Cell Size reduction and restoration of seasonally dominant diatoms in Lake Biwa

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Abstract

Introduction

Phytoplankton is the base of aquatic food webs and is significant for climate regulation and biogeochemical cycling. They are the primary producers in aquatic ecosystems, which contributes to nearly 50 % of global net primary production. Diatoms (Bacillariophyta) are the most diverse and ecologically essential phytoplankton groups. Since diatoms are ubiquitously distributed in lakes, their abundance and composition rapidly respond to subtle environmental changes. They have been used as one of the most valuable organisms in biomonitoring studies. Diatoms reproduce sexually or asexually to carry forward their generations. Cell size restitution in diatoms is thus an essential factor, and sexual reproduction is the primary way of restoring the cell size of the population. That is why studying cell size restitution and sexual reproduction is essential to understanding their morphological evolution. Even though sexual reproduction in diatoms is worth exploring, it is an understudied aspect of diatom life cycle dynamics. Studying the life cycle stages of the diatoms concerning various environmental parameters is thus necessary.

Materials and Methods

Firstly, five-year monthly samples were collected, and the cell size and density of *F. crotonensis* were estimated in the north basin of Lake Biwa. Vertical temperature profiles were measured with a CTD profiler, and the total nitrogen, phosphorus, and silicate concentration data were obtained from the literature. The relationships between the cell size of *F. crotonensis* and some environmental factors and between the cell density of the diatom and the factors were examined. Secondly, sampling was conducted to study the cell size changes of the seasonally dominant diatoms *Aulacoseira granulata, Aulacoseira ambigua* f. *japonica, Fragilaria crotonensis, and Praestephanos suzukii*. Both biotic and Abiotic samples were collected from the north basin of Lake Biwa. A total of 24 bi-monthly water samples were collected from June 2020 to June 2021 from the epilimnion (euphotic zone, 5m) and the hypolimnion (50 m). Vertical profiles of water temperature, chlorophyll *a*, and conductivity were measured with a CTD profiler. Water transparency and pH measurements were done onsite. Diatom samples were collected to estimate the dominant species' cell size and density. Water samples from each depth (5m and 50m) were collected and filtered through a plankton net of 20 μm mesh size and preserved by adding acid Lugol's Iodine for further enumeration.

For the two studies, Convergent Cross Mapping (CCM), time series decomposition analysis, correlation matrices, and Redundancy Analysis (RDA) analysis were used to understand the relationship between cell density and cell size of the seasonally dominant diatoms and various environmental factors.

Results

The cell density of *F. crotonensis* generally increased from March or April, resulting in a spring bloom. Another bloom was observed in September or October. *F. crotonensis* colony undergoes cell size reduction and restoration attributable to sexual reproduction. Using CCM, we found that water temperature may influence the cell density (vegetative reproduction) of *F. crotonensi*s, though we could not identify any possible causal variables for algal sexual reproduction. In addition, time series decomposition analysis, together with the seasonal changes in cell size mentioned above, proved that the diatom followed a reduction in cell size twice a year.

The second study revealed two diatom blooms in a year. The autumn bloom (early October to late November) was primarily dominated by all the dominant diatoms, *A. granulata*, *A. ambigua* f. *japonica*, and *F. crotonensis*. *P. suzukii* dominated the mixing period. *F. crotonensis* underwent cell size reduction and restoration, possibly due to sexual reproduction twice a year. By contrast, the others appeared once. The cell size of the diatoms decreased gradually with the increase in cell abundance, indicating that the population underwent vegetative reproduction followed by sexual reproduction. Correlation matrices and RDA analysis between cell size changes of diatoms and some environmental parameters, such as water temperature, pH, water transparency, conductivity, chlorophyll *a* concentration, and nutrient concentrations (Dissolved inorganic nitrogen (DIN), phosphate, and silicate), revealed that each diatom species would have distinct favorable environmental conditions for staging its life cycle.

Discussion

Cell size changes of diatoms have never been reported before from the waters of Lake Biwa, making the present study unique and novel. I analyzed annual cell size reduction and restoration, which may be due to vegetative and sexual reproduction with various seasonal environmental factors. In Chapter 2, I wrote the five-year-long observation of the changing pattern of cell size reduction and restoration for F. crotonensis. In Chapter 3, I reported annual cell size changes in four seasonally dominant diatoms (A. granulata, A. ambigua f. japonica, F. crotonensis, and P. suzukii). The frequency of cell size reduction and restoration was the same in A. granulata, A. ambigua f. japonica, and P. suzukii, as they corrected their population cell size once a year, whereas F. crotonensis corrected their size twice. Thus, the present study revealed different frequencies of sexual reproduction in seasonally dominant diatoms. I also demonstrated that various environmental factors influence the seasonal dynamics of diatoms. In Lake Biwa, the cell size changes of diatoms depended mainly on the changing temperature and availability of nutrients. However, many underlying biotic and abiotic factors likely affect the staging of the diatom life cycle events. It indicates that each diatom species would have a favorable environmental condition for bloom and sexual reproduction. This life cycle pattern of these species to reduce and restore their cell size can be a constant seasonal trend persisting in the water column of Lake Biwa, considering the present trophic status of the lake ecosystem.