論文名　Studies on the nematode community structure and diversity during the seasonal hypoxia in Omura Bay, Nagasaki, Japan

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Hypoxia in bottom environments of coastal marine ecosystems is one of the major threats adversely affecting numerous benthic organisms and thereby local fisheries. Under the ongoing global trend of the seawater temperature rise, it is very much likely that incidents of hypoxia would become more frequent and the severity of that would become more intensified around coastal seas. Considering the growing concerns on the impacts of ocean deoxygenation on the coastal fisheries, it is urgently needed to monitor precisely and consistently how benthic organisms respond to the decline of dissolved oxygen (DO) in the bottom environments. Meiobenthic organisms (meiobenthos) represent a major part of biodiversity of the bottom environments and play roles in carbon cycles and energy transfer through the ecosystems. As meiobenthos are much more numerous and considered to respond more sensitively to environmental perturbations than are macrobenthic organisms (macrobenthos), meiobenthos can serve as suitable target organisms for environmental monitoring to gain insights into the ecosystem response to hypoxia.

In this dissertation study, I particularly focused on nematodes as they predominate among meiobenthic fauna, and monitored nematode abundance, composition and feeding types under pre-, mid-, and post-hypoxic conditions during the period from June 2013 through October 2018 in Omura Bay, Nagasaki, Japan. The bay is almost completely enclosed, and consistently experiences seasonal hypoxia at the bottom every summer. The results of the present study are presented in three chapters, namely Chapter 2, 3 and 4.

In Chapter 2, I monitored abundance, genus level composition and feeding types of the nematode community in the uppermost layer of the sediment at a fixed sampling site locating in a central part of Omura Bay and found a positive correlation between DO concentration and nematode abundance over the entire sampling period of 2013 through 2015 ($r=0.61$, $p<0.05$). The nematode community compositions among the pre-, mid-, and post-hypoxic conditions were significantly different (one-way analysis of similarities (ANOSIM), $p<0.05$), which suggests that DO in the bottom water acts as a major driver for the community shift. The increases in abundance of nematodes with toothless feeding apparatus (selective and non-selective deposit feeders, referred as 1A and 1B type, respectively) in hypoxic periods, relative to normoxic periods, further suggested that the transfer of organic matter from bacteria through nematodes became more predominant in the sediment under hypoxia than normoxia. It was also demonstrated that full recovery of nematode populations from hypoxic to normoxic conditions would require more than two weeks of continuous normoxic DO levels (>3 mg L−1).

In Chapter 3, I assessed horizontal distribution of the nematode community in the bay by examining their abundance, community structure and diversity in the uppermost sediment of 4 selected sites representing gradients of some environmental variables across the bay during the study period of 2017. The severity of hypoxia varied typically along north-south axis of the bay, which was intensified southwardly. Nematode abundance and diversity were highest in the northern site than the other sites, and nematode communities were clustered into three groups by the sampling site. There were significant differences in composition (Two-way ANOSIM, Rho = 0.726, $p<0.05$) and in feeding types (Two-way ANOSIM, Rho = 0.589, $p < 0.05$) among the groups. Organic matter content alone was the best predictor for the shift in nematode compositions (Spearman's Rho = 0.666, $p < 0.05$), whereas the combination of salinity and DO correlated well with the shift in nematode feeding types (Spearman's Rho = 0.568, $p < 0.05$). These findings strongly suggest that the diversity and the structures of nematode assemblages were strongly affected by the gradients in terms of seasonal DO availability, salinity change and persistent food availability (organic carbon accumulation) over the surface sediment of the bay.

In Chapter 4, I examined vertical distribution of nematode community in the sediment down to 4 cm depth in 2018. Nematode abundance and the amount of chlorophyll a in the sediment below 2 cm depth were apparently less than those above the depth, suggesting vertical distribution of nematodes is strongly affected by the availability of phytodetritus as a food source in the sediment column. Genus level composition of the nematode population revealed that the uppermost sediment (0-1 cm depth) was predominated by a single nematode genus at each sampling time. However, the predominance declined with depth and the genus level diversity tended to increase at subsurface (1-4 cm). There was also a clear difference in the nematode feeding-type composition between the uppermost and the subsurface sediment layers. Relative percentage of epistrate feeding nematode (referred as 2A type) was highest in the uppermost sediment, whereas that of both 1A and 1B type nematodes increased at subsurface regardless of the time of sampling. This suggests that the importance of bacteria as a food source for nematode changes not only seasonally but also vertically in the sediment.

All of these results highlighted that free-living nematode abundance, genus level diversity and feeding type composition in the surface sediment of Omura Bay are highly responsive to DO concentration of the bottom water. One of the most important findings was that the proportion of nematode without teeth (1A and 1B types) to that with teeth (2A and 2B) could serve as a robust and sensitive measure to gauge the community response to the development and reduction of hypoxia in the bottom. Although DO availability inside the sediment was not determined, it is very much likely that DO availability for the infauna within the depth range of the present study closely reflect the extent of DO concentration in the bottom water. Therefore, monitoring the nematode community response to varying DO levels in the bottom water should give us ecologically relevant information on how nematode community would be affected by and respond to hypoxia.