

ZOOPLANKTON COMMUNITY BEFORE AND AFTER NUTRIENT DIVERSION AND REVETMENT CONSTRUCTION IN LAKE FUKAMI-IKE, JAPAN

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ABSTRACT: Lake Fukami-ike is a small eutrophic lake, to improve the water quality of the lake, a lake management project was carried out in 1992. This project involved nutrient diversion and revetment construction along the lake shore. A biotope was built near the lake in 2000. As a result, although the inorganic nitrogen in the lake decreased considerably, chlorophyll-a (phytoplankton) increased slightly. The zooplankton community in the lake before the project in 1978-1979 predominantly comprised large-sized species (about 1.8 mm), however, small-sized species (about 0.1-0.2 mm) were dominant after in 2013-2015. The reason for the decrease of the large-sized zooplankton was thought to be the possibility of losing habitat space because aquatic macrophytes of the littoral zone were filled up when revetment construction built in 1992. We compared the body length and composition of zooplankton community between the lake (nearly emergent plants on the lake shore) and the biotope (emergent and floating-leaved plant cover). Large-sized zooplankton (about 0.9-1.2 mm) were dominant in the biotope, and size distribution did not differ in 1978-1979. The presence of developed aquatic macrophytes was suggested to promote the survival of large zooplankton.

Keywords: Zooplankton community, Body length, Aquatic macrophytes, Revetment construction

1. INTRODUCTION

Lake Fukami-ike is a small monomictic and eutrophic lake, located in southern Nagano Prefecture in central Japan. In 1992, a lake management project was carried out to improve the water quality of the lake; this project involved a reduction in external nutrient loadings from surrounding paddy fields into the lake (nutrient diversion), revetment construction along the lakeshore (Except for some, the aquatic plants disappeared) [1]. This project was expected to improve the water quality of the lake, but only inorganic nitrogen, and not inorganic phosphorus, was found to be decreased significantly. Moreover, chlorophyll-a (chl-a) increased slightly after the project [2].

In June 2000 and July 2016, blue-green algae (Cyanophyceae, *Microcystis aeruginosa*, *Anabaena affinis*, respectively) blooms occurred, which was not observed before the project. Although more than 20 years have passed since the project, it is difficult to say whether it effectively improved the water quality by nutrient diversion.

Studies on Lake Fukami-ike began from 1978 onwards, and investigations are still being conducted mainly on water quality roughly once a month. However, zooplankton and phytoplankton have not been investigated in detail. Chl-a have

been measured, but its species composition as phytoplankton has not been clarified continuously.

Reference [2] shows the difference in species composition between zooplankton and phytoplankton before and after the project, which also reports that chl-a increase slightly despite the nutrient diversion and large-sized species (body length about 1.8 mm, e.g., *Cyclops vicinus*) dominated the lake in 1978-1979 (before the project), whereas small-seized species (body length about 0.1 mm e.g., *Keratella cochlearis*) dominated the lake in 2013-2014 (after the project).

In addition to the results of reference [2], results from 2014 to 2015 are also included, and the body lengths of zooplankton before and after the project have been extensively compared in this paper. Furthermore, in order to clarify the influence of aquatic macrophytes of the lake shore which was used for zooplankton as a habitat space and an evacuated space from fish, which is considered as one of the factors in the reducing of large-sized zooplankton, we decided to compare the appearance situation of biotope (Adjacent to the west side of the lake) to lakes with different vegetation and lake.

2. METHODS

2.1 Study Site

2.1.1 Lake Fukami-ike

The lake is located at a north latitude of 35°32' 55" 77 and east longitude of 137°81' 93" 56. Its short diameter is 150 m, the diameter is 300 m, the area is about 2.2 ha, and volume is 1.0×10^5 m³ (Fig.1). The lake has six inflows and an outflow [2, 3]. In 2016, the maximum depth of the water was observed to be 7.6 m.

The dominant macrophytes communities on the lake shore have been established as follows: *Zizania latifolia* and *Phragmites australis*, (both species belong to Poaceae). Among them, *Z. latifolia* were planted after the project [1]. The fish community is dominated by *Lepomis macrochirus* (Centrarchidae) and *Micropterus salmoides* (Centrarchidae), which are piscivorous fish [4].

2.1.2 Biotope

The biotope is on the west side of the lake and built by local residents in 2000. The biotope is connected to the lake by a hose filled in the ground. The range of water depth is about 0.1-0.3 m, water in the biotope will dry out in the midsummer and freezing in the midwinter temporarily.

In summer, the biotope was found to be covered with *Nelumbo nucifera* (Nelumbonaceae), *Z. latifolia*, and *P. australis* (<http://fukami-ike.jp/page012.html>). *Pelophylax nigromaculatus* (Ranidae) was also found in the biotope.

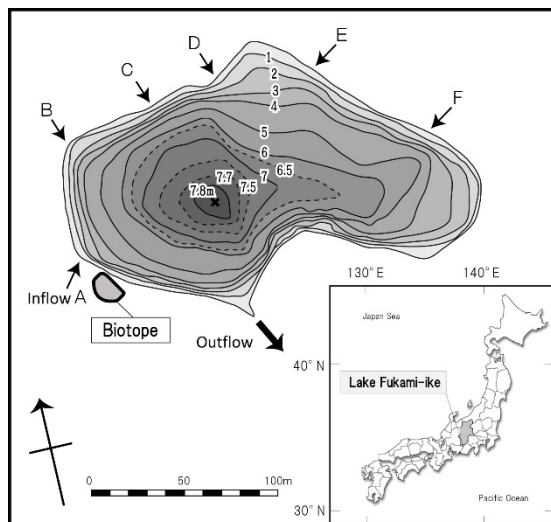


Fig. 1 Location of the Lake Fukami-ike and biotope (in 2004)

2.1 SAMPLING AND ANALYSIS

Field observations in the lake were conducted from March 2013 to February 2015, including the

observations in the biotope from May 2013 to June 2014, roughly once a month.

Lake plankton samples were collected at the deepest point with a Van Dorn water sampler (10L, Rigo Co., Ltd., Tokyo, Japan) from every 0.5m. Biotope plankton samples were collected with polyethylene bottle by scooping water directly.

All the samples were preserved in 1% formalin in the field immediately. Zooplankton was identified using an optical microscope (BX51, Olympus Optical Co., Ltd., Tokyo, Japan) in the laboratory.

3. RESULTS AND DISCUSSION

3.1 Comparing body length of zooplankton before and after the project

Reference [5] shows that the zooplankton was collected using plankton-net (mesh size 0.1 mm, Rigo Co., Ltd., Tokyo Japan) from 1978 to 1979. Therefore, we compared the length of zooplankton before and after project, excluding the size smaller than 0.1 mm.

The species with high frequency before and after the project is shown in Table 1. Before the project, the frequencies of large-sized zooplankton are as follows: *Cyclops vicinus* (36.2%), *Bosmina longirostris* (20.6%), and *Cyclops* sp. (11.8%), respectively. On the other hand, the small-sized zooplankton that appeared after the project is as follows: *Keratella cochlearis* var. *tecta*, *Keratella cochlearis* var. *micracantha* and Nauplius of Cyclopoida (15.6% in total), *Brachionus angularis* and *Polyarthra dolicoptera* (13.4%), *Filinia longiseta* (11.2%). While there were many large species in the species with high occurrence frequency before the project, there were many small species after the project.

Figure 2 shows the comparison of the body length of zooplankton collected before and after the project. This finding indicates that many large species inhabited the lake before the project, while the small species mainly inhabited the lake after the project.

3.2 Factors responsible for reducing the large species in the lake

In general, an increase in grazing pressure of planktivorous fish led to the loss of large-sized zooplanktons [6, 7]. Zooplankton behavior that escapes from predation from fish is well known, it is necessary to move vertically to the layer where light does not reach easily visible during the day [8, 9]. In addition, it is known that zooplankton moves horizontally to aquatic macrophytes community on the lake shore in order to conceal it from fish [10, 11].

Table 1 Comparison of high-frequency species and body length before and after the project

Project	Species	Body length (mm)	Frequency (%)
Before (1978-1979) [5]	<i>Cyclops vicinus</i>	1.8	36.2
	<i>Bosmina longirostris</i>	0.5	20.6
	<i>Cyclops</i> sp.	1.5	11.8
After (2013-2015)	<i>Keratella cochlearis</i> var. <i>tecta</i>	0.10	15.6
	<i>Keratella cochlearis</i> var. <i>micracantha</i>		
	Nauplius of Cyclopoida		
	<i>Brachionus angularis</i>	0.125	13.4
	<i>Polyarthra dolicoptera</i>		
	<i>Filinia longiseta</i>	0.25	11.2

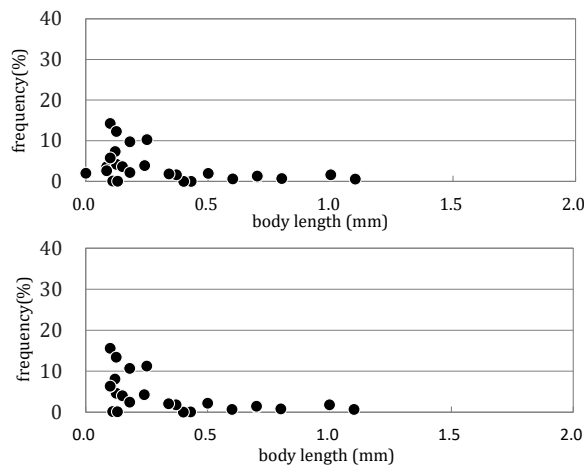


Fig.2 Comparison of the body length and frequency of the zooplankton in Lake Fukami-ike before (upper figure) and after (lower figure) the project.

The aquatic macrophytes communities are classified in the emergent plant, floating-leaved plant, and submerged plants mainly by their form and life-type. They are distributed in gently sloping places, generally called “lake-shelves”, in strips at different water depths, and established aquatic macrophytes community. Aquatic plants play an important role in the ecosystem of the lake. They provide habitats for living things, absorb nitrogen and phosphorus so as to maintain water quality, and so on [12]. The developed aquatic macrophytes in the lakeshore provide habitats for zooplankton and other organisms because there are three-dimensional structures. The developed aquatic macrophytes in the lake shore also helps the zooplankton to escape from predators such as fish. Emergent plants are shallowly submerged in water while the floating-leaved plants have only the leaves floating on the surface; both these categories of plants are less likely to form complex structures. However, the submerged plants have their whole body submerged in the water, so they have a high hiding effect from fish [10, 12]. For this reason, the

existence of a submerged plant community is considered important in places where large-sized zooplankton exists so as to help hide them from their predators.

In the Lake Fukami-ike, some of the aquatic macrophytes communities in the littoral zone on the shore were left behind before the revetment construction in 1992. But later, many of these macrophytes communities disappeared during the construction process. To see the influence of macrophytes community, species composition of zooplankton from biotope (emergent and floating-leaved plant cover) was compared with the lake (nearly emergent plants on the lake shore) after the project.

3.3 Relationship between macrophytes community and species composition of zooplankton

3.3.1 Macrophytes community of the lake and biotope

Table 2 shows the macrophytes community of the lake and biotope. Before the project in the lake, the macrophytes community included emergent plants, floating-leaved plants, and submerged plants. Although there is no data on the area to prove that the community disappeared by revetment construction, the macrophytes community of the lake became simpler with emergent plants on the lake shore.

3.3.2 Comparing body length of zooplankton in the lake and biotope after the project

To see the difference in zooplankton composition and macrophytes, the body size of the zooplankton collected from the biotope and the lake were compared (Fig. 3). The size of the circle indicates that the number of zooplankton corresponded to that position.

From the biotope, most cases were dominated by large zooplankton (*Cladocera*, *Scapholeberis kingi*)

with a body length of about 0.9 to 1.2 mm during

Table 2 Main macrophytes community of the lake and biotope.

Species	Living Forms*	Area	
		Lake Before[13]	Biotope After
<i>Zizania latifolia</i>	E	○	○
<i>Phragmites australis</i>	E	○	○
<i>P. japonica</i>	E	○	○
<i>Typha latifolia</i>	E	○	
<i>Nelumbo nucifera</i>	F		○
<i>Potamogeton cristatus</i>	S	○	

*E: emergent plants, F: floating-leaved plants, S: submerged plants

*Before: before the project, After: after the project

the study period. The distribution of the body size was different from the sample collected from the lake after the project. The size distribution of zooplankton collected from the biotope was similar to that of the lake before the project, and large-sized zooplankton was mainly obtained.

Reference [10] shows the difference between the living types of aquatic plants and the abundance of *Daphnia*. The abundance of *Daphnia* in the submerged plant's community shows that the population density has increased significantly compared with the floating-leaved plant group, the emergent plant group, and the control group (without water plants). These results suggested that the presence of developed aquatic macrophytes suggested the promotion of the survival of large-sized zooplankton.

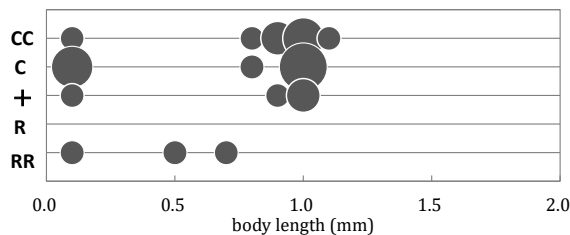


Fig.3 The body length and frequency of the zooplankton in the biotope. (CC: very common; C: common; +: present; R: rare; RR: very rare. The size of the circle indicates the frequency.)

4. CONCLUSION

With the lake management project in 1992, the amount of nitrogen in the lake was decreased significantly; however, the amount of chl-a did not decrease but increased slightly. Although this phenomenon was one of the questions, this may be due to the low prey pressure for chl-a (phytoplankton) with a remarkably small number of

large-sized zooplankton. Moreover, the decrease in large-sized zooplankton was believed to be due to the lack of developed macrophytes for cover from predators as a result of the large landfilling of the lakeshore by the revetment construction.

In order to reduce the amount of chl-a in the lake, it is important to increase the predation pressure against them. Developing aquatic macrophytes community on the lake shore is thought to promote the population of large-sized zooplankton, and it also has the effect of stable absorption of nitrogen and phosphorus in the lake.

Although it is still an issue to examine the influence of the predatory pressure of fish against zooplankton, restoring the developed community seems to have the potential to improve the ecosystem of the Lake Fukami-ike.

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