Doctoral Thesis

Study on the Quantitative Evaluation of Performance of Artificial Timber Reefs in Structuring New Habitats for Marine Life

(Summary)

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Japan is known as a country playing an important role in the world's fisheries. With strong fish-rich food culture with advanced fisheries management system, Japan was leading the fisheries production. However, the national fisheries production has declined sharply for these 30 years, and the production may drop even more in near future. This situation required the central government to fulfil domestic needs with imported products. Various measures have been taken to alleviate this serious problem, including deployment of ARs. Japan has a long history of developing ARs. Of them, artificial timber reefs (ATRs) that use timbers from forest thinning has been used more recently. In Japan where forest occupying one-third of the total land area, a regular forest thinning is required to maintain the forest in a healthy condition. Most of the logs from the forest thinning left behind in the forest for no use, because of expensive labour cost to collect them. Therefore, the use of timbers as AR material has a potential regarding its high availability. Thus, I studied how ATRs deployment is effective in terms of shaping a new ecosystem and performing an increase of fish production in Mitsu Bay, Japan.

Objectives of this study, as mentioned in Chapter 1, are (1) to understand the community composition of organisms associated at ATRs which are feed for fish community, (2) to illustrate the processes of food web creation in the ATRs and the comparison to other types of ARs (concrete) and area without ARs (Control), and (3) to elucidate the nutrient cycling processes enhanced by the deployment of ATRs. To perform the above objectives, in Chapter 2, species composition of animals associated with the deployed ATRs were described, which is also used for discussion as important component in the food web in Chapter 3. Then, in Chapter 3, based on the results of numerical calculations, functions of the newly formed ecosystem were discussed. In Chapter 4, the model was integrated with the processes in lower trophic levels, and the characteristics of ATRs were described in terms of nitrogen and phosphorus cycles. The model constructed in the present study consists of both pelagic and benthic systems and being interactive each other in and around of the ATRs areas in Mitsu Bay. The equations used in the model are those representing the biogeochemical processes occurring in the ATRs and Mitsu Bay system.

In Chapter 2, 272 taxa were identified for the associated animals from there types of ATRs (ATRs, ATRsOS and ATRsLB) in two deployment sites during 2016-2018. Arthropods dominated followed by molluscans and annelids. Individual number of those organisms was high in summer and low in winter. The individual number was high in the first year after the ATRs deployment, and it decreased in the second year and after, suggesting the animal community may have matured by balancing the growth and feeding by fish. All three types of ATRs were commonly large in individual number and small in species number, resulting a low diversity index. Of the three different types of ATRs, ATRsLB and ATRsOS showed the highest individual number and highest species number, respectively. The diversity index for simple ATRs was lowest compared to those for ATRsOS and ATRsLB. This result suggests that ATRs with additional materials can provide a wide range of feed animals which may attract more fish.

Several feed organisms growing at ATRs are staple for gathering fish and may be an important factor to determine the structure of fish community. The model used in Chapter 3 investigated the relative efficacies of the different types of ATRs and compared them with the conventional ACRs and Control area without ARs. Observed data were used to validate the model calculations, and the model outputs fit to the temporal variations of the observed biomass of both feed animals and fish. Here, fish behavior is taken into account by analyzing a series of video camera recordings. The feeding selectivity of dominant fish was also incorporated in the model referring to the vast published reports. Both ATRs and ACRs revealed to support far greater fish biomass compared to Control. Other than provision of feed, this may be coming from the function of ATRs that provides shelters particularly for juvenile and smaller-sized fish. Regarding ACRs, they are likely to host larger-sized fish by their larger room in the frame. The numerical model revealed that the newly created ecosystem in ATRs was productive judging from material flows through predator-prey relationships between feed animals and fish. Despite, as natural products, the decomposed timbers may act as source for organic matter in the deployment area as discussed in Chapter 4.

The simulation outputs for phosphorus and nitrogen cycles after the deployment of ATRs with integration of the food web model developed in Chapter 3 reproduced well the seasonal changes of nutrient concentrations in Mitsu Bay. Along with a background of the biomass increase in wintertime, it was detected the enhancement of nutrient regeneration in winter season through the processes of excretion, egestion and dead matter from mortality. Meanwhile these inputs were calculated low in spring and summer. This indicates that internal regeneration of nutrients is playing a key role in the nutrient cycling in ATRs system particularly in winter.

The higher nutrient concentration in the ATRs deployment area is due to increased input of organic matter from the ecosystem that was created at the ATRs. Evidently, the input of DIP and NH_4^+ due to excretion by organisms were double and triple higher than those in the surrounding water. Further, the model calculation also revealed that nutrient produced by regeneration process in the ATRs deployed area are transferred to the surrounding water by physical exchange of water. Thus, we can say that ATRs can act as a nutrient source to the surrounding water not only to enhance the biogeochemical processed in the ATRs area. Particularly, this is an important process in areas like Mitsu Bay where the other nutrient sources were quite small such as inputs from land, precipitation and benthic flux.

The results obtained by the application of numerical model in this study would have much improved our understandings on the enhancement of the biogeochemical processes in material cycles after the deployment of ATRs through created food web there. It is necessary to replace the ATRs regularly because of their longevity. As mentioned in Chapter 3, the materials, Japanese Cypress, used for ATR in this study, is comparatively harder and slowly decomposed to the other tree species, but the longevity is proved 5 years or so in the present study. Since the project here was a pilot study, in order to achieve more successful enhancement of fishery production in practical scale, much greater number of ATRs deployments with expansion of deploying area will be needed, in addition to increases of river and sewer discharges.

To perform this kind of activity, it is necessary to collaborate with fishermen, forest keepers, local government, NPOs, NGOs and volunteers. Deployment of ATRs using byproducts such as thinning timbers with leaves and branches and oyster shells may enhance not only the fish stock in the sea but also help fasten the people's connectivity by fostering the activity to establish a recycling-oriented society.