学 位 論 文 の 要 旨

論文題目 **Study on Sustainability of Oyster Production and Its Values in Hiroshima Bay, with Special References to Larval Settlement and Ecological Services**
（広島湾のカキ養殖の持続性とその価値，とくにカキ幼生の着床および生態系サービスの観点から）

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Hiroshima Bay is famous with its oyster culture, supplying for 60% of total oyster production in Japan. However, recent declining success rate of oyster spat collection in Hiroshima Bay is suspected to be basically the same root of declining of oyster production for 30 years due to phosphorus load reduction measure. Insufficient availability of phytoplankton as food sources, along with feeding competition among various filter feeders might have generated these poor culture conditions. The present study aimed to analyze the major causes of low recruitment success of oyster larvae and to evaluate the ecosystem services provided by oyster culture conducted in Hiroshima Bay. In chapter 1, general introduction was made on the importance of nutrients as agents to grow phytoplankton that are the exclusive food source for oyster. Particularly, abundance of small-sized phytoplankton can be a critical factor for larval recruitment because the larvae can feed only phytoplankton with the size of less than 5 μm. In this chapter, it was also described the importance of oyster culture in the aspect of economic and ecological benefit.

In chapter 2, the prey-predator numerical model with 25 compartments consisting of nutrient (nitrogen and phosphorus), phytoplankton, zooplankton, adult oyster and oyster larvae with different developmental stages, other filter feeders, and fishes was developed to understand the material cycle in the norther Hiroshima Bay (nHB) where the center of oyster culture. The field observations demonstrated that low food availability, particularly small-sized phytoplankton suitable for oyster larvae, was the primary cause for the failure of the oyster larvae recruitment in nHB. Out of the filter feeders identified in this study, oysters had the strongest grazing pressure (39%) on phytoplankton, followed by zooplankton

(19%). It was clarified by model analyses that the major cause of low recruitment success in Hiroshima Bay was due to low concentration of small-sized phytoplankton followed by feeding pressure by filter feeder animals, such as adult oyster, mussel, and barnacle on planktonic oyster larvae. Here, the accidental filtration of larvae by the adult of the same bivalve species is called “larviphagy”.

In chapter 3, sensitivity analyses were conducted to see if increase the nutrient loads and decrease of cultured oyster biomass would lead the increase of small-sized phytoplankton biomass and increase the oyster larvae settlement success. The sensitivity analyses showed that phytoplankton biomass, irrespective of size, increased with increasing nutrient load. Particularly, P was identified as a main limiting factor of phytoplankton growth and also key to the correction of declines in oyster larvae. Although the top-down forces (i.e., larviphagy) could be another potential cause for failed oyster larval recruitment, it was not a significant factor. Thus, we conclude that bottom-up forces, i.e., P in the bay was the main factor, rather than top-down forces, e.g., larviphagy, in determining the successful recruitment of oyster larvae. To maintain larval recruitment at the level required by fishermen, apparently high P loading (ten times higher than the present level) is needed. Relaxation of treated sewage discharge has just started as an oligotrophication measure for the Seto Inland Sea by the local government.

In chapter 4, to evaluate the ecological benefit of oyster culture in term of monetary value, ecosystem service provided by oyster culture was estimated. Nitrogen (N) removal from the system through the process of grazing phytoplankton and detritus by oysters was estimated to be 254 kg N km^{-2} $year^{-1}$ (\$207 km^{-2} $year^{-1}$.This value is higher than N removal though the denitrification processes (\$45 km^{-2} $year^{-1}$) and the calculated oyster harvest (\$10 km^{-2} $year^{-1}$), respectively. In addition, provisioning service for fish habitat by the oyster culture was estimated to be \$299 km^{-2} $year^{-1}$, which was obtained by converting from the catch amount of commercial fish (black seabream, black scraper, pufferfish, Japanese seabass, and black rockfish) during the observation period.

Oyster culture in Hiroshima Bay is like an “artificial hanging reef.” Oysters can filter suspended particles, improve water quality and provide a nurturing environment for the small living organisms that serve as food sources for the fish species with economic value. However, oyster production in Hiroshima Bay has been decreasing since the 1980s, which could adversely affect the

ecosystem services for human well-being. Thus, understanding the value of ecosystem services provided by the oyster cultures may lead to better ecosystem management strategies in the coastal areas. Due to their numerous environmental and economic benefits, oyster cultures would be of particular interest to threatened, protected habitats. Their existence in Hiroshima Bay is important, not only for harvesting oysters of course, but also for producing ecosystem service benefits.