南九州池田湖におけるゾウミジンコ, *Bosmina longirostris* (甲殻亜門:枝角目)の季節的形態変化

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Cyclomorphosis of *Bosmina longirostris* (Crustacea: Cladocera) in Lake Ikeda, Southern Kyushu, Japan

Wazir Ali BALOCH*1,2, Hiroshi SUZUKI*1, and Yoshio ONOUE*1

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**Abstract:** Cyclomorphosis of *Bosmina longirostris* was monitored in Lake Ikeda, Southern Kyushu, Japan from July 1993 to June 1994 and in February and June of 1995 and 1996. *B. longirostris* showed a marked cyclomorphosis in the lake; an increase in body size and lengths of the antennule and micro in winter and a decrease in these characters in summer. Cyclic changes in body size and protuberant structures were negatively correlated with water temperature of the lake except the density of a copepod *Mesocyclops* species. The body length, on the other hand, was positively correlated with the antennule and micro lengths. The protuberant structures were found coupled and positively correlated with each other. Precipitation and/or food availability, however, were not correlated with the cyclomorphosis of *Bosmina* population in the lake.

**Key words:** *Bosmina longirostris*; Cyclomorphosis; Lake Ikeda

*Bosmina longirostris*, a small planktonic cladoceran, is commonly found in lakes and ponds throughout the world. Many researchers have studied it from various aspects including population dynamics1-4, productivity2,5, effects of food6,7 and predation8,9 and population ecology10. Cyclomorphosis in *Bosmina* has received much attention during the last two decades.

It is well-known that many freshwater zooplankton undergo morphological changes from time to time. This phenomenon is also undertaken by *Bosmina* population that usually involves changes in the body size and lengths of the antennule and micro. Many scientists have discussed various causes of cyclomorphosis in *Bosmina*3,11-15. The most plausible reason of *Bosmina*’s cyclomorphosis has been considered to be related to predation. The enlargement of cyclomorphic characters is considered as anti-predator devices8,16-19 that can reduce the predator’s ability to catch and manipulate the prey. Some researchers support this hypothesis3,11,12,15, but others20,21 see no *Bosmina* cyclomorphosis caused by invertebrate predators.

*B. longirostris* is the most common cladoceran species in Lake Ikeda22, but its cyclomorphosis is not known. Apparently, no other invertebrate predators except a copepod, *Mesocyclops* sp. occurs in the lake.

The present study thus aims to clarify whether *B. longirostris* population undergoes cyclomorphosis in Lake Ikeda and, if so, from what reasons it occurs.

**Materials and Methods**

Field surveys were conducted in Lake Ikeda (area 10.95 km², max depth 233 m, mean depth 135 m) in southern part of Kyushu, Japan. The lake is a warm monomictic type and was formed as a caldera lake associated with pyroclastic eruption of the Ibousuki volcanic group.

Samples were collected every month from July 1993 to June 1994 and in February and June of

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1995 and 1996. The samples could not be collected in March 1994 due to bad weather conditions.

Since this species showed higher densities in the upper water layer, all the samples were collected from a 0–10 m depth by vertical hauls of a Kitahara-type plankton net (diameter 22.5 cm, mesh size 95 μm) at three stations. The samples were fixed with 5% formalin and concentrated to a volume of 30 ml. Surface water temperature was measured at these stations.

Three aliquot sub-samples of 1 ml were taken onto a Sedwick-Rafter chamber and *B. longirostris* and *Mesocyclops* sp. were counted under a stereo microscope. Lengths of body (BL), antennule (AL) and muro (ML) of *B. longirostris* (see Hanazato) were measured with an ocular micrometer. Usually 60 to 90 individuals from each sample were measured, except in February 1994 when only 39 animals were collected.

Results

Water Temperature

The mean surface water temperature ranged from 12.2 to 29.3°C, the highest being in August and lowest in February (Fig. 1).

Morphological Changes

The maximum body length (> 0.5 mm) of *Bosmina* was found in December and January. The body size showed an increase in winter, but decreased in summer. The mean body length increased to 0.37 mm in January, but decreased to 0.28 mm in August, showing a negative correlation with the water temperature (Fig. 2). The lengths of the antennule and muro of *B. longirostris* were longer in winter, but shorter in

![Fig. 1. Monthly changes in water temperature (a) and chlorophyll-a (b) in Lake Ikeda. The data on temperature and chlorophyll-a were presented as the mean values of three stations. The data on Chlorophyll-a were obtained from Kagoshima Prefectural Government, 1993 and 1994. Vertical bars indicate standard deviation.](image)

![Fig. 2. Monthly changes in cyclomorphic characters of *Bosmina longirostris* in Lake Ikeda. Vertical bars indicate standard deviation.](image)
summer. Their consistent lengths in February and June of 1995 and 1996 (Fig. 3) also indicated that this species demonstrated a similar pattern of cyclomorphosis.

Mesocyclops sp. Population

Mesocyclops sp., the only invertebrate predator in Lake Ikeda, showed a population density less than 1 individual/l (Fig. 4). The population of Mesocyclops sp. contained adults along with juveniles. This species was very rare or absent from February 1994 to October 1995.

BL, AL and ML of B. longirostris showed a significant negative correlation with water temperature, but no correlation was observed between the density of Mesocyclops sp. and the morphology of Bosmina (Table 1).

Discussion

Marked seasonal changes in BL, AL and ML of B. longirostris were observed in Lake Ikeda, and their lengths were negatively correlated with water temperature (Table 1), as have been reported previously. Some of the researchers associated the increase in muro length with the increased density of predators, but not with that of antennule length. In the present study the antennule and muro lengths are found highly coupled to each other.

Table 1. Regression equation and determination coefficients ($r^2$) between cyclomorphologic characters of B. longirostris and water temperature and Mesocyclops sp. in Lake Ikeda

<table>
<thead>
<tr>
<th>Characters</th>
<th>Temperature (t) Regression equation</th>
<th>$r^2$</th>
<th>Mesocyclops sp. density (d) Regression equation</th>
<th>$r^2$</th>
</tr>
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<tr>
<td>Body</td>
<td>BL = 398.04 - 3.90t</td>
<td>0.698*</td>
<td>BL = 318.83 - 1.72d</td>
<td>0.002</td>
</tr>
<tr>
<td>Antennule</td>
<td>AL = 176.12 - 2.26t</td>
<td>0.547*</td>
<td>AL = 129.60 + 2.25d</td>
<td>0.000</td>
</tr>
<tr>
<td>Muro</td>
<td>ML = 54.40 - 0.86t</td>
<td>0.587*</td>
<td>ML = 36.87 - 0.19d</td>
<td>0.000</td>
</tr>
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* Significant at $p < 0.01$.

Adults and copepodid stage V of *Mesocyclops leuckarti* can utilize larger prey animals and all the remaining stages of this copepod prefer smaller prey species like nauplii and Protozoa. Furthermore Janicki and DeCosta found that *Mesocyclops edax* selectively preyed upon *Bosmina longirostris*.

The determination coefficients did not show any significant relationship between the density of *Mesocyclops* sp. and the lengths of antennule and uro cephal of *B. longirostris* (Table 1), indicating that there is no predation pressure of *Mesocyclops* sp. on morphological changes of *B. longirostris*.

The available amount of food for cladoceran is also considered to influence the morphology of individuals. As for *B. longirostris*, it grows continually at high food concentrations, but stops growth after maturation at low food concentrations. In Lake Ikeda water mixing occurs in February-April, which results in a supply of nutrients for algal growth from the bottom of the lake. Thus, an increase in chlorophyll-*a* can be seen from spring to early summer. The pattern of seasonal variation of chlorophyll-*a* was different from that of *Bosmina*.

Replacement of one clone by another with different phenotypes is also considered a cyclo morphic phenomenon in *Bosmina* populations. In *Daphnia* populations interspecific hybrids and hybrid taxa have been reported and these adaptations are related to escape from predation. In Lake Ikeda, however, it is not clear if these morphological changes are due to succession of different clones or morphs of *B. longirostris* and hence further study will be required in this respect.

In view of our results we can conclude that the cyclo morphosis of *B. longirostris* in Lake Ikeda is related to the water temperature and thus does not support the hypothesis that cyclo morphosis in bosmids is caused by predation of invertebrate predators.

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南九州池田湖におけるゾウミジンコ，*Bosmina longirostris*
（甲殻亜門：枝角目）の季節的形態変化

Wazir Ali BALOCH・鈴木康志・尾上義夫

南九州薩摩半島にある池田湖において，1993年7月から1994年6月まで毎月1回，および1995年と 
1996年の2月と6月に淡水産ゾウミジンコの季節的形態変化について調査した。池田湖産ゾウミジン 
コは明瞭な季節的形態変化を示した。すなわち，体長，第1触角長および殻の後端部刺状突起長は冬 
季に増加し，夏季には減少した。この季節的形態変化は池田湖の水温と有魚の相関関係が認められ 
たが，捕食者であるコガタケンミジンコ類の生息密度と有意な相関関係は認められなかった。一 
方，第1触角長と後端部刺状突起長は，それぞれ体長と正の相関が認められた。以上のこととは，池田 
湖における本種の季節的形態変化が捕食圧の変化に起因しないことを示唆する。