ANNUAL PRODUCTION OF FIVE SPECIES OF CHIRONOMIDAE (DIPTERA) IN HOUHU LAKE, A TYPICAL ALGAL LAKE (WUHAN, CHINA)*

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Abstract Annual production and life cycle of five dominant species of Chironomidae (*Chironomus plumosus*, *Cryptochironomus* sp., *Tokunagayusurika akamusi*, *Procladius* sp., *Clinotanypus* sp.) were studied with samples collected monthly from April, 1996 to March, 1997 in Houhu Lake at four stations. Based on instar-frequency data, *C. plumosus* was univoltine, while the other four were bivoltine. Production rates in grams wet weight $m^{-2}a^{-1}$ calculated by the size-frequency method were *C. plumosus*, 2.170; *Cryptochironomus* sp., 0.602; *T. akamusi*, 3.160; *Procladius* sp., 0.964; *Clinotanypus* sp., 0.390. Their P/B ratios were 3.9, 4.9, 4.4, 5.3 and 6.6, respectively.

Key words: Chironomidae, annual production, P/B ratio, size-frequency method, Houhu Lake

INTRODUCTION

Although description of life history and estimation of animal production have a long history (Lindegaard, 1989), few studies on the production rate of benthic macroinvertebrates were carried out in Chinese waters (Liang, 1984). With fishery development and aquatic environment deteriorating in the country, researches in this field are of increasing urgency, since secondary production indicates the growth capacity of a particular population or community of organism. The above studies are essential for determination of potential fishery capacity, and for the formulation of fishery strategy in the waters. Moreover, production is a major parameter of the energy budget. It, together with metabolism, constitutes most of the currency of energy flow in a population or a community (Sameoto, 1972; Benson et al., 1980).

The present study deals with estimates of secondary production and P/B ratios of five predominant chironomids in an algal lake, Houhu Lake, to evaluate the ecological function of the Chironomidae and the potential fishery production capacity contributed by aquatic insects in the water.

MATERIALS AND METHODS

Sampling

Samples were collected from four stations at a transect in the middle region of the

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Lake from April, 1996 to March, 1997 (Fig. 1). From each station one sample was collected monthly with a modified Petersen grab ($1/16\ m^2$), and sieved in a 167 μm mesh net. Chironomid larvae were sorted manually in a white porcelain dish, and preserved in 10% formalin.

Life cycle

The developmental stages of chironomid larvae were determined by the dimensions of their head capsules according to Yablonskaya (1947). Larval head width was measured dorsally with an ocular micrometer. Instars were differentiated by discrete size-classes of head width, from which the number of instars was determined. Data on monthly instar-frequency and changes in density were analyzed to derive the annual generations of each species (Lindegaard and Johnsson, 1987; Lindegaard and Mortenson, 1988; Lindegaard and Maehl, 1992).

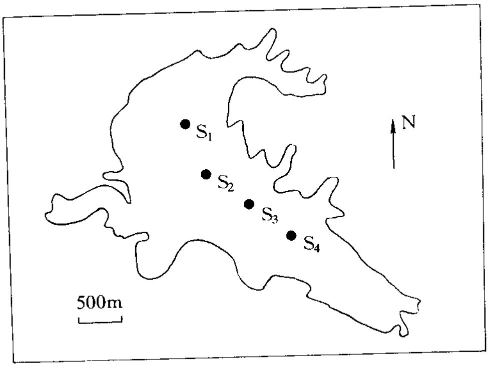

Fig.1 The Houhu Lake, sampling sites are marked with darkened circles

Biomass and production

Wet biomass of a species was determined by weighing 20 – 200 individuals per instar depending on their sizes. Annual production rates were calculated with the size-frequency method (Hynes and Coleman, 1968; Hamilton, 1969; Benke et al., 1984; Soluk, 1985; Prat and Rieradevall, 1995) based on the following equation:

$$P = i \cdot b \sum_{j=1}^{i} (W_{j+1} \cdot W_J)^{1/2} (N_j - N_{j+1})$$

Here we used the number of generation (b) instead of 365/CPI and ignored the correction factor Pe/P, disregarding of which actually produced little error (Menzie, 1980). Following the suggestion of Benke and Wallace (1980), the negative production values for the smallest size class were excluded from the calculation. For the other instars, negative production values were added algebraically to the total production.

RESULTS

Life cycle

Chironomus plumosus In this study, *Chironomus plumosus* completed one generation in a year. Adults mainly emerged and spawned from April to July. Hatching began in August and lasted for several months. Almost all larvae overwintered during the third or fourth instar. Emergence began as early as next April again (Fig. 2a).

Cryptochironomus sp. This species has two generations per year, one from late summer to winter and the other from the middle of winter to the next summer, resulting in an overlap between the two generations in summer (Fig. 2b).

Tokunagayusurika akamusi *T. akamusi* completes two generations in a year, one from middle spring to middle autumn; the other from middle winter to next spring (Fig. 2c).

Procladius sp. The life cycle of the present species is similar to that of *T. akamusi*, i. e. one generation appears between middle spring and middle autumn; the other between late autumn and the following spring (Fig. 2d).

Clinotanypus sp. A similar pattern of life cycle with two generations was observed. One generation in spring and summer and the other in the period from autumn to the following early spring. The winter generation's abundance was higher (Fig. 2e).

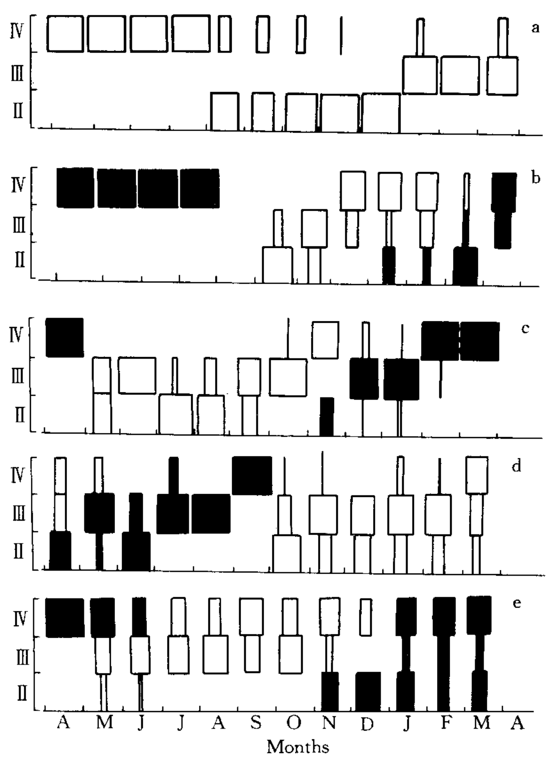

Fig. 2 Instar-frequency distributions on each sample date for the dominant chironomids in Houhu Lake. Instar designated as II through IV. Width of each bar represents percentage of total animal found in the instar

a. *Ch. plumosus*; b. *Cryptochironomus* sp.; c. *T. akamusi*; d. *Clinotanypus* sp.; e. *Procladius* sp.

Densities and biomass

Figure 3 shows the abundance of the five dominant species of chironomids. *C. plumosus* abundance minimized (12 ind/m^2) in August, 1996, and peaked (152 ind/m^2) in November. The species density in winter was higher than that in summer. *Procladius* sp. abundance peaked in June, 1996 (mainly due to the overlapping of the two generations in summer) and decreased to minimum in December, 1996. *T. akamusi* showed a peak in February, 1997, a much lower one in September, 1996, and decreased to minimum (only 4 ind/m^2) in April, 1996, composed of the remaining prepupated larvae of the fourth instar. The densities of *Clinotanypus* sp. showed a major peak in October, 1996, and a minor one in February, 1997. Compared with the former species, it had lower densities throughout the year; this might be due to the fact that the species is a predator. *Cryptochironomus* sp. was found to exhibit much lower abundance over the investigated period. Its density was no higher than 50 ind/m^2 and zero during sampling in August, 1996.

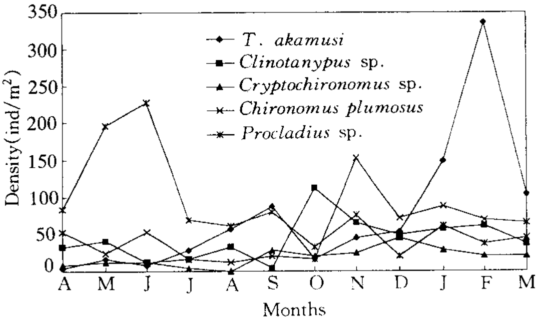

Fig.3 Population dynamics of the five dominant chironomids in Houhu Lake

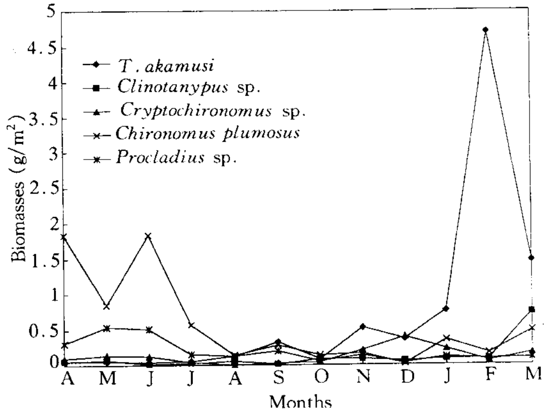

Fig.4 Dynamics of standing crops of the five dominant chironomids in Houhu Lake

The biomass of the five species comprised 95% of that of the chironomid community in Houhu Lake. *C. plumosus* biomass was large in spring, largest (1.836 g/m^2 wet wt) in June, 1996, although its maximum density occurred in November, 1996. The change of biomass of *Procladius* sp. showed the same pattern as that of *C. plumosus*: the maximum occurred in May, 1996, the minimum in December, 1996. Different from the preceding two species, the *T. akamusi* biomass obviously increased in winter, with maximum (4.705 g/m^2 wet wt) in February, 1996, but minimized (0.081 g/m^2 wet wt) in October, 1996. The biomasses of the remaining two species were also apparently large in winter, smaller in summer, generally much smaller than those of the other three species during the investigation period (Fig. 4).

Table 1 Production rate (in wet weight) of *C. plumosus* in Houhu Lake calculated with size-frequency method

Size class (Instar)	No./m^2	Mean Wt (mg)	Standing stock (g/m^2)	No. loss/m^2	Wt at loss (mg/m^2)	Wt loss (g/m^2)	Production (g/m^2)
I	/	/	/	/	/	/	0
II	21	0.231	0.0049	3.7	0.752	0.0028	0.0110
III	17.3	2.450	0.0425	2.6	9.274	0.024	0.0989
IV	14.7	35.106	0.5149	14.7	35.106	0.5149	2.0596
		Standing stock = 0.5622				Total production = 2.1695	
		P/B = 3.9					

Production and P/B ratios

As shown in Tables 1 and 2, the annual production in grams wet weight m^{-2}a^{-1} of *C. plumosus* was 2.170; *T. akamusi*, 3.160; *Procladius* sp. 0.964; *Cryptochironomus* sp., 0.602 and *Clinotanypus* sp., 0.390. The turnover ratios (P/B) for the five species were 3.9, 4.4, 5.3, 4.9 and 6.6, respectively. Thus, *T. akamusi* and *C. plumosus* contribute large shares of the chironomid production in Houhu Lake.

Table 2 Mean densities, mean biomasses, annual production rates (in wet weight) and P/B ratios of the other four dominant chironomids in Houhu Lake

Taxon	Instar				Mean number (No/m^2)	Mean biomass (g/m^2)	Annual production (g/m^2)	Annual P/B
	I	II	III	IV				
Cryptochironomus sp.	/	4.7 (0.4145)	4 (3.4357)	9 (11.8367)	17.7	0.1220	0.602	4.9
Procladius sp.	/	8.3 (0.163)	27.3 (0.913)	43 (3.623)	79.0	0.1825	0.964	5.3
Clinotanypus sp.	/	16 (0.3837)	21.3 (1.7376)	5.3 (3.0155)	42.6	0.0592	0.390	6.6
T. akamusi	/	10.3 (1.582)	13.7 (5.029)	41 (14.11)	75.0	0.7141	3.160	4.4

DISCUSSION

Life cycle

Few life cycle data of chironomid were available for calculating production in China (Wang et al., 1977). The life cycle information in the present work was deduced from the size-frequency distribution and also based on Lindegaard and Maehl (1992). Compared with the materials in literature, our results should be reasonable. The annual generations of *Procladius* sp., *Clinotanypus* sp., *Cryptochironomus* sp. were identical to those obtained by Wang et al. (1977) in Donghu Lake despite some time deviation. The life cycle of the remaining two was not reported in China previously.

Production and P/B ratio

Secondary production estimation of chironomids in standing waters has a long history, so some data are available for comparison. Generally, the annual production rates of the five dominant chironomids were fairly low. The low rates probably resulted from intensive predation pressure exerted by the large fish population in our waters. However, the values were close to the lower range of published data (Table 3). According to Waters (1977), the turnover ratios of univoltine and bivoltine species are frequently 4 – 7, so, the calculated P/B ratios in the present study are within the range. Wolfram (1996) reported P/B ratios of *T. punctipennis* from 2.35 to 5.13, to which our results are similar. Wilda (1984) found very high ratios for chironomids in Lake Norman; perhaps because species there completed more generations in a year.

Sampling error

For young larvae with head-width less than 167μm (mesh size) or those retaining pelagic habit, ineffective sampling might occur to a certain extent. However, sampling error is thought to have little effect on the production estimation. Kirmerle and Anderson (1971) reported that the loss of early instars of *Glyptotendipes barbipes* (Staeger) through a 0.195 mm mesh bucket caused an underestimate of production by less than 20%. Maitland et al. (1972) reported an even lower underestimate for *Stictochironomus*, only 2.7% of the annual production.

Table 3 Biomass (mg dry wt m^{-2}), production (mg dry wt $m^{-2}a^{-1}$) and P/B ratios for the same species or genera reported in literature. The values of biomass and production of Houhu Lake was multiplied by a ratio of dry-wet weight, 0.2

Species	B	P	P/B	Authority	Locality
Chironomus plumosus	4300	24000	5.58	Iwakuma et al.	Kasumgatura
Ch. plumosu	2983	9250	3.10	Grigelis	Vorstijarve
Ch. plumosus	8530	8970	1.05	Plante and Downing	Federsee
Ch. plumosus	6100	5650	0.91	Lindegaard and Jonsson	Hjaback Fjord
Ch. plumosus	184	536	2.92	Prat and Rieradevall	Banyoles (7m)
Ch. plumosus	90	260	2.89	Prat and Rieradevall	Banyoles (13m)
Ch. plumosus	548	3508	6.4	Potter and Learner	A reservoir of South Wales
Ch. plumosus	112.4	433.9	3.9	The authors	Houhu Lake
Cryptochironomus sp.	24.4	120.4	4.9	The authors	Houhu Lake
T. akamusi	142.8	631.9	4.4	The authors	Houhu Lake
Procladius. sp.	36.5	192.8	5.3	The authors	Houhu Lake
Clinotanypus sp.	11.8	77.9	6.6	The authors	Houhu Lake
Tanytarsus inopertus	174.9	909.5	5.2	Potter and Learner	A reservoir of South Wales
T. holochlorus	235	1549	6.6	Potter and Learner	A reservoir of South Wales
T. Lugens	316	2399	7.6	Potter and Learner	A reservoir of South Wales

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References

Benke, A. C., Van Arsdall Jr; Gillespie, D. M., 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. *Ecol. Monogr.* **54** (1): 25 – 63.

Benke, A. C., Wallace, J. B., 1980. Tropics basis of production among net-spinning caddisflies in a southern Appalachian stream. *Ecology* **61** : 108 – 118.

Bensen, D. J., 1980. Production and energy flow in the benthic community of a Texas pond. *Hydrobiologia* **74**: 81 – 93.

Grigel, D. A., 1989. Distribution and ecology of Chironomidae larvae in the different types of lakes of the Lithuanian SSR. *Acta. Biol. Debr. Oecol. Hung.* **2**: 127 – 134.

Hamilton, A. L., 1969. On estimating annual production. *Limnol. Oceanogr.* **14**: 771 – 782.

Hynes, H. B. N., Coleman, M. J., 1968. A simple method of assessing the annual production of stream benthos. *Limnol. Oceanogr.* **13**: 569 – 573.

Iwakuma, T., Yasuno, M., 1983. Chironomid production in relation to phytoplankton primary production in the Kasumigaura Japan. *Verh. int. Ver. Limnol.* **22** :1149 – 1159.

Kimerle, R. A., Anderson, N. H., 1971. Production and bioenergetic role of the midge Glyptotendipes barbipes (Staeger) in a waste stabilization lagoon. *Limnol. Ocaenogr.* **16**: 646 – 659.

Liang Y. L., 1984. Annual production of Branchiura sowerbyi (Oligochaeta : Tubificidae) in the Donghu Lake, Wuhan, China. *Chin. J. Oceanol. Limnol.* **2**(1): 102 – 108.

Lindegaard, C., 1989. A review of secondary production of zoobenthos in freshwater ecosystems with special reference to Chironomidae (Diptera). *Acta. Biol. Debr. Oecol. Hung.* **3**:231 – 240.

Lindegaard, C., Johnsson, E., 1987. Abundance, population dynamics and high production of Chironomidae (Diptera) in Hjarback Fjord Denmark, during a period of eutrophication, *Entomol. Scand. Suppl.* **29**: 294 – 302.

Lindegaard, C., Mortensen, E., 1988. Abundance, life history and production of Chironomidae (Diptera) in a Danish lowland stream. *Arch. Hydrobiol.* **81**: 563 – 587.

Lindegaard, C., Maehl., P., 1992. Abundance, population dynamics and production of Chironomidae (Diptera) in an ultraoligotrophic lake in south Greenland. *Neth. J. Aquat. Ecol.* **26**: 297 – 308.

Maitland, P. S., Charles, N. W., Morgan, N. C. et al., 1972. Preliminary research on the production of Chironomidae in Loch Leven. Scotland. *In*: Z. Kajak & A. Hillbricht- Ilkowska (eds.), Productivity Problems of Freshwater. IBP, UNESCO, Polish Sci. Publ., Warsaw, p.795 – 812.

Menzie, C. A., 1980. A note on the Hynes method of estimating secondary production. *Limnol. Oceangr.* **25**(4): 770 – 773.

Plante, C., Dowing, J. A., 1990. Empirical evidences for differences among methods for calculating secondary production. *J. Nor. Amer. Benthol. Soci.* **9**: 9 – 16.

Potter, D. W. B., Learner, M. A., 1974. A study of the benthic macroinvertebrates of a shallow eutrophic reservoir in South Wales with emphasis on the Chironomidae (Diptera): their life-histories and production. *Arch. Hydrobiol.* **74**: 186 – 226.

Prat, N., Rieradevall, M., 1995. Life cycle and production of Chironomidae (Diptera) from Lake Banyoles (NE Spain). *Freshwat. biol.* **33**:511 – 524.

Soluk, D. A., 1985. Macroinvertebrate abundance and production of psammophilous Chironomidae in shifting sand areas of a lowland river. *Can. J. Fish. Aquat. Sci.* **42**:1296 – 1302.

Sameoto, D. D., 1972. Yearly respiration rate and estimated energy budget for Sagitta elegans. *J. Fish. Res. Bd. Can.* **29**(7): 987 – 996.

Waters, T. F., 1977. Secondary production in inland waters. Advances in Ecological Research (A. Macfadyen, ed.), Academic Press, **10**:91 – 164.

Wang, S. D., Qian, Q. P., Xie, C. X., 1977 Studies on the Chironomidae from the vicinity of lake Tunghu, Wuchang. *Acta Hydrobiol. Sinica* **6**(2): 227 – 240.

Wilda, T. J., 1984. The production of five genera of Chironomidae (Diptera) in Lake Norman, a North Carolina reservoir. *Hydrobiologia* **108**: 145 – 152.

Wolfram, G., 1996. Distribution and production of chironomids (Diptera: Chironomidae) in a shallow, alkaline lake (Neusiedler See, Austria). *Hydrobiologia* **318**: 103 – 115.