Fine-scale distributions of phytoplankton in space and time

Doctoral Dissertation

FINE-SCALE DISTRIBUTIONS OF PHYTOPLANKTON IN SPACE AND TIME

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ABSTRACT

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論文題目 Title	Fine-scale distributions of phytoplankton in space and time （微細規模の時空間における植物プランクトンの分布）		

Motivation and Objectives

The phytoplankton distribution pattern can change within a short timescale such as several hours due to the changes in the water mass and hydrodynamic conditions. In addition, because the spatial distributions of phytoplankton and zooplankton can vary within a few meters in depth, to quantify their vertical structure, and to examine the interaction between the two communities, high-frequency and fine-scale samplings for phytoplankton and zooplankton are needed.

In the present study, I conducted a series of pump sampling throughout the vertical water column, at a fine-scale of 0.5-2 m depth interval, with a timescale of hours, dealing with the physicochemical properties of the water column. The objectives of the present study were (1) to clarify the fine-scale spatial and temporal heterogeneity of phytoplankton distribution in species-level; (2) to observe the species-specific or group-specific distributions within the communities during different hours of the study period; (3) to examine the spatial and temporal couplings between phytoplankton and zooplankton communities, and (4) to know the size distribution of phytoplankton.

Methods

Phytoplankton samples were collected at two different stations in Tokyo Bay: one at the outer bay (Tateyama Bay) and another at the inner bay, both with a bottom depth of 23 m. Surface (0 m) to near bottom (20 m) pump samplings were done to observe the fine-scale distributions of phytoplankton. Water samples of 500 mL were collected for phytoplankton analysis. At the same time, zooplankton samples were also taken by filtering 500 L seawater with a 100 μm mesh net. During each time of sampling, surface to bottom CTD observation was done to know the vertical profiles of water temperature, salinity, sigma-*t*, dissolved oxygen concentration (DO), chlorophyll-*a* concentration (Chl-*a*), turbidity, and PAR (photosynthetically active radiation). Phytoplankton samples were analyzed in triplicate with a FlowCAM (Flow Cytometer and Microscope: Fluid Imaging Technologies, USA), and 4 mL

aliquots of zooplankton samples were counted under a light microscope for the abundance.

Results and Discussion

Short-term phytoplankton dynamics were corresponding with the changes in the water mass and hydrodynamic gradients such as stratification and vertical mixing processes. Gradients of temperature and salinity brought density stratifications in the water column, which were likely to be influencing the spatial heterogeneity of phytoplankton distribution. On the other hand, the vertical mixing process homogenized the phytoplankton distribution in the water column. Both diatoms (51%) and dinoflagellates (41%) dominated the phytoplankton community in the outer Tokyo Bay, whereas the inner bay had higher contributions of diatoms, accounting for 77% of the total phytoplankton cell concentration. This result was consistent with the previous finding by Nakane *et al.* (2008), who reported diatoms were the most dominant group (84.4%) in the inner Tokyo Bay. It was suggested that diatoms can grow rapidly in the eutrophic conditions (Tada *et al*., 2009; Guo *et al*., 2014) because Tokyo Bay (especially the inner section) is one of the most eutrophic embayments in Japan (Furukawa, 2015).

Thalassiosira sp., *Dactyliosolen fragilissimus*, *Pseudo-nitzschia* sp., *Prorocentrum minimum*, and *Scrippsiella trochoidea* were noted as the dominant species which altogether contributed more than 80% of the total phytoplankton cell concentration in the outer Tokyo Bay. Amongst, *Thalassiosira* sp. and *P. minimum* were found at all sampling depths and times, whereas *D. fragilissimus* and *S. trochoidea* were not observed in the colder and saltier water mass after high tide. In terms of cell concentration, nine phytoplankton species, including 8 diatoms species such as *Lauderia annulata, Skeletonema* sp., *Thalassiosira* sp. 1 and 2, *Chaetoceros* sp., *Thalassionema frauenfeldii, T. nitzschioides*, *Pseudo-nitzschia* sp., and a Raphidophycean flagellates, *Heterosigma akashiwo* dominated the phytoplankton community in the inner Tokyo Bay, and the percentage of their abundance comprised 89.5% of the total phytoplankton cell concentration. Among these species, the cell concentrations of *Pseudo-nitzschia* sp. and *H. akashiwo* apparently increased at night, approximately 4 to 8 times higher than in the daytime, probably due to the changes in the water mass. At most depth range, all species had higher cell concentrations in the upper layers above the pycnocline where Chl-*a* showed the maximum. However, a significant decrease in cell concentration was noted below the pycnocline where the hypoxic layer was observed.

Comparing the cell concentration of phytoplankton and zooplankton, I presumed that there is a strong relationship between phytoplankton and zooplankton communities because

zooplankton were concentrated at the depth of high phytoplankton. Moreover, sudden changes in zooplankton distributions and cell concentration were observed when the colder and saltier water mass came in. Therefore, the influence of water column characteristics was found to be equally important for sudden changes in the communities at the anchored sampling point.

Regarding the size distribution of phytoplankton, a positive correlation was observed between phytoplankton biovolume and Chl-*a* throughout the sampling periods except 12 and 16 h. At these exceptional times, Chl-*a* concentration was high at the bottom layers where high turbidity water was observed. This might be corresponding with the resuspension of aggregate particles at the bottom layer which still keeps active Chl-*a* pigment. Therefore, the bottom high-value of Chl-*a* was not only from the live phytoplankton but also from the pigments deposited in the aggregate particles.

Conclusions

To assess the fine-scale spatial and temporal phytoplankton dynamics over a short time period, we used the FlowCAM, which can rapidly count, identify and size the phytoplankton. Our results indicated that the phytoplankton distribution pattern changed significantly in a short timescale (several hours) and in a few meters in depths, related to the changes in the water masses and hydrodynamic conditions. Moreover, species-specific distribution patterns of phytoplankton also changed in a short time reflect the generation time of phytoplankton is quite short. After these surveys, I stress that to know the community structure and the distribution pattern of phytoplankton, high-frequency and fine-scale samplings are needed.