

Restoration attempt of submerged macrophytes in an eutrophic shallow lake in Japan

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Abstract

We have tried to develop a procedure to rehabilitate submerged macrophytes in lakes and marshes where they had been disappeared. Diaspore of submerged macrophytes from bottom sediments should be retrieved and used to restore locally native species. We investigated the distribution of the density of diaspore in lake bottom sediments and the germination potential of diaspore in Lake Kasumigaura, Japan. We have shown that the densely distributed diaspore was found in the vicinity of the river mouths and bays. Germination tests for sediment samples taken from several depths showed that the density of diaspore was high at the depth of 20-50cm from sediment surface, and the number of germination of submerged macrophytes was high at the depth of 10-40cm from sediment surface. Age determination of the bottom sediment showed that these sediment layers were deposited during periods when submerged plants were dominant in the lake. This result implies the possibility of the rehabilitation of native submerged macrophytes from diaspore in bottom sediments in Lake Kasumigaura.

Introduction

Vegetation of submerged macrophytes is known to suppress the resuspension of bottom sediments, leading to the improvement of the water quality of eutrophic shallow lakes and marshes (James et al., 2004, Scheffer et al. 2001, van den Berg et al., 1998). Therefore, rehabilitation of submerged macrophytes in shallow lakes and marshes should be promoted in terms of water quality conservation besides ecosystem restoration. Submerged macrophytes have been disappeared due to water quality deterioration and physical disturbance on littoral zone such as levee construction in many Japanese lakes and marshes. Lake Kasumigaura, which is the second largest lake in Japan, is not the exception. Submerged macrophytes started to

disappear in 1970s and they can hardly be found recently because of the deterioration of water quality due to the development in the basin and the construction of levees.

The demand for the rehabilitation of submerged macrophytes in the littoral zone is becoming higher, being accompanied with the movement of the restoration of natural environment. Diaspores of submerged macrophytes from bottom sediments have a possibility to be used to restore locally native species. Since the distribution of diaspores of submerged macrophytes may be heterogeneous, the probability of germination is different depending on the sampling points when the bottom sediments are used for germination experiments. Therefore, it is preferable to find places where the density of buried diaspores is high to retrieve submerged macrophytes efficiently. We have done field surveys and germination experiments to find places where the density of germinable diaspores of macrophytes is high.

Method

Bottom sediments sampling to measure the density of diaspores

Bottom sediments have been sampled from 12 stations in Lake Kasumigaura (Fig. 1) in total. Surface 20 cm of the bottom sediments was taken from Stations 1 to 10 (Fig. 1) to measure the density of diaspores of submerged macrophytes in March 2005. The total volume of the sample was 6 liters.

Core sampling of the bottom sediments was conducted in Stations 1, 3 and 11 (Fig. 1). Sampled cores were 20 cm in diameter and about 60 cm in depth. Sampling was done in March 2004 and 2005, at Stations 3 and 1 and 11, respectively. Core sampled from Station 3 was divided into three by approximately 20 cm and that from Stations 1 and 11 was divided into five by 10 cm.

Extraction of diaspores from sediment samples was performed manually using a microscope. Extracted diaspores were sorted and counted.

Bottom sediments sampling for germination experiments

Cores were sampled for germination experiments from Stations 1, 3 and 9 (Fig. 1). Size of the cores is 20 cm in diameter and 60 cm in depth. Core sampled from Station 3 was divided into three by approximately 20 cm and that from Stations 1 and 9 was divided into five by 10 cm. Divided each layer of the sediments was spread onto a small plastic pond in a greenhouse for germination experiments. The details of the germination experiments will be explained later.

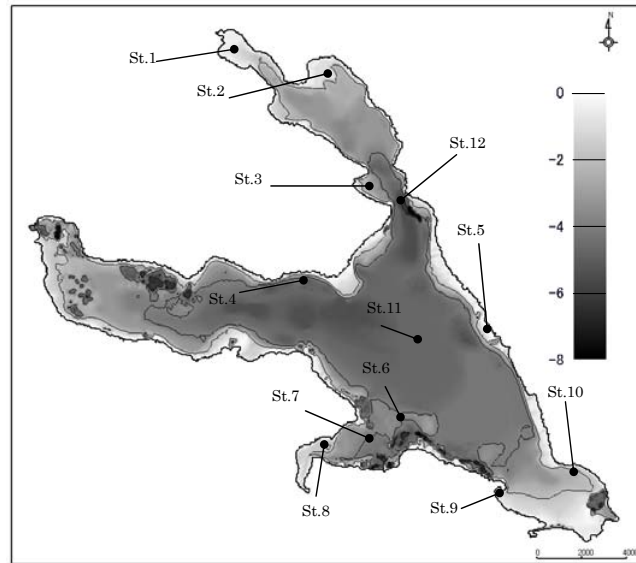


Figure 1 Plan view of Lake Kasumigaura with depth contour and sampling stations
(Legend: depth in meter)

Bottom sediments sampling for age determination

Sediment cores were also sampled for age determination from Stations 1, 3 and 12. Core size is 10 cm in diameter and 60 cm in depth. Sampled cores were divided by 2 cm making 30 layers of sediment sample. Age determination procedure will be discussed later.

Germination experiments

We have conducted germination experiments in a greenhouse. Experiment for the sediment samples from Station 3 was done from March 24 to May 19, 2004, and that for samples from Stations 1 and 9 was done from April 22 to July 22, 2005. Each sample was laid on a small plastic pond with the size of 200 cm X 200 cm X 2 cm (depth) for the experiment of sediment from Station 3, and 150 cm X 150 cm X 1 cm (depth) for the experiment of sediment from Stations 1 and 9.

Each experimental pond was filled with continuously pumped groundwater. Ponds were covered by meshed net to prevent overheat. Diagram of the experimental pond and view of the greenhouse are shown in Fig. 2.

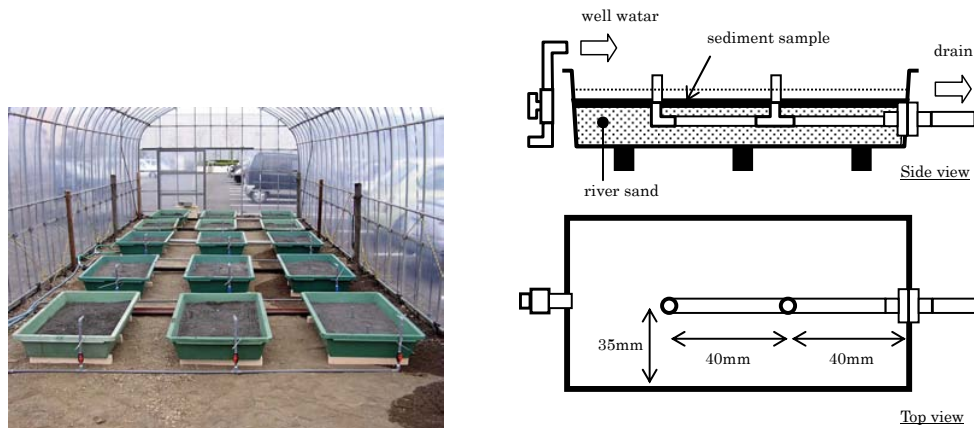


Figure 2 Diagram of an experimental pond and the view of the greenhouse used

Sediment age determination

Sediment age determination to estimate the period of the deposition for each layer of sediment cores was done using Pb-210 and Cs-137 method (The Oceanographic Society of Japan, 1986). Short Lived Isotope Counting such as Pb-210 and Cs-137 method is suitable for relatively new materials. Pb-210 method was applicable only for the samples from Station 12 because the bottom sediments at this station seemed to have received minimum disturbance by wind wave. Ce-137 method was applied to all samples.

Results

Distribution of diaspores in surface 20 cm layer of the bottom sediments was heterogeneous and concentrated in Stations 1, 3, 9 and 10 (Fig. 3). Estimated density of diaspores is about 20,000 individuals per cubic meter at Station 3. On the other hand, no diaspore was found at Stations 2 and 5. Diaspores are more likely to be found in bay area, where submerged macrophytes had been found.

Vertical diaspore distribution for found species at Station 3 is shown in Fig. 4. Mainly diaspores of six species have been extracted (i.e. *Chara* sp., *Ceratophyllum demersum*, *Potamogeton* sp., *Ranunculus* sp., *Zannichellia palustris* and *Najas marina*).

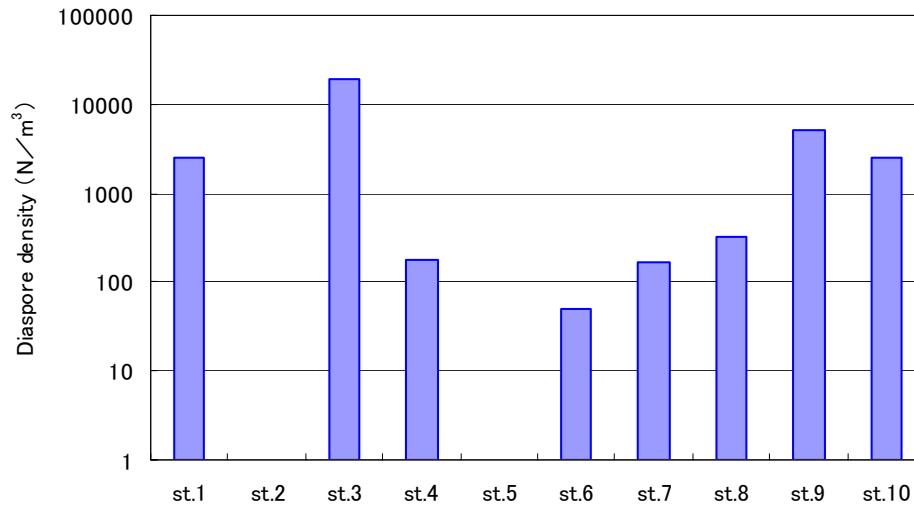


Figure 3 Distribution of diaspores in surface 20 cm layer of the bottom sediments

Most diaspores belong to *Chara* sp. followed by *Potamogeton* sp. These two species occupies more than 98% of diaspores found in this station. The density of diaspore is higher in deeper portion for these dominant two species. Diaspore of *C. demersum* and *Ranunculus* sp. was found only at the surface layer and that of *Z. palustris* and *N. marina* was found only at the deepest layer, suggesting the succession of macrophyte species around this area.

Vertical distribution pattern of diaspore at Station 1 is shown in Fig. 5. Three species were found and their vertical distribution did not show conspicuous peak except the value for *Nitella* sp. found in 40-50 cm layer. Diaspore density at Station 11 was sparse and only *Chara* sp. and *Potamogeton* sp. were found.

Germination of only *Chara* sp. from the surface 20 cm of the sediment was recognized within the sediment sampled at Station 3. The number of germinated *Chara* sp. individuals was 10 in 94.1 liters of sediment sample. Three species, *Vallisneria spiralis*, *Chara* sp. and *Nitella* sp., have germinated from sediments sampled at Station 1 (Fig. 6). The number of germinated individuals showed maximum in the layer of 30-40 cm depth. *Vallisneria spiralis* can reproduce from their propagules. Since their propagules were not counted in diaspore counting, this species was not shown in Fig. 4.

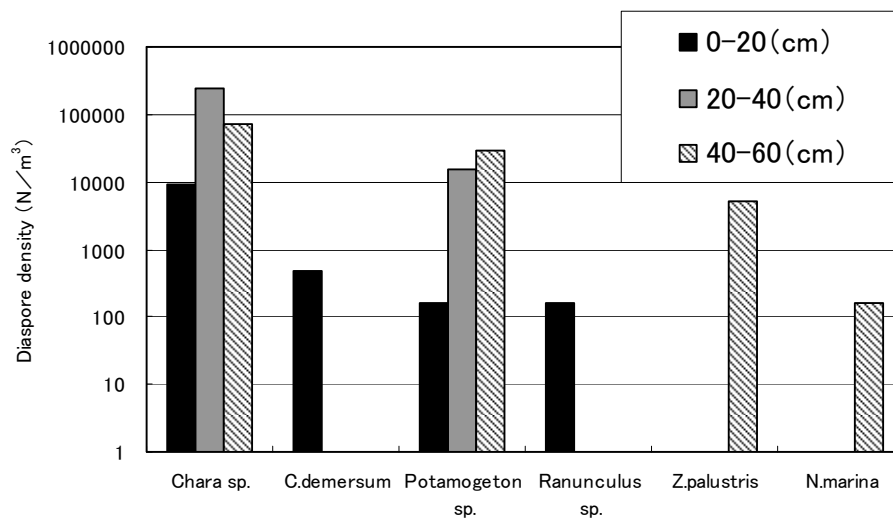


Figure 4 Vertical distribution of the diaspore density of six submerged macrophyte species at Station 3

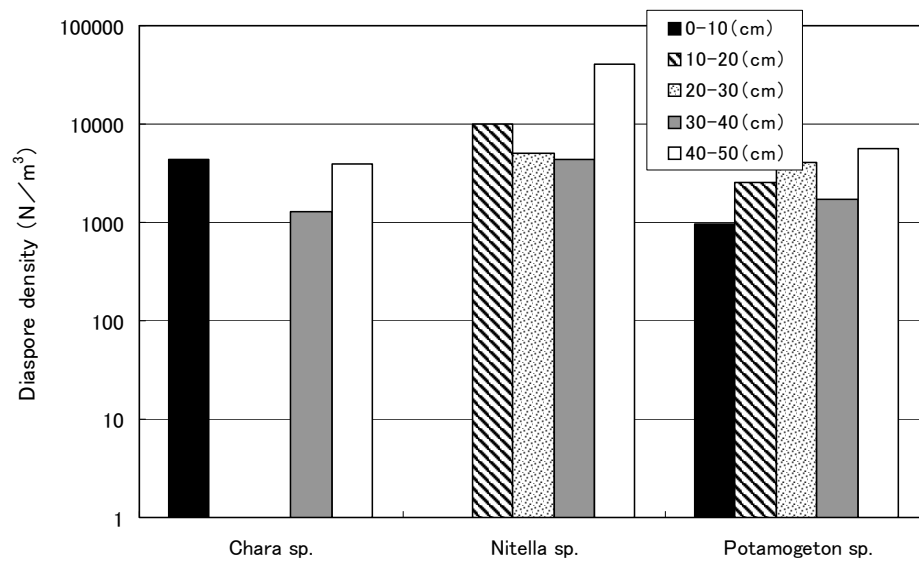


Figure 5 Vertical distribution of the diaspore density of three submerged macrophyte species at Station 1

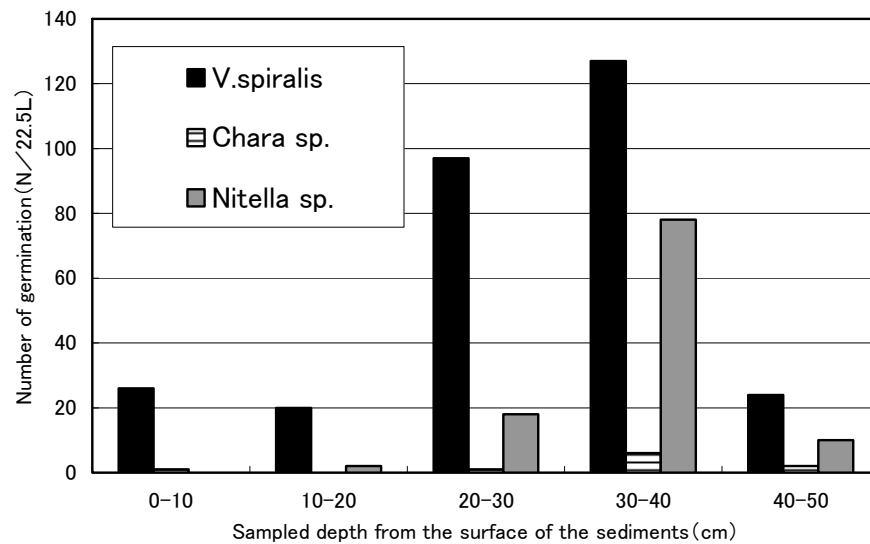


Figure 6 Number of germinated individuals from different layer of the sediments at Station 1

Same three species have germinated from sediment sampled from Station 9. However, most individuals have germinated from surface 20 cm layer at Station 9. Age determination of bottom sediments showed different accumulation speed for three locations (Fig. 7). Mean accumulation speed of sediment is 0.69, 0.46 and 1.33 cm/yr for Stations 1, 3 and 12, respectively. Sediments which lie deeper than 20 cm from the surface and contained a number of diaspore are presumed to have been accumulated before around the year of 1953 at Station 3 (Fig. 7). Layer which is located deeper than 40 cm from the surface and contained abundant diaspore is also estimated to have deposited before around the year of 1955 at Station 1. Although the density of diaspore was high in layers older than 1950s, diaspore which has the potential to germinate is distributed within newer sediment layer. Sediment layer that is located in 20 cm to 40 cm from the surface possesses the largest population of germinable diaspore and propagule at Station 1 (Fig. 6). This layer seems to be accumulated from the year of 1955 to 1978.

Discussion

Points where a number of diaspore of submerged macrophytes were buried (Stations 1, 3, 9 and 10) seem to have following three common features. 1. These points are located in bay-like topography which is half enclosed by lake shore. 2. River outlet can be found nearby. 3. Community of submerged macrophytes had been found previously. First feature is common among all four stations, second one is common between Stations 1 and 3, and third one is common among Stations 1, 3 and 10.

Current is more likely to be stagnant and the disturbance on the bottom caused by wind wave is minimal in bay-like topography. Therefore, diaspore and propagule of submerged macrophytes can settle relatively easily and resuspension of them can be suppressed; leading to the accumulation of them in such place.

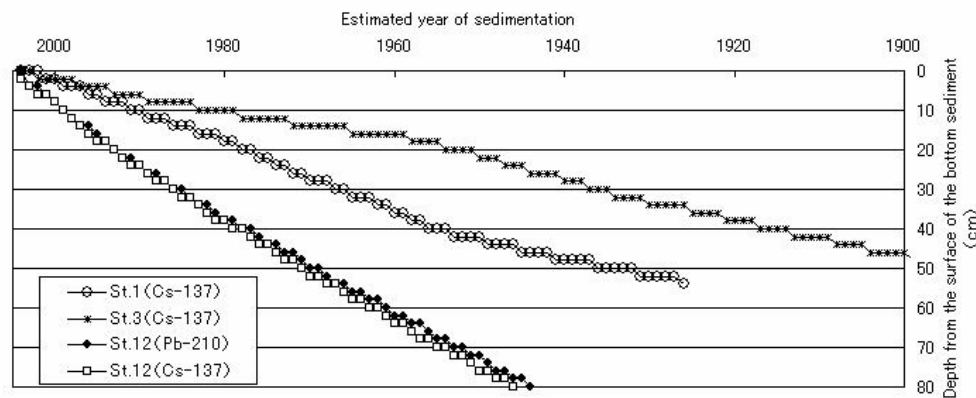


Figure 7 Estimated sediment deposition rate at different points

Within a bay with river outlet, deposition of sediment which is supplied by a river may occur in significantly high rate. One of the largest inflowing rivers of Lake Kasumigaura has its outlet near Station 1. This can result in the higher sediment deposition rate than in Station 3 (Fig. 7). In particular, sediment deposition increases suddenly during floods. Diaspore and propagule can be buried in short period during floods. The degradation of diaspore and propagule can be suppressed in such case because the surrounding condition can be in reduction soon. Also expectable is the supply of diaspore and propagule of macrophytes from river basin. *V. spiralis*, *Chara* sp. and *Nitella* sp., which have germinated from sediments sampled at Station 1 can also be found in streams and ponds within the river basin.

Supply of diaspore and propagule must had been large in areas close to the previous

colony of submerged macrophytes. Dense population of submerged macrophytes was found in Stations 1, 3, 5 and 10 during a survey in 1972. Although diaspore density was high in Stations 1, 3 and 10, no diaspore was found in Station 5. This can be attributable to the topography of the station. Physical disturbance induced by wind wave may be too intense in Station 5.

Almost neither diaspore nor propagule was found in lake center (Station 11) in another set of field survey. Diaspore density was highest in Station 8 among Stations 6, 7 and 8. These suggest that the density of diaspore and propagule is not high in deeper area of the lake (pelagic zone).

Considering above mentioned discussions, it can be induced that large amount of diaspore and propagule of submerged macrophytes have been deposited and buried in bottom sediments of areas where following two or three conditions are satisfied. The area is semi-enclosed bay-like littoral area; a colony of submerged macrophytes had been found previously and/or an outlet of river exists nearby (Horizontal condition).

Density of diaspore and germination rate seemed not to have a clear relationship (Fig. 4 to 6). Although diaspore density is much higher in Station 3 than in Station 1, the number of germinated individuals is larger in Station 1. This may be caused by the difference in the condition of the bottom sediments in both Stations. Station 1 has a faster deposition rate (Fig. 7) and this means that sediment at the same depth is newer in Station 1 than in Station 3. It seems obvious that newer diaspore has higher germination potential. Therefore, surface sediments have advantage of containing diaspore and propagule with higher germination potential. However, the number of the diaspore and propagule is sparse in surface sediments because grown submerged macrophytes have been sparse recently. Past surveys have revealed that the area of colonies of submerged macrophytes in Lake Kasumigaura has decreased rapidly since 1980. This means that bottom sediments which are newer than this period are not likely to contain large number of diaspore. Both sediment layer which is deeper than 20 cm in Station 3 and that which is deeper than 40 cm in Station 1 have very small germination potential and these portion of the sediment were deposited more than 50 years ago (Figs. 6 and 7). This suggests that most buried diaspore will lose its germination potential in 50 years. By considering above two limitations, we can induce that bottom sediments which were deposited from 1950s to 1980s have largest possibility to contain germinable diaspore and propagule in Lake Kasumigaura (Vertical condition).

Conclusion

Restoration of shallow eutrophic lakes by re-establishing submerged macrophytes has been paid strong attention recently (Gulati and van Donk, 2002, Hilt et al., 2006). Re-establishing submerged macrophytes can return the condition of shallow eutrophic lakes to their past clear state. However, submerged macrophytes in Lake Kasumigaura has decreased and some species has already disappeared. We have shown that diaspore and propagule of these species can still be found in bottom sediments and used to prepare for the re-establishment. At least 8 taxa were retrieved from bottom sediments of Lake Kasumigaura.

If we take surface 40 cm of the bottom sediments from semi-enclosed bay-like littoral area where a colony of submerged macrophytes had been found previously and/or an outlet of river exists nearby, they can provide better chance of retrieval of disappeared submerged macrophytes.

Acknowledgement

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