WATER QUALITY CHARACTERISTICS IN THE PLANKTOTHRIX DOMINANT YEARS IN SHALLOW LAKE KASUMIGAURA

Takao Ouchi[1*], Hisao Kobinata[1, 2], Koichi Kamiya[1], Keita Nakagawa[1], Kazuhisa Sugaya[1], and Morihiro Aizaki[1]
[1] Ibaraki Kasumigaura Environmental Science Center, Japan
[2] Fisheries Administration Division, Department of Agriculture, Forestry, and Fisheries, Ibaraki Prefectural Government, Japan

*Corresponding author: ta_oouchi@pref.ibaraki.lg.jp

ABSTRACT

Cyanobacterial blooms in lakes cause serious problems in the world. In Lake Kasumigaura, a eutrophic lake located in Japan, the bloom of Planktothrix (one of the filamentous cyanobacterium) occurred during winter and spring from 2007 to 2011. In this study, we analyzed characteristics of lake water quality during the Planktothrix dominant years (2007-2010) by comparing with that in the succeeding years without Planktothrix blooms (2012-2015) at the center of Lake Kasumigaura. Average phytoplankton biovolume in the dominant years was larger than that in the succeeding years. This would attribute to high chemical oxygen demand (COD_{Mn}; 9.7 mg/L in annual average) in the dominant years as compared to the succeeding years (7.6 mg/L). Total phosphorus (TP) concentration peaked in spring and summer in the dominant years but only in summer in the succeeding years, whereas the seasonal variation in total nitrogen (TN) concentration between two periods was relatively small. Annual average of Secchi disk depth increased before the dominant years by the decrease of fixed suspended solids (FSS) concentration which is mainly composed of inorganic materials. The change of irradiance condition seems to affect in occurrence of the Planktothrix blooms.
Keywords: filamentous cyanobacteria, Lake Kasumigaura, Planktothrix suspensa, shallow

INTRODUCTION

Occurrence of cyanobacterial blooms have recognized in many lakes and reservoirs around the world and caused serious problems such as toxic production. The most common blooms in eutrophic lakes, mainly formed by Microcystis, Anabaena and Aphanizomenon, occur in the epilimnion. Most of cyanobacteria have gas vesicles enabling cells to regulate their buoyancy to maintain vertical position in response to physical and chemical factors (Reynolds, 2006). On the other hand, the bloom of Planktothrix, one of a filamentous cyanobacterium, appears in the dysphotic zone and does not accumulate in the epilimnion. In the lake of European countries, Planktothrix bloom is typically encountered (e.g. Lake Steinsfjorden in Norway, Halstvedt et al., 2007). The bloom was also known in North American lakes (Konopka et al., 1993). Some Planktothrix species produce toxic and musty odor compounds, causing serious problems in lakes as a drinking water source. The Planktothrix bloom has occurred in many lakes in the world.

In Lake Kasumigaura, located in the eastern part of Japan, the Planktothrix blooms have occurred during 1992 to 1999 and 2007 to 2010 after heavy bloom of Microcystis (Takamura & Nakagawa, 2012). After the latter bloom, Microcystis blooms occurred again. In this study, we focus on the lake water quality during the Planktothrix bloom period (2007-2010) to understand the reason and results of occurrence of Planktothrix bloom. We analyzed the characteristics of the lake water quality during the bloom period by comparing with that in the succeeding period without Planktothrix blooms (2012-2015).

METHODS

Study area

Lake Kasumigaura (Fig. 1), located in Ibaraki Prefecture in the eastern part of Japan, about 50 km northeast of Tokyo, is the second largest lake in Japan (219.9 km^2 as the total lake area). This lake is relatively shallow (4 m as the average depth), polymictic and eutrophic lake. The watershed area is 2,157 km^2. 975,000 people live in the watershed. The dominant landscapes in the lake watershed are paddy fields (~31,400 ha), ploughed fields (~31,400 ha), forests and the others (~83,000 ha) in 2010. The lake water is used as drinking, industrial, and agricultural water. Drinking water is supplied to about one million people. And the irrigation area is about 35,000 ha.

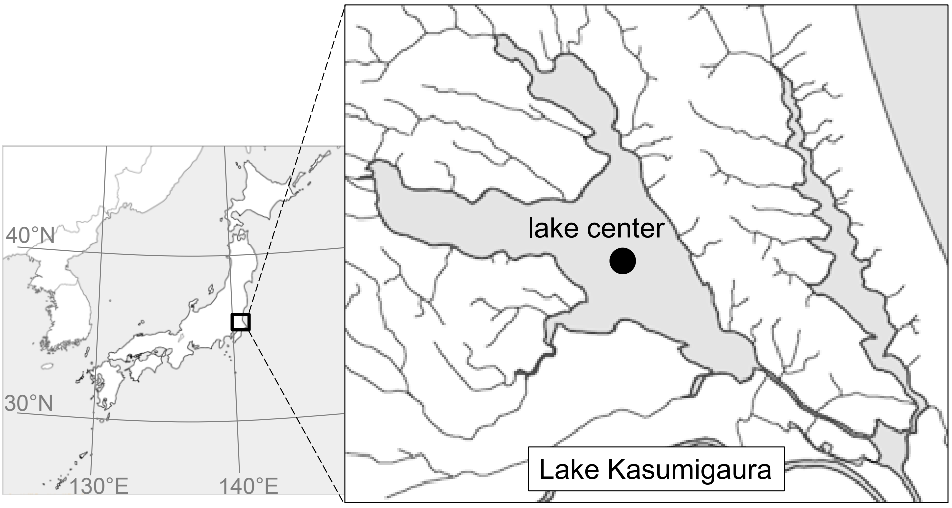

Figure 1. Location of Lake Kasumigaura and the sampling point.

Sampling and chemical analysis

The survey was carried out from January 2007 to December 2015. Lake water samples were collected from the surface layer (0.5 m below the water surface) at the lake center (shown in Fig. 1) by a peristaltic pump. Samples for phytoplankton biovolume measurement were fixed by glutaraldehyde fixative immediately after the collecting.

Chemical oxgen demand (COD_{Mn}) was analyzed according to the standard method (Japanese Industrial Standards Committee, 2016). Concentrations of total nitrogen (TN) and total phosphorus (TP) were measured by the continuous flow analysis (CFA) method using an autoanalyzer (BRAN+LUEBBE AutoAnalyzer3). The data of Secchi disk depth (SD) and suspended solids (SS) concentration taken by Freshwater Branch Office, Fishery Research Institute, Ibaraki Prefecture were used. The SS concentration was separated as volatile SS (VSS) which is mainly composed of organic materials and fixed SS (FSS) which is mainly composed of inorganic materials by heating to 450 °C for 2 hours.

RESULTS AND DISCUSSIONS

Temporal variation of phytoplankton biovolumes

Figure 2 shows temporal variation of phytoplankton biovolumes at the lake center since 2007. Planktothrix blooms have occurred during 2007 and 2010. We divided the study period into the two periods for analysis of water quality characteristics in Planktothrix dominant period. The Planktothrix dominant period, 2007 to 2010, is defined as “dominant years”. The period after dominant years, 2012 to 2015, is defined as “succeeding years”. In the dominant years, Planktothrix bloom occurred during winter and spring. In the succeeding years, bacillariophyceae had dominated in the lake center area, and heavy Microcystis blooms also occurred in bay areas. According to Takamura and Nakagawa (2012), bacillariophyceae (e.g. Aulacoseira, Nitzschia) had dominated for about 5 years before 2007.

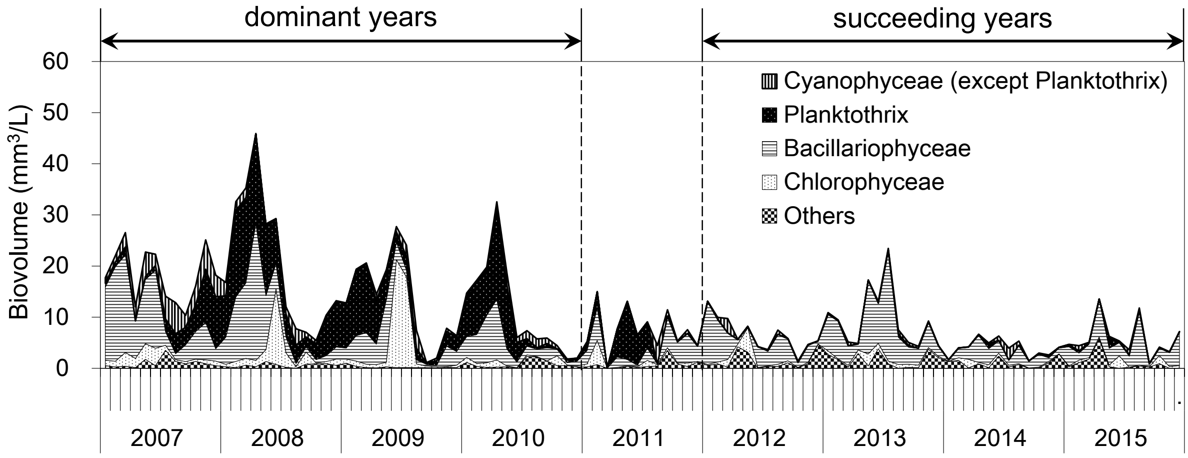

Figure 2. Temporal variation of phytoplankton biovolumes at the lake center.

Changes in COD_{Mn}, TN and TP concentrations

Figure 3 shows monthly mean values of COD_{Mn} and phytoplankton biovolumes in each period. COD_{Mn} was high in the dominant years (annual average of 9.7 mg/L, whereas annual average of 7.6 mg/L in the succeeding years at lake center). Especially, high COD_{Mn} was observed during winter and spring in the dominant years. The phytoplankton biovolumes during winter and spring in the dominant years were also larger than that in the succeeding years due to the occurrence of Planktothrix bloom. Thus high COD_{Mn} in the dominant years would be largely explained by large biovolumes of phytoplankton, especially Planktothrix.

The seasonal variation in TN concentration between the two periods was relatively small (Fig. 4(a)). Average TN concentrations of each period were 0.94 mg/L. On the other hand, the seasonal variation in TP concentration was different between two periods (Fig. 4(b)). Average TP concentrations in the dominant and succeeding years were 0.091 and 0.074 mg/L, respectively. Two peaks of TP concentration were observed in dominant years, but only one peak in summer was observed in the succeeding years. The peak in

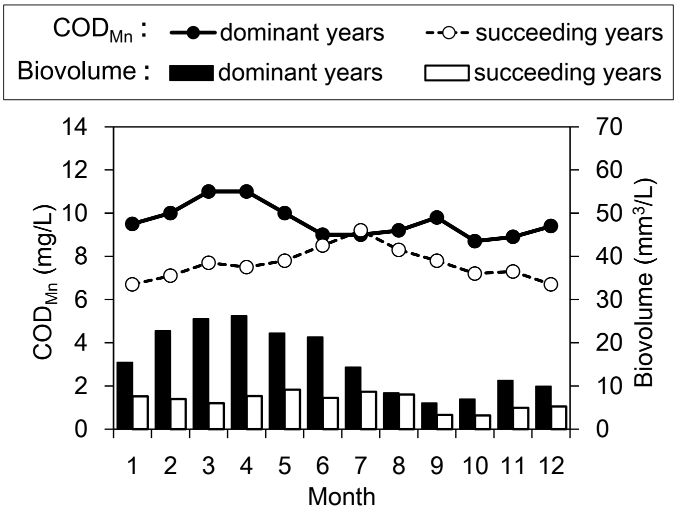

Figure 3. Monthly mean values of COD_{Mn} and phytoplankton biovolumes in the Planktothrix domonant years (2007-2010) and succeeding years (2012-2015).

summer of both periods would be due to the phosphate release from the bottom sediment (Ishii et al., 2009). However, TP concentration during winter and spring was higher in the dominant years than the succeeding years. Occurrence of Planktothrix bloom would have a relationship with the high TP concentration, although the mechanism of this interaction has not been clearly resolved.

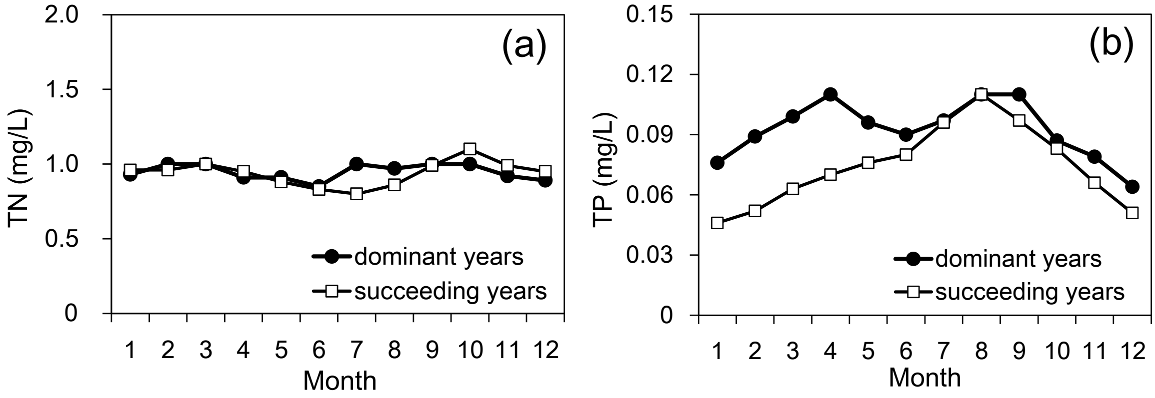

Figure 4. Monthly mean concentrations of (a) TN and (b) TP during the Planktothrix domonant years (2007-2010) and succeeding years (2012-2015).

Changes in SD and SS concentration

Figure 5(a) shows the change in annual average of SD from 2004 to 2013. Since the difference of SD would be related to the reasons and results of the occurrence of Planktothrix bloom, we indicated as annual average before and after the dominant years in Fig. 5(a). The SD increased before and after the dominant years, and the SD was maintained about 0.8 m in the dominant years. Figure 5(b) shows the change in annual average concentration of SS. The SS concentration indicated roughly inverse correlation with SD. SS concentration was about 20 mg/L throughout in the dominant years.

Figure 6 shows the concentrations of VSS and FSS. They also changed before and after dominant years. FSS which is mainly composed of inorganic materials decreased before the dominant years. The decrease of inorganic materials seems to relate to occurrence of Planktothrix blooms. From 1998 to about 2005, the lake water had white turbidity in Lake Kasumigaura, called “whiting period” (Naya & Kitamura, 2006,

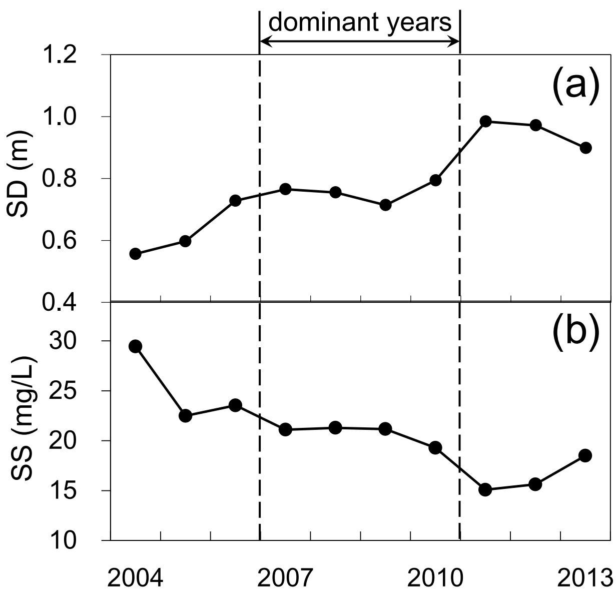

Figure 5. Changes in annual average of (a) SD, (b) SS.

Utagawa & Takamura, 2007). According to Takamura and Nakagawa (2012), bacillariophyceae had dominated in this period. Nakamura et al. (2012) demonstrated Planktothrix can be dominant at low light intensity condition “dysphotic zone” in Lake Kasumigaura. The increase of SD caused by the decrease of FSS concentration before dominant years would expand dysphotic zone, and it would bring Planktothrix bloom. On the other hand, the VSS concentration decreased after the dominant years. This result indicated the decrease of organic materials such as Planktothrix. At this time, Daphnia, one of a zooplankton, increased significantly, and Planktothrix may be taken by Daphnia.

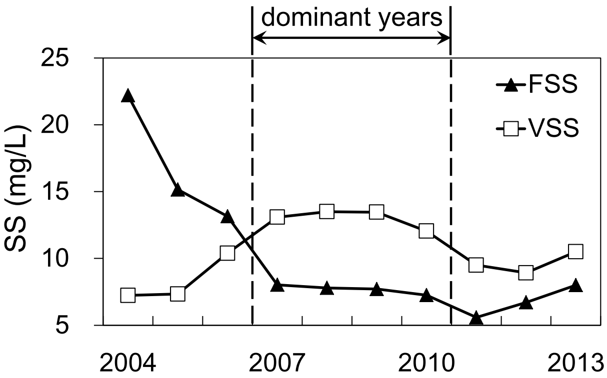

Figure 6. Changes in annual average concentrations of FSS and VSS.

CONCLUSIONS

We analyzed characteristics of water quality in Lake Kasumigaura during the Planktothrix dominant years (2007-2010) by comparing with that in the succeeding years (2012-2015). Average phytoplankton biovolume in the dominant years was larger than that in the succeeding years. This would attribute to high COD_{Mn} in the dominant years as compared to the succeeding years. TP concentration peaked in spring and summer in the dominant years but only in summer in the succeeding years, whereas the seasonal variation in TN concentration between two periods was relatively small. Annual average of SD increased before the dominant years by the decrease of FSS which is mainly composed of inorganic materials. The increase of SD caused by the decrease of FSS concentration would expand dysphotic zone, and it would bring the Planktothrix bloom.

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