Ecological Regime Shift in the South Basin of Lake Biwa: Focus on Algal Blooms and Submerged Macrophyte Overgrowth

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Abstract. Eutrophication of Lake Biwa has not increased since the 1980s. Long-term trends of TN and TP have been decreasing while transparency has been increasing since 1995. Submerged macrophyte growth expanded rapidly after 1994, especially in the South Basin, and long-term chlorophyll a concentration has been decreasing. This suggests that a so-called "ecological regime shift" is occurring. In this report, we examine long-term changes in submerged macrophytes in the South Basin, presenting monitoring results of current prolific growths obtained by echo sounder, and results from macrophyte sampling, obtained by diving, to investigate species compositions as well as biomass. This data has contributed to macrophyte and ecosystem management in the lake.

Key Words: submerged macrophytes, biological monitoring, water quality, ecological management

1. INTRODUCTION

Lake Biwa (area 670 km^2, max depth 103 m) is the biggest lake in Japan. The lake is separated into two parts, a large and deep North Basin and a small and shallow South Basin. The average depth of each is 43 m and 4 m respectively, and the ratio of the two basins in area is 11:1. The city area is located in the southern part and the main water outflow is the Seta River in the south; therefore the North Basin is mesotrophic and the South Basin is eutrophic. The lake provides drinking water to 14.5 million people in the Kansai area. Lake Biwa Environmental Research Institute, the Kinki Regional Development Bureau and the Japan Water Agency have been monitoring surface water quality every month at 28 stations in North Basin and at 19 stations in South Basin since 1978. Eutrophication occurred between the 1960s and1980, but has not increased since the 1980s. Long-term trends of TN and TP have been decreasing and that of transparency has been increasing since 1995 (Shiga prefecture 2014).

At the same time, submerged macrophyte volume expanded rapidly after 1994 and long-term chlorophyll a concentration has been decreasing, which suggests a so called "ecological regime shift" is occurring. It is well known that switches occur between clear-water state with macrophyte dominance and turbid-water state with phytoplankton dominance (Jeppesen et al. 1998; Scheffer et al. 2001). However, the reason the lake ecosystem changed from a phytoplankton dominant state to a macrophyte dominant state has not yet been clarified. After consideration by an organizing committee, it was concluded that the worst drawdown in 1994 (-123cm BSL) might be a trigger of the regime shift (Shiga prefecture 2009, Haga 2012). Lake Biwa Museum started periodic macrophyte monitoring in 2002 and the Lake Biwa Environmental Research Institute joined the work in 2007.

In this report, we discuss submerged macrophyte changes in the lake and our work to control them with adaptive management methods based on biomass monitoring results and macrophyte height monitoring results.

2. METHODS

To determine the biomass and species composition of submerged macrophytes, we collected samples from a 50 x 50 cm lake bottom area, by diving at 52 stations in the South Basin. The macrophyte samples were divided into species, and their weight was measured after being dried at 60°C.

The height of submerged macrophytes was measured by an echo sounder fixed on the bottom of the R/V Umindo. The research boat navigated between the west and east coasts of the South Basin every 500 m from North to South.

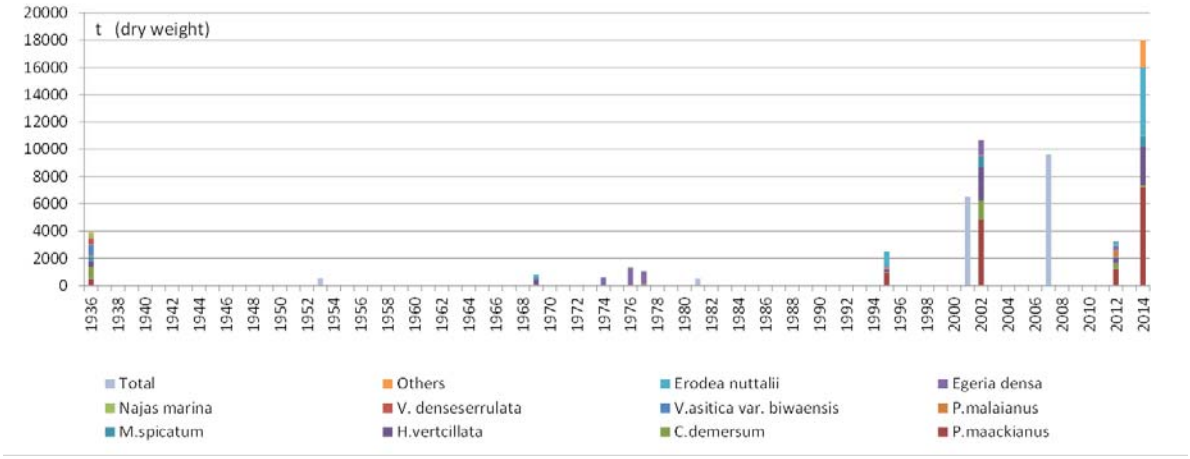

Figure 1: Long term fluctuation of submerged macrophytes in the South Basin of Lake Biwa

Figure 2: Ecological regime shift in the South Basin of Lake Biwa
(a) Cyanobacterial blooms in summer1994 (Photo by Etsuji Hamabata)
(b) Clear water with submerged macrophytes in summer 2014 (Photo by Kanako Ishikawa)

3. Results and Discussion

Biomass changes in submerged macrophytes

Long-term fluctuation of submerged macrophytes is shown in Figure 1. The oldest record on biomass in the South Basin is only for the southern part of the basin in 1936 (Yamaguchi 1938). Haga et al. (2012) estimated the total biomass (dry weight) based on several sources. Long-term fluctuation can be classified into three main periods: 1936-1958, 1963-1994 and 1994-present. During the first period (1936-1958), the biomass of submerged macrophytes was approximately 4000 t (dry weight) from the data in 1936, and submerged macrophytes occupied nearly half of the surface area of the south basin (Yamaguchi 1938). Before eutrophication, the lake ecosystem was in a healthy condition without any serious environmental problems. For this reason, the biomass and species compositions of submerged macrophytes in the first period were adopted as our long-term goals for restoration. During the second period (1963-1994), they decreased dramatically (Figure 2-a). During the third period (1994-present), they recovered with water clearing (Figure 2-b), and the present prolific growth, exceeding 10000 t (dry weight), has caused negative impacts such as oxygen depletion at the lake bottom and/or lentic algal blooms, as well as having detrimental effects on fisheries, navigation, and the landscape value of the lake.

There was an exception: the biomass in 2012 decreased to 30% or that of 2007 (Figure 1) because of phytoplankton blooms coming from the North Basin in spring and following cyanobacterial blooms in the South

Basin during summer. However, the biomass recorded the maximum value in 2014, which suggests that the phase of submerged macrophytes is stable.

In addition to biomass fluctuations, Hamabata and Yabu'uchi (2012) pointed out that dominant species of submerged macrophytes changed from the small *Vllisneria asiatica* var. *biwaensis* to the large-sized *Hydrilla verticillata, Potamogeton maackianus* and *Elodea* during eutrophication of water quality in the1960s to early 1970s.

Horizontal Distributions of Submerged Macrophyte

To determine the distribution and approximate biomass of submerged macrophytes, an echo sounder is a useful tool that provides the height of submerged macrophytes. Seasonal changes of horizontal distribution are shown in Figure 3.

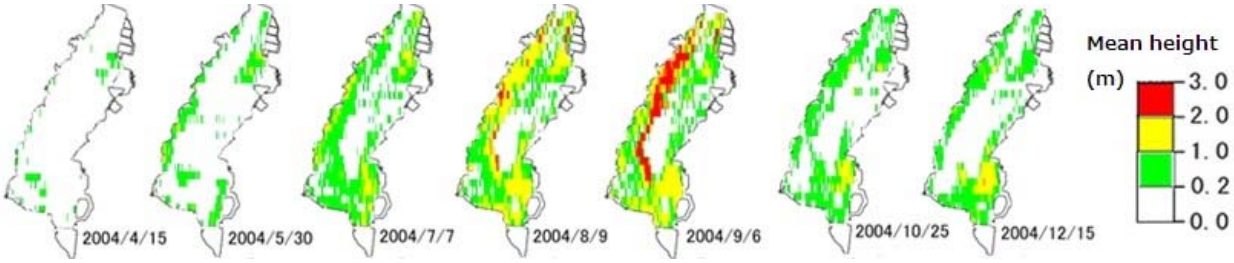

Figure 3 Seasonal changes in submerged macrophyte height in 2004 (arranged from Haga 2008)

Submerged macrophytes in the South Basin grew rapidly in June, reached a maximum height on average in September and decreased in October. Since the highest area and distribution are not the same each year, frequent monitoring is required.

4. CONCLUSION

Submerged macrophytes are one of the important constituents of a shallow lake ecosystem. However, excessive macrophyte propagation is likely to occur during the period that the lake is recovering from eutrophication. Without biological monitoring and water quality monitoring, we cannot develop effective management methods and future initiatives to meet our goals for ecosystem restoration.

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