Population dynamics and production of cladoceran zooplankton in the highly eutrophic Lake Kasumigaura

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Abstract

The growth rate, birth rate, death rate and production of the cladocera of Lake Kasumigaura were studied. Standing crop of zooplankton seemed to be governed by predation rather than food. Maximum productivity of cladocerans was observed in late August and early September. There were differences in production between sampling stations. The highest production was recorded in the most eutrophic basin, where heavy water blooms of *Microcystis aeruginosa* occurred. Maximum secondary production coincided with maximum primary production, which was mainly due to *M. aeruginosa*. Cladocerans probably utilize decomposed or decomposing *Microcystis* cells and bacteria in summer. Estimates of annual production of cladocerans varied from 4.2 to 13.1 g dry wt · m⁻³, and annual P:B ratios ranged from 36 to 108. The production of cladocerans in Takahamairi Bay was 2.7% of gross primary production.

Introduction

Lake Kasumigaura, the second largest lake in Japan (surface area 167.7 km²), is shallow (maximum depth 7.3 m, mean depth 4.0 m) and highly eutrophic. Seasonal changes of zooplankton in this lake have been investigated from 1976 onwards (Yasuno et al., 1977; Morishita & Yasuno, 1979; Yasuno & Morishita, 1981; Yasuno et al., 1981). The standing crop of zooplankton reached its highest level in the summer, when cladocerans (mostly *Bosmina fatalis* and *Diaphanosoma brachyurum*) became dominant.

Important factors controlling the density and production of zooplankton are temperature, food and predation. Temperature influences the egg development time, growth rate, brood size and mortality of zooplankton (e.g. Hall, 1964; Vijverberg, 1980; Orcutt & Porter, 1983). A difference in temperature adaptation among zooplankton species might also be important for their seasonal succession (Allan, 1977). The effects of food quantity and quality on growth and reproduction of zooplankton have been studied (Hall, 1964; Arnold, 1971; Vijverberg, 1976). In Lake Kasumigaura as in other eutrophic lakes, blue-green algae, mainly *Microcystis aeruginosa*, form heavy water blooms in summer (Imamura, 1981). It has been demonstrated in the laboratory that some blue-green algae including *M. aeruginosa* are inadequate food for zooplankton (Schindler, 1968; Stangenberg, 1968; Arnold, 1971; Lampert, 1977a, b, 1981a, b, 1982). Also in field observations, blue-green algae were utilized less than other algae by zooplankton (Straskraba, 1966) and decreased the reproduction rate of daphnids (George & Edwards, 1974; Jones et al., 1979). Invertebrate or vertebrate predators limit the density of zooplankton and their selective predation affects the species composition of zooplankton (Hall, 1964; Wright, 1965; Brooks & Dodson, 1965; De Bernardi & Giussani, 1975; Andersson et al., 1978). Fish predation is the most important factor regulating the zooplankton population in the eutrophic Tjeukemeer (Vijverberg & Richter, 1982a,
b). The standing crop of fish and macrocrustaceans is high in Lake Kasumigaura; the total annual catch was about 600 kg wet weight - ha⁻¹, of which the prawn was the highest (30%), and was followed by the goby (26%) and the oppossum shrimp (17%). They fed on zooplankton to a considerable extent (Kasuga, 1982; Onuma et al., 1984). Most other fishes were also planktivorous.

In the present study, population parameters (population growth rate, birth rate, and death rate) and production of cladoceran zooplankton were studied to analyse the factors regulating their populations.

Methods

Fig. 1 shows the sampling stations in Lake Kasumigaura. Stations A and B were selected in Takahamairi Bay, a region known to be peculiar in quality. To represent the main lake, a sampling station (St. D) was selected at its center. In Tsuchiurairi Bay, which receives inflows from rivers and a sewage plant, another sampling station (St. C) was selected. At each station, bimonthly water samples were taken during 1981 and 1982 and approximately weekly during 1983. An acrylic tube sampler of 5 cm diam. and 2 m length was used. Zooplankton was collected by filtering the water sampled through a 93 μm mesh net. It was fixed with sugar formalin (Haney & Hall, 1973). Duplicate samples were taken at each station. In 1983, samples of cladoceran zooplankton were not only counted, but the number of eggs in the brood chamber and the body length (from the top of the head to the posterior of the carapace) of each individual was recorded as well.

Water temperature was measured at a depth of 0.5 m with a thermistor thermometer, and chlorophyll a concentration was determined by the UNESCO-SCOR method (UNESCO, 1966).

The instantaneous birth rate (b) of cladoceran species was determined according to Paloheimo (1974). The instantaneous rate of population growth (r) was calculated as \( r = (\ln N_T - \ln N_0)/t \), where \( N_T \) and \( N_0 \) are the population size after time \( t \) and the initial population size, respectively. The difference between \( b \) and \( r \) is the instantaneous death rate (d), which equals \( b - r \). Production was calculated as the sum of the biomass increment and the mortality of the population according to Adalsteinsson (1979) as follows;

\[
P = B_T - B_{T-1} + \left( N_{T-1} + \frac{E_{T-1} + E_T}{2} \cdot \frac{I}{D} \cdot N_T \right) \frac{W_{T-1} + W_T}{2}
\]

where \( P \) is the production between successive samplings, \( B_T \) is the biomass at sampling time \( t \), \( N_T \) is the number of individuals at sampling time \( t \), \( E_T \) is the number of eggs at sampling time \( t \), \( W_T \) is the mean individual biomass at sampling time \( t \), \( I \) is the time interval in days, and \( D \) is the egg development time in days. To obtain the population biomass, a body length-weight relationship for each dominant species was determined as shown below.

- **Diaphanosoma brachyurum**: \( W = 3.41 L^{3.11} \)
- **Bosmina fatalis**: \( W = 46.6 L^{3.31} \)
- **Bosmina longirostris**: \( W = 47.3 L^{3.53} \)
- **Moina micrura**: \( W = 8.67 L^{3.31} \)

\( W \) is the dry weight in μg and \( L \) is the length in mm. The weight of *Chydorus sphaericus* was calculated using the equation of Dumont et al. (1975): \( W = 89.43 L^{3.93} \).

The egg development time, \( D \), at the sampling occasion was estimated from the following equations determined in a previous study (Hanazato & Yasun, 1985):

- **Diaphanosoma brachyurum**: \( \ln D = 4.356 - 0.385 (\ln T)^2 \)
- **Bosmina fatalis**: \( \ln D = 3.262 - 0.269 (\ln T)^2 \)
- **Bosmina longirostris**: \( \ln D = 3.102 - 0.261 (\ln T)^2 \)
- **Moina micrura**: \( \ln D = 4.522 - 0.399 (\ln T)^2 \)