Research article

Verification of Drainage with Biotope Placed on Artificial Floating Island Using *Phragmites australis* (Cav.) Trin. for Water Purification

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Abstract Soil and fertilizer runoff from farms causes water pollution and eutrophication of streams and lakes. A method for cleaning the polluted water is the placement of artificial floating islands of *Phragmites* on the water surface. *Phragmites* plants absorb nitrogen dissolved in water, promoting lateral bud sprouting. The grown lateral buds are then cut, removing the pollutants. This purification method is suitable for cold regions such as Hokkaido. We devised a drainage system with a biotope to apply this purification method with a minimum of effort. The advantage of the method is that because the artificial floating islands of *Phragmites* after sprouting are placed in the drainage and streams, no *Phragmites* nursery is required. In this study, to determine the effectiveness of this method, *Phragmites* plants after sprouting or in the 3rd year of growth were placed in a stream in Biei Town, Hokkaido and were observed every 2 weeks. In the 3rd-year *Phragmites* plants, terrestrial stems were lying on the ground after a month, but new lateral buds grew from the culms of fallen stems and underground stems. Thus, if *Phragmites* grown to a certain stage could be used, this method is a promising approach to improve water quality. In contrast, in *Phragmites* plants after sprouting, the number of terrestrial stems continued to decrease during the observation period because no underground stems were established by running water and accreted sand. The method should therefore be investigated in other locations, such as wide river channels and stable streams.

Keywords *Phragmites australis* (Cav.) Trin., water purification, drainage system with a biotope, stream

INTRODUCTION

Hokkaido is located in the northernmost part of Japan and covers the largest area in the country. Land-extensive farming is practiced in this area. This area plays an important role as a food supply area for Japan. However, because large amounts of fertilizer are applied to fields to increase yield, soil and fertilizer run off into streams, lakes, and marshes after heavy rains. This runoff is the most

important cause of water contamination and eutrophication. Given that pollutant loads from farm fields have recently been increasing, it is desirable to investigate methods and strategies for improving and maintaining the water quality of streams, lakes, and marshes.

One method to clean eutrophic water is to place the artificial floating islands of *Phragmites australis* (Cav.) Trin. on the water surface (Uchida et al., 1999, 2001; Uchida and Maruyama, 1998; Tazaki, 2002). This method comprises three steps. First, the artificial floating islands are placed on the surface of a eutrophic water body, and lateral buds sprouting from nods of *Phragmites* plants are inserted into a drain mat. Second, after the lateral buds have sprouted, they grow and absorb large amounts of nitrogen, including nitrogen from the eutrophic water. Finally, in autumn, *Phragmites* plants that have accumulated nitrogen are cut and removed from the system. The artificial floating islands are left in place during the winter and reused in the following year. To investigate the suitability of this method in cold regions such as Hokkaido, Tsuji et al. (2009) and Kimura et al. (2012) placed the artificial floating islands on a biotope developed adjacent to Lake Mizusawa in Hokkaido and observed the growth of *Phragmites*. The result was that the plants grew steadily and were not damaged by cold during the following winter. Thus, water quality in cold regions could be improved by this method.

In this study, to assess a drainage system with a biotope using the artificial floating islands of *Phragmites*, we placed two *Phragmites* at different growth stages in a stream flowing into Lake Mizusawa, Hokkaido and observed their growth. The two kinds of *Phragmites* are following: one is the *Phragmites* in the 1st year after sprouting, another is the *Phragmites* in the 3rd year which the rhizome fully grew in the site for breeding of *Phragmites*. If the 1st-year *Phragmites* grew successfully, water quality improvement employing the drainage system with a biotope using the artificial floating islands of *Phragmites* would be more efficient, given that a *Phragmites* nursery would not be required.

METHODOLOGY

Study Area

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

The study area was in one of the three streams flowing into Lake Mizusawa (Fig. 1), a manmade lake at latitude 43 ° 32 ′ 14 ″N and longitude 142 ° 29 ′ 41 ″ E located in Biei-cho in central Hokkaido. The terrain around these streams and lake is hilly and comprises mostly farm fields (293.8×10^{-2} km^2) for wheat, corn and so on. During the growing season, large amounts of fertilizer are applied to the fields to increase yield. According to Ote et al. (2011), the amount of nitrogen applied to these hillside farms was 1.8×10^3 kg in 2010. However, following heavy rains, soil and fertilizer flowed into the streams and lake from the water catchment area. In 2010, the rate of nitrogen runoff from farms was 11% (Ote et al., 2011). Thus, the nitrogen loading of the three streams and Lake Mizusawa was estimated to be 2.0×10^3 kg. This is the most important cause of eutrophication of the streams and lake and leads to the occurrence of blue-green algae and

unpleasant smells. To preserve the local environment, it is desirable to improve water quality.

Growth of *Phragmites*

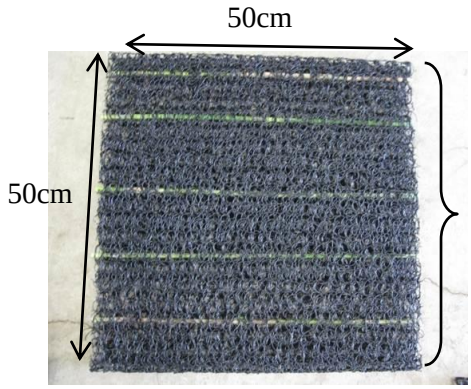

Fig. 2 Drain mat used to make artificial floating islands for water purification

As shown in Fig. 2, the artificial floating island of *Phragmites* comprises a drain mat (Yoshiharakakou Co., Ltd.) and five stems of *Phragmites*. First, the mats are placed on the water surface until sprouting from the stems occurs. The mats are then transferred to the nursery and left there until the rhizome grows to maturity.

Fig. 3 Aerial parts and rhizomes of 1st-year *Phragmites*

Fig. 4 Aerial parts and rhizomes of 3rd-year *Phragmites*

Figures 3 and 4 show the artificial floating islands of 1st- and 3rd-year *Phragmites*, respectively. The 1st-year *Phragmites* was placed on the water surface of Lake Mizusawa on July 5, 2012 and then sprouted. The 3rd-year *Phragmites* was transferred to the nursery on September 25, 2010. These *Phragmites* overwintered and the rhizomes grew as shown in Fig. 3.

These two types of the artificial floating island of *Phragmites* were transferred to the stream shown in Fig. 1 on August 24, 2012. Figure 5 shows the arrangement of the artificial floating

islands of *Phragmites*. As shown in this figure, the artificial floating islands of 1st- and 3rd-year *Phragmites* were placed alternately in the stream at 1-m intervals from upstream to downstream. Moreover, each one was placed on the stream at 0.3 m intervals from water route and sandbank. All the artificial floating islands of *Phragmites* were rooted to the bottom of the stream by anchor pins. The number of stems was recorded every 2 weeks.

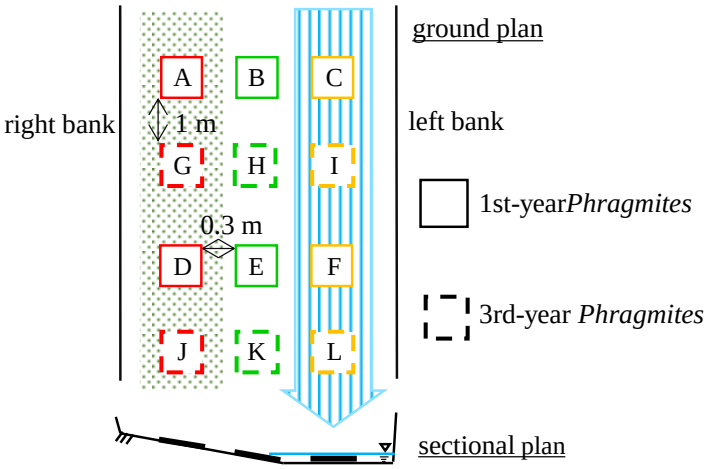

Fig. 5 Arrangement of artificial floating islands of 1st- and 3rd-year *Phragmites* in a stream

RESULTS

Figures 6 and 7 show changes in the number of stems of 3rd- and 1st-year *Phragmites*, respectively. Each line in the two plots represents the total number of stems of the artificial floating islands of *Phragmites* that lay in the same column, namely "A" and "D," "B" and "E," "G" and "J," or "H" and "K." However, because the artificial floating island of *Phragmites*, "F" and "L" were flown to downstream, the line, "C" or "I" represents the number of stem of the artificial floating island of *Phragmites*, respectively.

As shown in Fig. 8, in most 3rd-year *Phragmites*, the aerial part fell over and was partly covered with sand on September 5, 2012. However, the number of stems increased steadily in all positions, especially from September 5 to September 28, as shown in Fig. 6. The number of stems in "A" and "D," "B" and "E," and "C" was 104, 105, and 64, respectively, on September 28. The reason for the increase in the number of stems was the extension of lateral buds from stems that fell over and the appearance of sprouts from the rhizomes, as shown in Fig. 8. After September 28, because the air temperature dropped, the increase in the number of stems ceased.

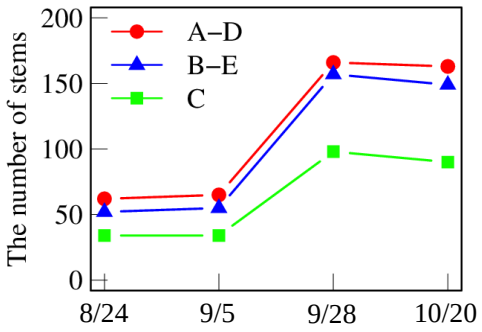

Fig. 6 Change in the number of stems of 3rd-year *Phragmites* placed in a stream

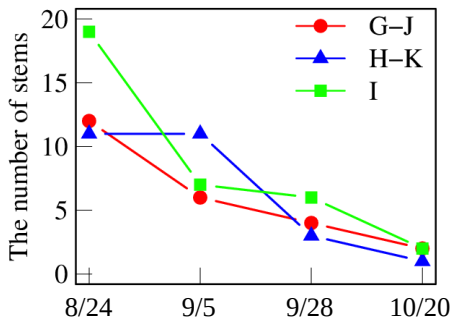

Fig. 7 Change in the number of stems of 1st-year *Phragmites* placed in the stream

In contrast, as shown in Fig. 7, the number of stems of 1st-year *Phragmites* continued to decrease in all positions. Two months after placing in the stream, the number of stems decreased to 10 in "G" and "J," 10 in "H" and "K," and 17 in "I" because of the deposition of sand on *Phragmites*.

Fig. 8 Growth of *Phragmites* in the 1st year, September 28, 2012

DISCUSSION

Growth of 1st- and 3rd-year *Phragmites* showed opposite behavior. The number of stems of 3rd-year *Phragmites* increased steadily (Fig. 6), whereas those of 1st-year *Phragmites* decreased (Fig. 7). We speculate that this difference was associated with rooting of the rhizome.

The aerial parts of 3rd-year *Phragmites* fell over in 2 weeks after placement in the stream, and sediment deposits were observed. However, because the rhizomes had matured in the nursery (Fig. 4), they rooted readily in the stream bed after transplanting. Therefore, the lateral buds and sprouts could be stretched and appeared because of capable of absorbing nourishment from the rhizome (Fig. 8).This result suggests that if artificial floating islands of 3rd-year *Phragmites* are used, the drainage system with a biotope can be used practically. However, because in this case a breeding nursery of *Phragmites* will be required, land must be reclaimed.

As shown in Fig. 3, rhizomes did not grow to maturity. We infer accordingly that they could not root in the stream bottom. In addition, sediment deposition was observed. From this result, we infer that *Phragmites* does not readily grow in streams with irregular flow such as the stream studied here. However, given an environment in which the rhizome can grow to maturity, we suggest that 1st-year *Phragmites* can grow steadily in a stream. In future, for practical application of a drainage system with a biotope, we plan to determine the locations to which 1st-year *Phragmites* can adapt and observe *Phragmites* growth again.

CONCLUSION

The drainage system with a biotope using the artificial floating islands of *Phragmites* was suggested to improve the water quality of Lake Mizusawa, Biei-cho, which has been made eutrophic by an influx of soil and fertilizer from surrounding farm fields. To investigate the practicality of this method, 1st- and 3rd-year *Phragmites* were placed in a stream flowing into Lake Mizusawa and their growth was recorded at 2-week intervals. The 3rd-year *Phragmites* grew steadily because nutrients could be absorbed via rhizomes rooted in the stream bed. Thus, if the artificial floating islands of 3rd-year *Phragmites* are used, a drainage system with a biotope can be used practically. In contrast, the number of stems of 1st-year *Phragmites* decreased because their rhizomes did not mature and nutrients required for growth could not be absorbed. However, in an environment where rhizomes can mature, we suggest that 1st-year *Phragmites* may also be used in a drainage system with a biotope. It is necessary to investigate the growth of 1st-year *Phragmites* transplanted to floating islands.

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