

Mechanism of phytoplankton outbreaks in the western part of the inner Ariake Sea during winter

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論 文 内 容 の 要 旨

Thesis Summary

In the Ariake Sea, seaweed aquaculture has been conducted on a large-scale from autumn to winter in shallow coastal area. Since about 30 years ago, phytoplankton outbreaks have frequently been occurred in the western part of the inner Ariake Sea during the aquaculture season, which have caused economic damage to the seaweed farming industry due to color bleaching of seaweed. Thus, revealing the mechanism of phytoplankton outbreaks is an important issue for the conservation and management of the aquaculture resources.

In order to investigate the generation mechanism of phytoplankton outbreaks in the western part of the inner Ariake Sea, field observations have been conducted by using vessels. However, a lot of efforts and cost are required for the vessel observations to capture the phytoplankton dynamics spatially and temporally. Thus, in-situ vessel observations should be carried out in combination with other more detailed observations. One of the observation methods satisfying this requirement is a continuous mooring observation, which can provide high-resolution temporal information, but hardly provide spatial one. Satellite observations for sea surface chlorophyll-a concentration have often been used to spatially grasp phytoplankton outbreaks, but it is difficult in the satellite observations to find the detailed phytoplankton distribution in the seaweed aquaculture area. This suggests that we need the establishment of a new high spatial resolution observation technique to replace satellite observations. Furthermore, environmental data taken from field observations are usually limited, so that numerical simulations are also effective to clarify the physical and biochemical environments relating to the phytoplankton outbreaks in the western area of the inner Ariake Sea.

The purpose of this study is to reveal the mechanism of phytoplankton outbreaks in the western part of the inner Ariake Sea by using both of field observations and numerical simulations. In order to clarify the mechanism, we established a new observation approach to grasp the detailed spatial distribution of phytoplankton outbreaks, and developed a numerical ecosystem model to estimate such phenomena accurately. The results and findings obtained from this study are summarized as follows:

In Chapter 1, we described the background, purpose and outline of this thesis. We also stated the importance of revealing the mechanism of phytoplankton outbreaks, and the contents in the respective chapters in this thesis.

In Chapter 2, we investigated the mechanism of phytoplankton outbreaks which occurred at the first neap tide after the annual minimum water temperature by continuous mooring observation in the western part of the inner Ariake Sea during winter. The formation of two physical environmental factors favorable for phytoplankton proliferation was found to play a trigger role in the outbreaks. The first factor was the stabilization of water column due to net heat flux transition at the sea surface from cooling to heating in mid-winter. After mid-January, the atmosphere stabilized as the air temperature exceeded the water temperature, and the sea surface cooling due to the latent heat weakened. In addition, with the increase in the solar radiation, the sea surface heat flux changed from negative to positive, and their actions made the water column stabilized. The second factor was the improvement of light condition by deepening of euphotic layer up to or exceeding the water depth with the decrease in suspended sediment concentration at the neap tide.

In Chapter 3, a high spatial resolution observation for sea surface chlorophyll-a concentration was newly established by the use of a Fixed-wing type Unmanned Aerial Vehicles (FUAV) equipped with two multi-spectral radiometer sensors capable of being on board for detection of upward radiance and downward irradiance in an estuary under high human influence. It can grasp the detailed spatial information about phytoplankton outbreaks in the western part of the inner Ariake Sea during winter. As a result, a robust FUAV-based remote sensing technology of retrieving sea-surface chlorophyll-a concentration based on the spectral reflectance at three wave-lengths from red to near infrared was successfully developed and validated under different hydro-meteorological conditions and different phytoplankton specie dominance for two years. We found out the patchy distribution of high chlorophyll-a concentration in the seaweed aquaculture field by the spatially high-resolution observation due to FUAV. The spatial distributions of chlorophyll-a concentration taken for two years showed that the phytoplankton proliferated locally in the central region of the western part of the inner Ariake Sea in the early stage, and then it expanded further along the northern coast.

In Chapter 4, we investigated the physical environment for chronical high concentration of phytoplankton cell in the western part of the inner Ariake Sea through the numerical simulation. The field observation data from 2000 to 2017 during autumn and winter indicated that three phytoplankton species of diatom, i.e., *Skeletonem* spp., *Eucampia zodiacus* and *Asteroplanus karianus*, were chronically high in the western area. The numerical simulation showed that the favorable environment for these species resulted from weakness of the water exchange in the western area due to low buoyancy flux.

In Chapter 5, an ecosystem model was applied to investigate the chemical-biological environments favorable for the phytoplankton growth in the western part of the inner Ariake Sea during winter. In order to develop the ecosystem model, we incorporated the effects of the seaweed aquaculture on the surrounding environment into the model. The numerical simulation reproduced accurately the coastal biochemical environment during winter. The results concluded that the favorable conditions for phytoplankton growth in the western part were caused firstly by optimal photosynthesis environment in terms of light conditions and secondly by supply due to horizontal advection in the lower layer from offshore area.

The conclusions of this thesis were described in Chapter 6 by summarizing the results and findings in this study.