Research article

Growth Situation of *Phragmites australis* (Cav.) Trin. Used in Artificial Floating Islands for Water Purification in Cold Regions

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Abstract In this study, growth experiments of *Phragmites australis* (Cav.) Trin., used as part of artificial floating islands for water purification, were conducted. The Lake Mizusawa, which is the study area, is located in Biei Town, Hokkaido. The area around this lake is hilly and mostly comprises farm fields . Due to the topography and land use, soil particles and fertilizer flow into the lake after heavy rains. This is the most important cause of lake eutrophication. One way to clear up this eutrophied lake is to place artificial floating islands using the *Phragmites* on the lake surface. The *Phragmites* used for the artificial floating islands absorb nitrogen, including the contained in lake's water, to promote lateral buds sprouting. After that, grown lateral buds are cut and hence the pollution is carried away outside the system. However, this method has been little tested in cold regions such as Hokkaido. Thus, on July 2010, we put artificial floating islands in the biotope which was developed on a drained paddy close to the lake. The *Phragmites* grew steadily. There were about four hundreds lateral buds sprouting by October 2010, and the maximum plant length of lateral buds was 0.74 meters. Observed artificial floating islands were left in the biotope during winter. In 2011, the lateral buds sprouted and grew in a shorter period of time compared to 2010. Similarly, maximum plant length of lateral buds was 1.86 meters. Ear emergence was also observed, although it was not observed in 2010. Therefore, it is considered that there was no damage to the *Phragmites* due to the cold. From these results, it was found that the *Phragmites* used for the artificial floating island were able to grow in cold region. Thus, this method is a promising way to improve water quality of Lake Mizusawa.

Keywords water purification, *Phragmites australis* (Cav.) Trin., lake eutrophication, cold region

INTRODUCTION

Biei-cho, Hokkaido, is one of the areas with the most beautiful scenery in Japan. Lake,Mizusawa a representative scenic spot, is known as a stopover for migratory birds and is familiar to people as a precious waterside space. Conservation activities are therefore undertaken in this area to protect the beautiful landscape and local environment.

However, Lake Mizusawa suffers from a significant eutrophication problem arising from the topography and land use of this area. The terrain around this lake is hilly and mostly comprises farm fields. During periods of agricultural production, large amounts of fertilizer are applied to the fields to increase yield. However, following heavy rains, soil and fertilizer flow into the lake. This is the most important cause of lake eutrophication, which negatively affects the ecosystem and landscape around the lake and leads to occurrence of blue-green algae and generation of an unpleasant smell. Therefore, to preserve this beautiful landscape and local environment, it is necessary to improve water quality.

One way to clear up eutrophied lakes is to place artificial floating islands of *Phragmites australis* (Cav.) Trin. on the lake surface. However, this method, which was suggested by Uchida et al. (1999, 2001), Uchida and Maruyama (1998), and Tazaki et al. (2002), has been little tested in cold regions such as Hokkaido. Tsuji et al. (2009) studied the artificial floating islands of *Phragmites* and confirmed sprouting of lateral buds. However, they were unable to fully examine the subsequent growth because most *Phragmites* plants could not adapt to the changing water level and died as a result of dehydration.

In the present study, we observed the growth of *Phragmites* for 2 successive years. In the first year, the artificial floating islands of *Phragmites* were placed in the biotope in July, and the growth of *Phragmites* was examined. The artificial floating islands were left in the biotope during the subsequent winter to examine the winter hardiness of *Phragmites*. In the second year, the growth was examined from July to September. The results were used to assess the possibility of using the artificial floating islands of *Phragmites* for water purification.

METHODOLOGY

Study area

The study area was at Lake Mizusawa (Fig. 1), a man-made lake at latitude 43°32′14″ north and longitude 142°29′41″ east located at Biei-cho in the central part of Hokkaido. The area (approximately 2×10^6 m^2) around this lake comprises hillside farms. Most farms in this area grow potatoes, beet, and corn, which require large amounts of fertilizer. According to Ote et al. (2011), the amount of nitrogen applied on these hillside farms was 1.8×10^3 kg in 2010. Because the rate of nitrogen runoff from farms was 11%, the nitrogen loading into Lake Mizusawa was estimated to be 2×10^3 kg (Ote et al., 2011).

The biotope on which the artificial floating islands were placed adjoined Lake Mizusawa. This biotope was developed on a drained paddy.

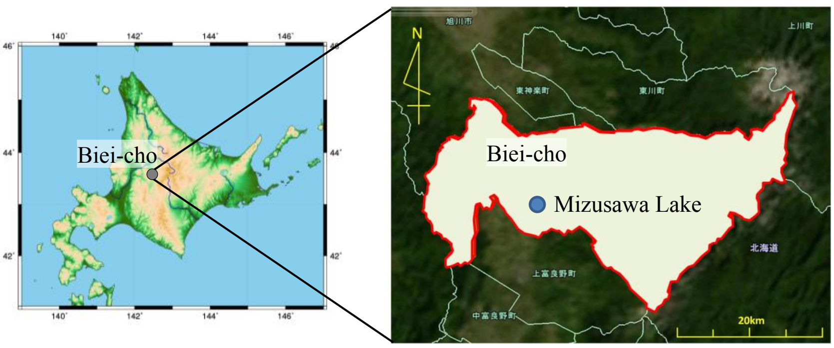

Fig. 1 Study area in Lake Mizusawa located at Biei-cho, Hokkaido

Construction of artificial floating islands

Figure 2 shows the drain mat (Yoshiharakakou Co., Ltd.) used to form the artificial floating islands of *Phragmites*. The mat measured 0.50 m × 0.50 m × 0.02 m (length × width × height). The completed island comprised a drain mat and stems of *Phragmites* plants that were growing wild around Lake Mizusawa. As shown in Fig. 2, 5 stems cut to about 0.50 m were inserted into holes in the mat. Twenty-one artificial floating islands were constructed in this way and they were wired each other (Fig. 3). As shown in Fig. 3, the mats were arranged in two rows and were placed in the biotope.

Fig. 2 Drain mat used to make artificial floating islands for water purification

Fig. 3 Artificial floating islands wired each other and placed on biotope surface

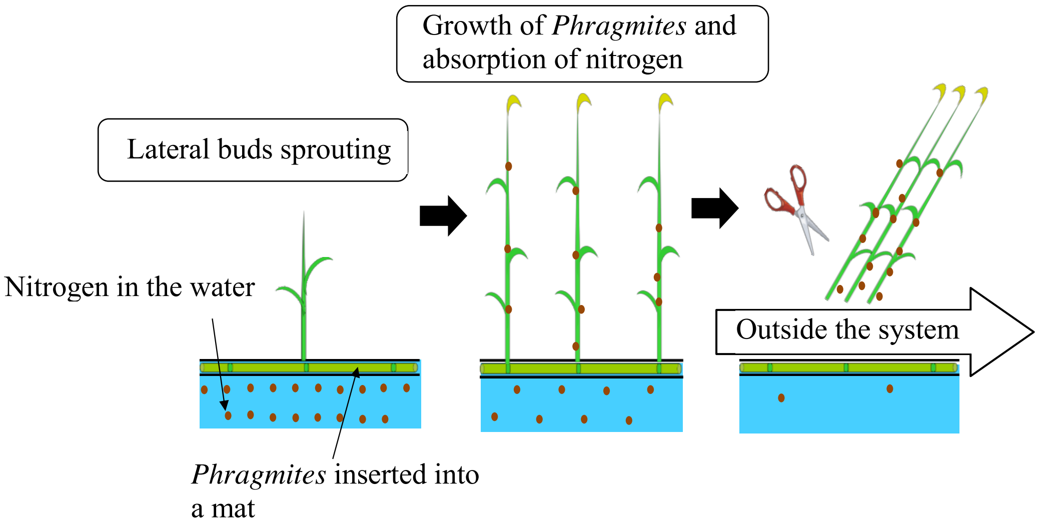

Fig. 4 Outline of the water purification scheme using artificial floating islands of Phragmites

Figure 4 shows the outline of the water purification scheme using the artificial floating islands of *Phragmites*. The scheme comprises the following 3 steps: First, the artificial floating islands are placed on the surface of eutrophied water, and lateral buds sprouting from nods of *Phragmites* plants are inserted into the drain mat. Second, after lateral buds have sprouted, they grow and absorb large amounts of nitrogen, including nitrogen from the eutrophied water. This is an important step in water purification using *Phragmites*. Finally, in autumn, *Phragmites* plants, which accumulate nitrogen, are cut and transported outside the system. The artificial floating islands are left in place during winter and reused next year.

Growth of *Phragmites*

The stem length and sprouting rate of the plants were recorded every 2 weeks in 2010 and 2011. The sprouting rate is the ratio of the total number of sprouts to the total number of nods. Because more than 2 lateral buds sprout from a nod, the sprouting rate generally exceeds 100%.

In 2010, growth was assessed from July 4 to October 31. After the last assessment in 2010, the artificial floating islands were left in the biotope to evaluate their winter hardiness. The growth of the overwintered *Phragmites* plants was assessed between July 7 and September 21 in 2011. In addition, to check the growth of rhizomes, the mats that were fixed to the ground surface in the biotope were dug up on October 21, 2011.

RESULTS

Growth of *Phragmites* in 2010

Figure 5 shows changes in the sprouting rate and maximum and average stem length during 2010. The artificial floating islands were placed in the biotope on July 4. After 2 weeks, sprouting of lateral buds was observed. At this time, the sprouting rate and maximum stem length were 4% and 0.15 m, respectively. From late July to mid-September, both the sprouting rate and maximum stem length increased steadily with increasing air temperature. However, the maximum stem length stopped increasing on September 8. In contrast, the sprouting rate increased moderately after that date because lateral buds continued sprouting. On October 31, 419 lateral buds sprouted and the sprouting rate was 153%.The maximum stem length was 0.74 m. After examination in 2010, the artificial floating islands were left in the biotope during winter to examine the winter hardiness of *Phragmites*.

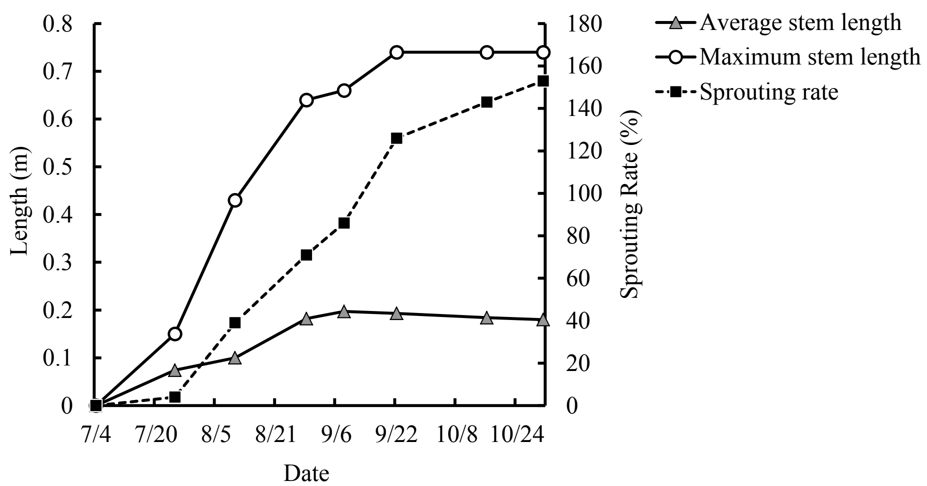

Fig. 5 Seasonal changes in sprouting rate and average and maximum stem length in 2010

Growth of *Phragmites* in 2011

The growth of *Phragmites* plants that had overwintered on the floating artificial islands was assessed in 2011. Figure 6 shows changes in the sprouting rate and maximum and average stem length. As shown in Fig. 6, the overwintered plants grew more steadily in 2011 than in 2010. When the first evaluation was made on July 7, 2011, the sprouting rate was already 578% and the maximum stem length was 1.35 m. However, although the sprouting rate increased steadily until late September, the maximum stem length showed little increase after August. In contrast, ear emergence was observed in 2011, although it was not observed in 2010. Figure 7 shows a *Phragmites* rhizome photographed during growth examination on October 21. This figure shows that *Phragmites* took root in the biotope.

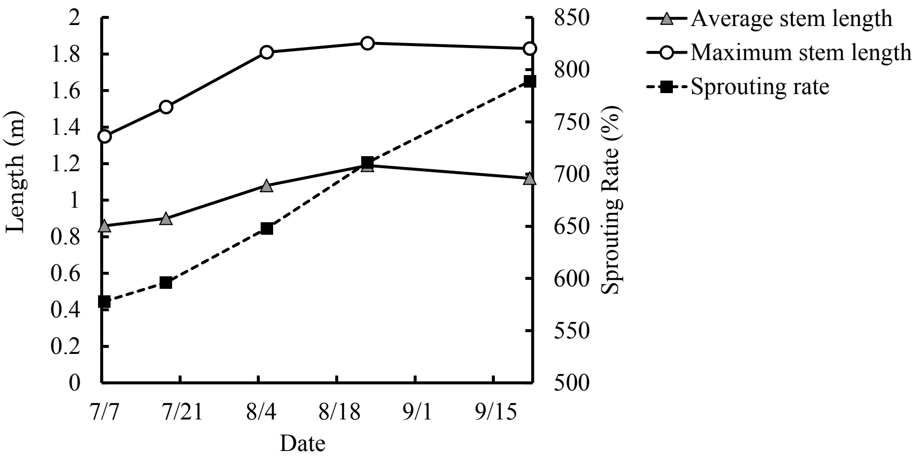

Fig. 6 Seasonal changes in the sprouting rate and average and maximum stem length in 2011

Fig. 7 *Phragmites* rhizome on October 21, 2011

DISCUSSION

On October 31, 2010, the sprouting rate and maximum stem length were 153% and 0.74 m, respectively (Fig. 5). In summer, both these values increased rapidly with increasing air temperature, indicating that *Phragmites* plants used to form the artificial floating islands were able to grow in the warm season in a cold region such as Hokkaido. However, the artificial floating islands were left in the biotope during the subsequent winter to evaluate the growth of *Phragmites* plants that had overwintered.

The *Phragmites* plants on the artificial floating islands grew more steadily in 2011 than in 2010, and on September 21, 2011, the sprouting rate and maximum stem length were 788% and 1.89 m, respectively (Fig. 6). Two factors were considered to cause the difference in growth increment: first, the *Phragmites* plants were not damaged by cold and second, the plants could absorb nutrient salts more effectively because their rhizomes had grown steadily (Fig. 7).

These results show that *Phragmites* used in the artificial floating islands for water purification can grow for multiple years without difficulty. Thus, this method could be put to practical use for water purification of the eutrophied Lake Mizusawa.

CONCLUSION

The use of the artificial floating islands of *Phragmites* was suggested to improve water quality of the eutrophied Lake Mizusawa. However, because this method has been little tested in cold regions, we placed the artificial floating islands in the biotope near Lake Mizusawa and examined the growth of *Phragmites* plants on these islands in 2010 and 2011. The plants grew steadily both in 2010 and 2011. From the results obtained in 2011, we observed that the *Phragmites* plants were not damaged by cold during the preceding winter. These results indicate that *Phragmites* plants on the artificial floating islands can grow in cold regions. Thus, it could be possible to improve water quality by use of the artificial floating islands of *Phragmites*.

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