【Grant-in-Aid for Scientific Research (S)】

Broad Section K

Title of Project : Virus-driven clockwork in lower tropic level marine ecosystem and its impact on the ocean

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Keyword : Marine virus, Marine microorganism, microalgae, omics analysis, Lower trophic level marine ecosystem

【Purpose and Background of the Research】

In the ocean primary production is mainly accomplished by the photosynthetic microorganisms, such as cyanobacteria and eukaryotic microalgae, and the net primary production is comparable to that of land. Marine ecosystems are established on a wide variety of microbial metabolisms originating from the organic matter produced by the photosynthetic microorganisms. Additionally, infectious viruses lead to the death of 10 to 40% of microorganisms per day and exert high influence on the marine biogeochemical cycle through infection and lysis. However, it has been difficult to elucidate the genetic diversity, distribution and dynamics of marine viruses due to the absence of conserved genes. For this, we established a comprehensive method for viral metagenome (Virome) analysis and found diurnal infection cycle of viruses infecting cyanobacteria. Based on our results, we hypothesized that the diurnal cycle is spread across the entire lower trophic level marine ecosystem, starting from the photosynthetic products (= organic matter) being dispersed with the release of the daughter viruses. Therefore, in this project, we aim to elucidate the periodic mechanism (clockwork) underlying the interaction between microorganisms and viruses and its influence on the medium- to long-term changes in the structure of marine ecosystems. With this, we will also unveil the basic principles driving the biogeochemical cycle in the ocean.

【Research Methods】

One of the keys to achieve the above-mentioned objective is to constantly collect samples at various time intervals from 3 hours to long-term intervals. Using the collected time-series samples, the entire community structure analysis covering both the prokaryotic and eukaryotic microorganisms and their viruses will be performed as depicted in Fig. 1. (1) We will investigate the diurnal dynamics of metabolism and infection in marine ecosystems using a microbial sorting technology and a comprehensive multi-omics metaanalysis method. Additionally, (2) the molecular mechanism of clockwork will be elucidated through mesocosm experiments using the cultured microorganism-virus systems. Also, we will try to isolate viruses that infect major marine algae, including Rappephyceae. (3) We will investigate causal networks that connect microorganisms, viruses and their metabolism. (4) We will examine the extent to which the periodicity of the lower trophic level ecosystem in the surface water affects through measuring growth of anchovy larvae and microbial activity in the mesopelagic zone.

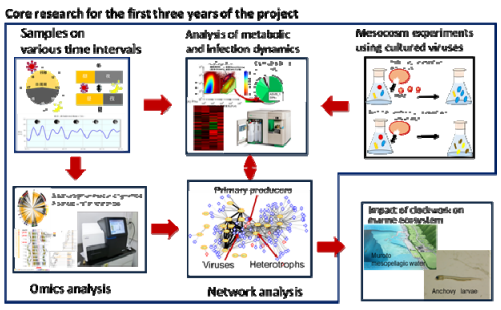

Fig.1 Summary of this project

【Expected Research Achievements and Scientific Significance】

The photoperiodicity, also known as chronobiology, has been well studied in land plants. Conversely, studies on the lower trophic level marine ecosystem have been conducted so far through fixed-point made once to several times a month, and mainly focused on the correlation between microbial communities and physicochemical factors such as nutrients and temperature. In the project, we will perform time-series sampling at both short- and long-term time intervals and directly detect various periodicity in not the only community structure but also metabolic activity and infectious dynamics in the lower trophic level marine ecosystem, starting from the virus-primary producer interactions, to elucidate the clockwork mechanisms involving the periodicity. Moreover, we will investigate the ranges of the effect of clockwork through accessing the correlation between the lower and higher trophic level ecosystems, and surface and mesopelagic ecosystems for example, and consequently address the unknown basic principle of the ocean.

【Publications Relevant to the Project】

- Locality and diel cycling of viral production revealed by a 24 h time course cross-omics analysis in a coastal region of Japan. Yoshida, T. et al. *ISME J.,* 12, 1287–1295 (2018).
- Predetermined clockwork microbial worlds: Current understanding of aquatic microbial diel response from model systems to complex environments. Morimoto, D., Šulčius, S., Tominaga, K. and Yoshida, T. *Adv. Appl. Microbiol.*, 113, 163-191 (2020).

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