A comparison of improvemental ability of water quality among five chironomid species of the genus *Chironomus*

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Abstract: Five chironomid species of the genus *Chironomus* were examined for caloric contents in adults and for their ability of calory removal from bodies of water by emergence and of water quality improvement in laboratory experiments. Calory per g adults was the highest (about 5,000 cal) for *Chironomus kiiensis*, higher than 2,500 cal for *C. circumdatus*, *C. nippodorsalis* and *C. yoshimatsui*, and the lowest (about 2,000 cal) for *C. nipponensis*. The actual rate of removal by emergence was the highest (about 13%) for *C. nippodorsalis*, moderate (about 10%) for *C. circumdatus* and *C. yoshimatsui*, and the lowest (about 6%) for *C. kiiensis* and *C. nipponensis*. For inhibitory ability of eutrophication, in terms of PO₄-P concentration, about 89% of inhibition was observed for *C. nipponensis*. Inhibition was higher than 70% for *C. circumdatus* and *C. yoshimatsui*, about 31% for *C. nippodorsalis*, and the lowest (about 24%) for *C. kiiensis* at 4 weeks. For inhibitory ability in terms of protein concentration, inhibition was the highest (about 80%) for *C. circumdatus*, higher than 50% for *C. kiiensis*, *C. nipponensis* and *C. yoshimatsui*, and the lowest (about 41%) for *C. nippodorsalis* at 4 weeks.

Key words: Chironomidae, improvement, rearing experiment, water quality

INTRODUCTION

Chironomid larvae live in a wide variety of inland waters in high density, feed actively on algae, detritus or other benthic invertebrates, grow rapidly, metamorphose to adults, and emerge into the air in large masses. Therefore, they are considered to play an important role in the circulation of materials and in suppression of eutrophication in aquatic ecosystems. Particularly, the genus *Chironomus* whose larvae are abundant in more or less eutrophicated waters (Sasa and Kikuchi, 1995), is considered to be the most important genus in this respect. Iwakuma (1990) has demonstrated a suppression of regression of nitrogen from sediment to water by the larval development of two large profundal

species, *Chironomus plumosus* and *Procladius akamusi* in Lake Kasumigaura, Japan. Larvae of *C. circumdatus* have been reported to remove daily up to 31% of the organic matter in a sewage canal (Sankepperumal and Pandian, 1992). In our previous study, five Japanese species of the genus *Polypedilum* were examined for their ability to remove organic materials from bodies of water by measuring caloric contents of emerging adult midges and for their ability in improvement of water quality by monitoring concentrations of PO₄-P and protein in waters, and *P. sordens* was considered to have the highest ability in improving water quality (Kawai et al., 2000). However, no studies have been conducted on the differences in the ability to remove organic materials and to improve water quality among various species of

the genus *Chironomus* under experimental conditions.

In this study, five Japanese species of the genus *Chironomus* were selected as materials for experiments, and they were examined to determine their ability to remove organic materials and to improve water quality by the same methods as the previous study.

MATERIALS AND METHODS

Chironomids

Larvae of *Chironomus circumdatus*, *C. kiiensis*, *C. nippodorsalis*, *C. nipponensis* and *C. yoshimatsui* were obtained by laboratory culture. The conditions for obtaining fertilized egg masses and rearing of the larvae were described in Kawai and Konishi (1986) and others.

Rearing method

The newly hatched larvae were reared at a density of 200 individuals per container. Each container ($\phi 15 \times H 9$ cm) was layered with 150 ml of 1% (w/v) agar plate containing 2% (v/v) milk (fat content 3.5%) on the bottom, filled with 500 ml of dechlorinated water, aerated through an airstone at room temperature and covered with a nylon net on the top. A container was set for each species. The water level in the container was kept constant during the experiment by replacing the amount of water lost by evaporation. Emerging adults were collected daily for 4 weeks and preserved as dry specimens. Control containers without larvae were also prepared and kept under the same conditions.

Measurement of calory

The caloric content retained by dried specimens was measured with a calorimeter (Ogawa Seiki Co. Ltd., Tokyo, Japan) according to the manufacturer's instruction.

Measurement of removal rate of calory

The caloric removal rate was calculated

by the following formula:

Removal rate (%) = $\frac{\text{the total calory of emerging adults}}{\text{the total calory of milk (1,969 cal) put into a container}} \times 100$

Measurement of PO₄-P and protein concentrations

A water sample (about 50 ml) was collected weekly from each container after being gently mixed and settled down. PO₄-P concentration was measured by the molybdenum blue method as an indicator of concentration of nutritional salts. Protein concentration was measured by the method described by Lowry et al. (1951) as an indicator of concentration of dissolved organic materials.

Measurement of inhibition of eutrophication

Inhibition of eutrophication was measured by the following formula:

Inhibition (%) = $\frac{[\text{PO}_4\text{-P (or protein) conc. for control water} - \text{PO}_4\text{-P (or protein) conc. for sample water}]}{\text{PO}_4\text{-P (or protein) conc. for control water}}$

RESULTS

Emergence rate

The emergence rate was below 60% for all species (Table 1). It was higher than 50% for *C. circumdatus*, *C. nippodorsalis* and *C. yoshimatsui*, and was 35–40% for *C. kiiensis* and *C. nipponensis*. Only a few larvae or pupae were observed to be alive after 4 weeks, the end of the experiment (data not shown).

Calory content of adult midges

The total calory of the emerging adults was the highest (245 cal) for *C. nippodorsalis*. It was in the range of 170–200 cal for *C. circumdatus* and *C. yoshimatsui*, and was very low (about 110 cal) for *C. kiiensis* and *C. nipponensis* (Table 1).

Calory per g adults was by far the highest (about 5,000 cal) for *C. kiiensis*. It was higher than 2,500 cal for *C. circumdatus*, *C. nippodorsalis* and *C. yoshimatsui*, and was very low (about 2,000 cal) for *C. nipponen-*

Table 1. Emergence rate and adult calory for 5 *Chironomus* species.

Species	Emergence rate (%)	Total calory of emerging adults	Calory per g adults	Calory per individual
<i>Chironomus circumdatus</i>	58.5	176.69	2,561	1.51
<i>C. kiiensis</i>	34.5	111.39	4,973	1.61
<i>C. nippondorsalis</i>	57.0	244.77	3,335	2.15
<i>C. nipponensis</i>	40.0	107.88	2,035	1.35
<i>C. yoshimatsui</i>	58.5	196.61	2,883	1.68

Fig. 1. Differences in removal rates of calory by emergence among 5 *Chironomus* species.

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Calory per individual was by far the highest (2.15 cal) for *C. nippondorsalis*. It was higher than 1.5 cal for *C. circumdatus*, *C. kiiensis* and *C. yoshimatsui*, and was the lowest (1.35 cal) for *C. nipponensis*.

Removal rate

The actual rate of caloric removal by emergence was the highest (about 13%)

Fig. 2. Differences in inhibitory abilities of eutrophication among 5 species in terms of $PO_4\text{-P}$ concentration.

for *C. nippondorsalis*, moderate (about 10%) for *C. circumdatus* and *C. yoshimatsui*, and was lower than 6% for *C. kiiensis* and *C. nipponensis*. The estimated rate of removal in 100% emergence was the highest (about 22%) for *C. nippondorsalis* and was higher than 15% for *C. circumdatus*, *C. kiiensis* and *C. yoshimatsui*. It was the lowest (about 14%) for *C. nipponensis* (Fig. 1).

Inhibition of eutrophication

1. $PO_4\text{-P}$ concentration

$PO_4\text{-P}$ concentration of the control water was 0.38, 0.72, 0.71 and 0.73 $\mu\text{g/ml}$ at weeks 1, 2, 3 and 4, respectively (Fig. 2). The inhibition rate of eutrophication compared to the control water gradually in-

creased until the 3rd week for *C. circumdatus* and *C. kiiensis*. After 1 week, the highest inhibition (about 84%) was observed for *C. nipponensis*. Inhibition was higher than 60% for *C. circumdatus* and *C. yoshimatsui*. Only 15% of inhibition was observed for *C. nippodorsalis*. About 8% of promotion in eutrophication was even observed for *C. kiiensis*. After 2 weeks, the highest inhibition (about 80%) was observed for *C. nipponensis*. Inhibition was higher than 70% for *C. circumdatus*, *C. kiiensis* and *C. yoshimatsui*. Practically no inhibition was observed for *C. nippodorsalis*. After 3 weeks, the highest inhibition (about 88%) was observed for *C. circumdatus*. Inhibition was higher than 75% for *C. kiiensis* and *C. nipponensis*. Inhibition was lower than 60% for *C. yoshimatsui*. The lowest inhibition (about 28%) was observed for *C. nippodorsalis*. After 4 weeks, the highest inhibition (about 89%) was observed for *C. nipponensis*. Inhibition was higher than 70% for *C. circumdatus* and *C. yoshimatsui*. Only 31% of inhibition was observed for *C. nippodorsalis*. The lowest inhibition (about 24%) was observed for *C. kiiensis*.

2. Protein concentration

Protein concentration of the control water was 85, 60, 65 and 81 $\mu\text{g/ml}$ at weeks 1, 2, 3 and 4, respectively (Fig. 3). Inhibition rate compared to the control water gradually increased until the 3rd or 4th week for all species. After 1 week, inhibition was 12% at the highest. More than 60% of promotion in eutrophication was even observed for *C. circumdatus* and *C. kiiensis*. After 2 weeks, about 50% of inhibition was observed for *C. kiiensis* and *C. nipponensis*. Inhibition was higher than 30% for the other 3 species. After 3 weeks, about 60% of inhibition was observed for *C. circumdatus*, *C. kiiensis* and *C. nipponensis*. Inhibition was lower than 40% for *C. nippodorsalis* and *C. yoshimatsui*. After 4 weeks, by far the highest inhibition (about 80%) was observed for *C. circumdatus*. Inhibition was higher than 50% for *C. kiiensis*, *C. nipponensis*

Fig. 3. Differences in inhibitory abilities of eutrophication among 5 species in terms of protein concentration.

and *C. yoshimatsui*. The lowest inhibition (about 41%) was observed for *C. nippodorsalis*.

DISCUSSION

The emergence rate was lower than 60% for all the species of the genus *Chironomus* examined in this study. In contrast, it was higher than 80% for 4 out of 5 species of the genus *Polypedilum* examined in the previous study (Kawai et al., 2000). The reason for this is unknown. This might be explained by a stronger density effect (i.e., smaller amounts of various resources available to an individual) exerted on the former than on the latter, resulting from the much larger body size of the former (Wiederholm, 1989). The low emergence rates in the present study are also attributable to the deficiency of granular material for tube-building that is essential to larval life of *Chironomus*, espe-

cially for pupation. Indeed, in our preliminary study, a remarkable improvement in emergence rate was attained by the use of agar plates which were spread with fine glass beads on the surface.

On the other hand, a low emergence rate means the death of many larvae during the experiment. Neither the dead larvae were removed nor the water in the container was renewed throughout the experimental period in this study. Therefore, there must have been a considerable level of eutrophication resulting from bacterial degradation of the dead larvae. Nevertheless, remarkable inhibition of eutrophication was observed in the experimental container. Thus, inhibition rates might have been much higher if the emergence rate was rendered 100%.

The calory per gram of adults was in the range of about 2,000–3,300 cal except for *C. kiiensis* in the present study whereas it was in the range of about 4,700–7,800 cal except for *P. sordens*, in the previous study (Kawai et al., 2000). This may be attributable to the difference in larval foods between these genera. That is, the species of *Chironomus* are usually scavengers (collector-gatherers) (Beck, 1977), then ingesting low calory, half-degraded materials such as detritus in the experimental container whereas those of *Polypedilum* are collector-filterers or shredders (Berg, 1995), mainly ingesting high calory, newly produced algae.

In this study, remarkable eutrophication of water was observed early for the control container whereas eutrophication was distinctly inhibited in the experimental container with larvae. This may be explained as follows. In the control container, nutritional materials such as salts and proteins are gradually released from the agar plate and incorporated into bacteria or algae. Bacteria and algae rapidly increase and die, and their dead bodies form a pile of detritus, from which nutrients are again rapidly eluted into the water. In contrast, in a container with larvae, nutrient-incorporating bacteria or

algae are rapidly and efficiently ingested and exhausted by the larvae. Thus, detrital compilation is effectively inhibited, resulting in inhibition of eutrophication. That is, there may be some differences in the process and rate of material circulation between the control and experimental containers.

More than 60% of promotion of eutrophication in terms of protein concentration was observed after 1 week for *C. circumdatus* and *C. kiiensis*. In our previous study, about 20% of promotion of eutrophication was also observed after 2 weeks for *Polypedilum nubeculosum* (Kawai et al., 2000). Use of the interior as well as the surface of the agar plate as a habitat by these species, observed throughout the experiment, might have made the dissolved proteins efficiently elute from the whole agar plate, resulting in such promotion.

Milk-containing agar plates were used for larval rearing from the 1st instar in this study. This plate was worked out in order to strictly examine the differences in energy removal and in inhibition of eutrophication among the species under identical rearing conditions. Considering some differences in major habitats among the species of *Chironomus* (Sasa et al., 1980; Sasa and Hasegawa, 1983; Yasuno et al., 1983; Kikuchi et al., 1985), however, the results obtained in this study may not necessarily reflect the above-mentioned properties of each species living in the field. Therefore, a detailed study should be conducted on the differences in composition of food materials in the field among the species.

Concentrations of $\text{PO}_4\text{-P}$ and protein in the water were measured as an indicator of eutrophication in this study since such measurements neither need a long time, high cost nor skillful technique. However, these items of water quality do not necessarily reflect the trophic status of the water correctly. Therefore, other items, widely used as an indicator, such as $\text{NO}_3\text{-N}$, BOD and chlorophyll a, should also be measured.

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