A study concerning the restoration of the littoral vegetation in Lake Kasumigaura

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1. Introduction

Lake Kasumigaura is the second largest lake in Japan. Since the lake is significantly longer in one direction, the waves are high and submerged macrophyte cannot live stably on most of the shore, except for submerged plants. Nevertheless some scientists and a civic organization suggested to build breakwaters as a restoration effort for *Nymphoides peltata*, for its high genetic diversity in Lake Kasumigaura. Following this request, the Ministry of Land, Infrastructure, Transport and Tourism decided to start construction without prior environmental assessments, because the restoration of *Nymphoides peltata* was deemed urgent; although local residents disagreed with this idea for *Nymphoides peltata* dit not flourished largely before.

The distribution of *Nymphoides peltata* was originally limited in Lake Kasumigaura, and the restoration on shore which it flourished in 1980s, when the quality of water got worse, can damage the original ecosystem. Now, the area of *Nymphoides peltata* in such places getting smaller though about 10 years have passed. This means such a restoration has less positive effect.

In this study, we attempted to reconstruct the distribution of aquatic plants prior to eutrophication and the construction of bank revetments in order to examine the original littoral vegetation in Lake Kasumigaura. The exposure with/without breakwaters was estimated in order to examine the effect of breakwaters quantitatively. Furthermore, we also analyzed the quality of both the water and the sediments. By integrating these results, we examined the restoration efforts of the littoral vegetation in Lake Kasumigaura.

2. Study sites and methods

Lake Kasumigaura is a lagoon, which mainly consists of Lake Nishiura and Lake Kitaura. The area of Lake Nishiura is 167.6km^2, with the mean and maximum depths of 3.4m and 7.3m, respectively. As a consequence of constructing the Hitachigawa-suimon sluice gate, whose purpose was water conservation, Lake Kasumigaura became a freshwater lake. Such kinds of restoration projects consisting of breakwaters was conducted in 11 areas in Lake Nishiura and Lake Kitaura.

Prior to the actual field survey, in order to reconstruct the original distribution of aquatic plants and sandy beaches, 61 photographs taken by the U.S. Forces in 1947 were used for photographic interpretation.

In this study, the exposure, the presence of *Nymphoides peltata*, the accessibility from land are considered. Three areas in Lake Nishiura and two areas in Lake Kitaura were selected. In each area, four stations were set due to the inherent structure of breakwaters in different areas.

The survey was conducted on 21st of August, 17th of September in 2011, and 14th of August in 2012. In every station, sediments are taken, and analyzed for total sulfide, organic mud, and grain size distribution. Dissolved oxygen measurements were taken only in areas where *Nymphoides peltata* flourished.

To examine the effect of waves quantitatively, we estimated the exposure at the lakeshore on the same day, using wind velocity, frequency of each wind direction, and the length of the lakeshore from the structures.

3. Results and Discussion

In 1947, the distribution of floating-leaved plants is limited, and most of the lakeshore was composed mainly of sandy beaches in Lake Kasumigaura. The distribution of emergent plants was mainly in estuaries and in sandy beaches (**Fig.1**). Through this study, the original littoral environment without anthropogenic effects was reconstructed, through the present measurement of restoration of the littoral vegetation with aim of reconstituting the situation in the 1970s before bank construction and eutrophication were started.

Through the year, exposure is largest at the offshore of breakwaters, followed by the area under the *Nymphoides peltata* communities behind of breakwaters. Behind the breakwaters, independent of structure, the exposure in winter was lower than that of the area beneath *Nymphoides peltata* communities. This means the dead *Nymphoides peltata* is likely to be accumulated behind the breakwaters because in this season most of these plants wither. The results of the analysis of the organic mud (concentration of total nitrogen and organic carbon) indicated the same tendency as the above.

After organic mud is accumulated, sediments will become anaerobic due to decomposition. In the anaerobic situation, sulfate reducing bacteria generate H_2S and CO_2 by oxidation-reduction reaction between SO_4^{2-} and the organic mud. In this study, TS is especially high behind the breakwaters (**Fig.2**). H_2S is notorious for its fatal effect to creatures with aerobic respiration, thus setting the breakwaters had a bad influence on sediments, which is important for creatures to survive. The station with the highest and the second highest TS where *Nymphoides peltata* communities disappeared after they once flourished; this also supports the influence of breakwaters.

As the organic mud, fine particles were accumulated at the area behind the breakwater. It can change the original sandy littoral environment; fine particles are small enough to occlude the gills of a bivalve.

Beneath *Nymphoides peltata* communities, the results indicated that even in areas located inside these breakwaters, high exposure and organic mud or fine particles did not accumulate. This is possible because of the location and structures of breakwaters. However, in the area 50m behind the breakwater, accumulation occurred. Monitoring survey for the changing sediment condition is needed to keep the littoral condition healthy.

Breakwaters in Lake Kasumigaura lower the exposure at the lakeshore, and have bad influences on the sediments. Thus this way of the restoration of the littoral vegetation is not adequate. In addition, increasing H_2S can change the biota, thus it can be inferred from this study that breakwaters should be removed as soon as possible.

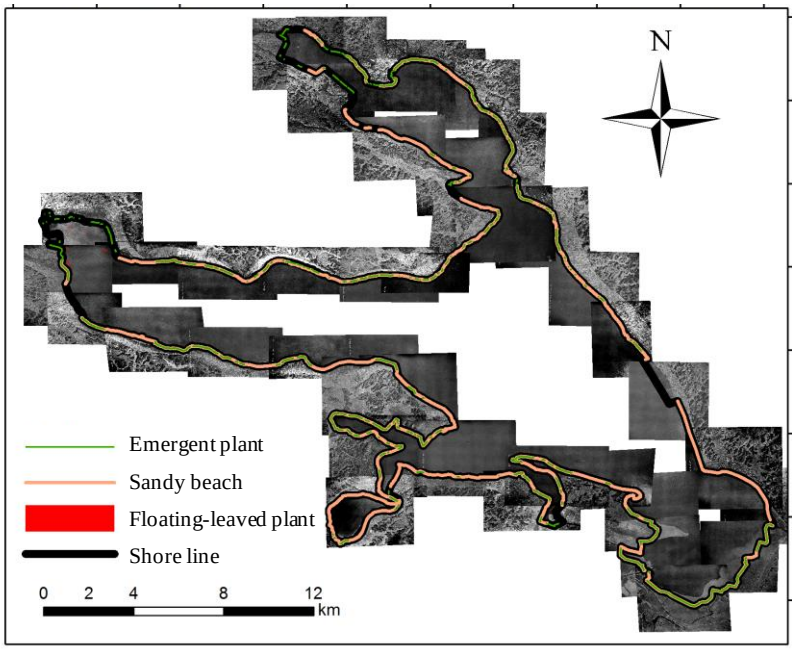

Fig.1 Aquatic vegetation and sandy beach in L. Kasumigaura, 1947.

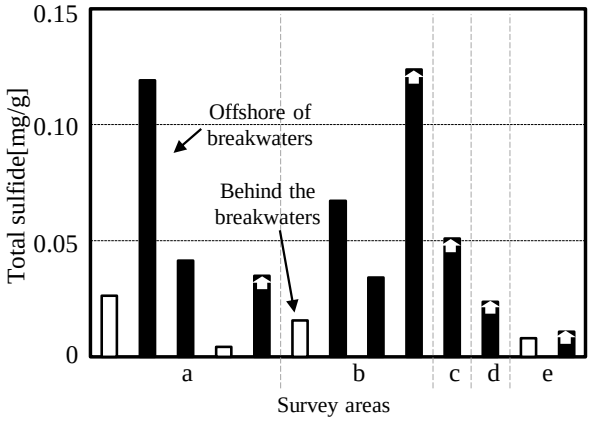

Fig.2 TS from the sediment of each station. White arrow shows the presence of *Nymphoides peltata* communities.