.A.; *Propsilocerus akamusi*, Tanyp.; Tanypodinae, Oli.; Oligochaete; Difference is significant * P <0.05, **P <0.01.

Population density of benthic macroinvertebrates differed between sites (Fig. 2). Oligochaetes and *P. akamusi* inhabited the entire lake bottom but *C. plumosus* inhabited only the western part and the lake centre. The maximum number of oligochaetes, *P. akamusi* and *C. plumosus* larvae reached 2,978 ind./m^2 at site 7 (depth; 8.4 m), 918.5 ind./m^2 at site 10 (depth; 8.7 m) and 281.5 ind./m^2 at site 14 (depth; 6.7 m), respectively. Water depth showed a positive correlation with the mud temperature (Table 2). The density of *C. plumosus* was closely related to the density of Tanypodinae and oligochaetes. The density of Tanypodinae versus water depth showed a negative correlation (Table 2).

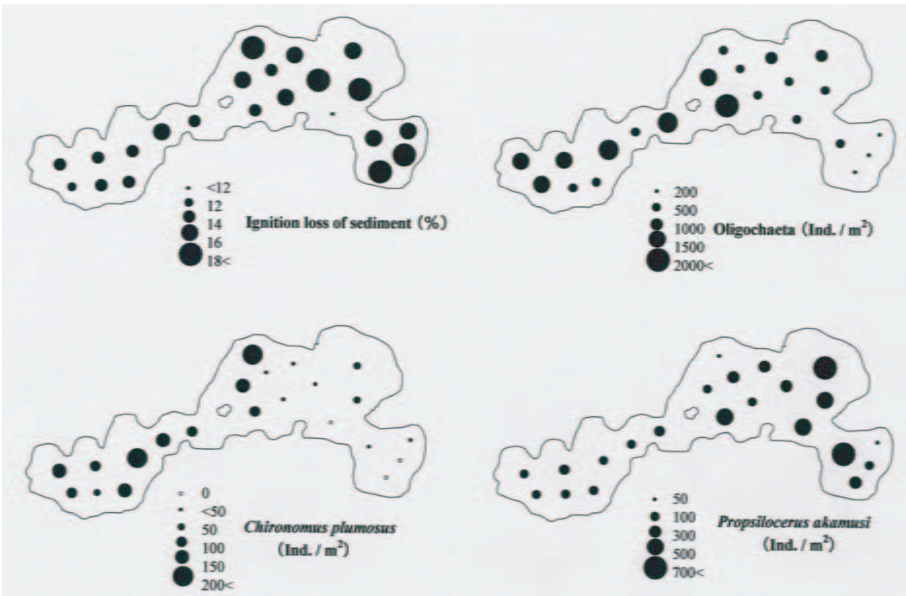

Fig. 2. Horizontal distribution of the densities of chironomid larvae, oligochaetes and ignition loss of sediment in Lake Kawaguchi, 2006.

DISCUSSION

Many researchers have used distribution patterns of particularly profundal benthic macroinvertebrates as indicators of trophic state and pollution of lakes (BRINKHURST, 1970; IWAKUMA *et al*., 1988). Trophic classifications of Japanese lakes have been made using chironomid fauna and chaoborids (MIYADI, 1933; KITAGAWA, 1978; YASUNO *et al*.,1983). *C. plumosus* and *P. akamusi* are common in eutrophic lakes in Japan (IWAKUMA *et al*., 1988). We compared our results with previous Lake Kawaguchi stuies (MIYADI, 1932; KITAGAWA; 1973 and HIRABAYASHI *et al* 1995) (Table 3).

Our results show an increase in the mean value of organic matter in the upper sediment layer since HIRABAYASHI *et al*. (1994). No noticeable change has occurred in the mean density of *C. plumosus* larvae since 1931, when the density was lower than that on other occasions. Many pupae were collected at this time, indicating an imminent emergence period of *C. plumosus* and possibly causing underestimate of *C. plumosus* abundance. In our study *C. plumosus* density was low, (97±96 ind./m^2). Our comparative analyses found that percentage of *C. plumosus* larvae in the chironomid communities has decreased since KITAGAWA (1973). However, the percentage of *P. akamusi* larvae in the chironomid communities showed a percentage increase over time (KITAGAWA, 1973; HIRABAYASHI *et al*. 1995), from 29.2% and 50.5% to 70.7%. In our study, *P. akamusi* larvae were the most abundant chironomid species.

TABLE 3. Change in dominant chironomid fauna in Lake Kawaguchi

	Miyadi (1932) 02.05.1931	**Kitagawa (1973) 17.02.1973**	**Hirabayashi *et al.* (1994) 05.03.1993**	**Present study 07.03.2006**
No. of sampling points	16	12	22	22
Mean depth (m)	10,1±1.3	109±3.2	10,6±2.1	9,9±2.2
Ignition loss of sediment (%)	-	-	10,4±2.4	15,8±3.2
Total Chironomid density (Ind. / m^2)	429±317	885±384	1256±661	474±418
C. plumosus (Ind. / m^2)	75±102	593±258	341±182	97±96
(%)	17,4	66,9	27,2	20,5
P. akamusi (Ind. / m^2)	0	259±149	634±280	335±257
(%)	0	29,2	50,5	70,7
Oligochaeta (Ind. / m^2)	1258±500	139±150	5489±2769	1135±717
(%)	74,6	13,6	81,4	70,5

Recently, the number of *C. plumosus* and *P. akamusi* larvae in Lake Kawaguchi has decreased (Table 3). However, the percentage of *P. akamusi* larvae in the chironomid community has increased. In addition, the organic matter in the upper layer of sediment has increased. According to IWAKUMA & YASAUNO (1981), high temperature and low oxygen concentrations are unfavorable for *C. plumosus* larvae. However, mature *P. akamusi* larvae can withstand anoxic conditions, especially during the summer, by burrowing deep into the sediment to aestivate (YAMAGISHI & FUKUHARA, 1972). The greater densities of *P. akamusi* larvae than *C. plumosus* in the Fuji Five lakes which are becoming increasingly eutrophic IWAKUMA & YASUNO, 1981; HIRABAYASHI *et al*., 2003), indicates that the former species is more adaptable to such conditions. IWAKUMA *et al*. (1988) classified Japanese lakes into four categories based on the present/absence of three large species of Chironomidae: in hypertrophic lakes, both *P. akamusi* and *C. plumosus* are present and *C. nipponensis* is absent; in eutrophic lake all three species are present; in mesotrophic, *P. akamusi* and *C. nipponensis* occur and *C. plumosus* does not; in oligotrophic lakes, only *C. nipponensis* is present. The increased percentage of *P. akamusi* larvae in Lake Kawaguchi suggests increased eutrophication of this water body.

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