A conceptual framework of ecosystem-based approaches to coastal habitat evaluation

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SUMMARY: It is an urgent need to establish ecosystem-based approaches to the evaluation of coastal habitat values for habitat conservation/restoration and sustainable utilization of coastal fishery resources. In this paper, recent research activities related to the above-mentioned task are reviewed and re-organized in light of major functions of the coastal ecosystem. It is proposed that habitat values should be evaluated in two directions: ecosystem stability depending on the species diversity and smoothness of material circulation, the latter of which directly links with material removal/recycle. In addition, reproductive capacity as a nursery for fishery resources should be included in the evaluation. For further development of the ecosystem-based approach, it is of great importance to accumulate long-term records of biological and ecological changes in the coastal water. In such context, newly emerged concept on the health examination of marine coastal environment is also discussed.

KEY WORDS: *habitat evaluation, ecosystem-based approach, environmental monitoring*

INTRODUCTION

The coastal marine environment of Japan is characterized by its high biological productivity. This productivity contributes to generally high fishery yields. However, both the biological productivity of coastal ecosystems and the productivity of coastal fisheries are being threatened by substantial changes in the coastal marine environment. This situation is making it increasingly imperative to take an ecosystem approach to management of the coastal marine environment.

Pollution due to rapid industrial development and urbanization is a primary cause of the degraded condition of the coastal environment. Besides the direct effects of pollution, indirect effects such as red tides and oxygen depletion in the bottom waters also contribute. Furthermore, engineering projects such as dredging, reclamation, and construction of marine facilities take their toll. Of particular concern to the fishing industry is the destruction of coastal nurseries. Most commercially valuable species spend their larval and juvenile stages in coastal nurseries such as tidal flats and seaweed beds.

In the context of global issues such as the explosive growth of the human population, wise use of renewable marine living resources has become indispensable to the future development of human society. In general, economic development aims to maximize short-term benefits, whereas maintenance of ecological integrity aims to minimize long-term losses.

Sustainable development seeks to balance economic goals with ecological integrity (Fig. 1). An optimal development strategy should consist of both the short-term goal of raising production efficiency and the long-term goal of maintaining ecological quality. It is not easy to put this into practice, however it is obvious that economy-based approaches with less concern for the ecological cost have caused many serious damages to the coastal marine environment. We therefore have to seek for ecosystem-based approaches.

The aims of this paper are to briefly describe some of the present environmental problems in Japanese coastal waters, especially in relation to the fishing industry, and to discuss management of these problems from an ecosystem perspective, focusing on ecosystem-based approaches to coastal habitat evaluation.

SOME ENVIRONMENTAL PROBLEMS IN JAPANESE COASTAL WATERS

Deficiency of dissolved oxygen in the bottom water

Among the factors controlling environmental carrying capacity of coastal living resources, dissolved oxygen (DO) concentration is the most critical¹⁾. In Japan the formation of DO-depleted waters near the bottoms of some hypereutrophicated

Fig. 1 Ecological system vs. economic system

bays has significantly affected the benthic living resources of the bays (Sasaki et al., 1988, for example)²⁾. When nutrient loads from the land are small, eutrophication can increase fishery production. And the fishery catches can contribute to the removal of organic products from the bays. However, when the nutrient loads exceed a certain limit there emerge negative feedback processes. Eutrophication is succeeded by rapid growth of phytoplankton (outbreaks of red tide, etc.). This leads to an increase in the organic flux to the bottom waters. Increased organic inputs in turn deplete the oxygen in the bottom waters. This further accelerates eutrophication through nutrient regeneration from the bottom. The DO depletion damages the habitats of fishery resources, and inhibits removal of the organic products.

In general, primary production in the bay seems to have increased in response to increased nutrient loading. This may enhance the production of pelagic fish, while benthos and demersal fish production may start to decline owing to DO deficiency³⁾. In Osaka Bay, in fact, catches of mantis shrimp and flat fish declined in proportion to phosphorus loading which exceed 14 tons per day⁴⁾.

Loss of tidal flats and seaweed/seagrass beds

One of the most serious causes of deterioration in the quality of Japanese coastal waters is the loss of tidal flats and seaweed/seagrass beds. Tidal flats and seaweed/seagrass beds are localized zones of high biodiversity where pelagic and benthic ecosystems interact. The high biodiversity apparently contributes to high biological productivity. Coastal engineering works such as reclamation projects and dredging are mainly responsible for the loss of these areas. More than 80 percent of the coastline of Tokyo Bay between 1950 and 1988 has been reclaimed, and the remainder

is still threatened by development⁵⁾.

The loss of tidal flats and seaweed/seagrass beds, in addition to directly affecting biodiversity and bio-productivity, has exacerbated eutrophication problems because these areas play a significant role in the removal of nutrients and organic materials. Parallel to the loss of tidal flats, seaweed/seagrass beds, such as eelgrass (*Zostera marina*) beds, have also rapidly disappeared. According to the Nansei (formerly Naikai) Regional Fisheries Research Laboratory, approximately 53 percent of all the original eelgrass beds in the Seto Inland Sea were lost by 1965. Furthermore, half of the remainder disappeared between 1965 and 1971, and by 1971 eelgrass beds occupied only 2.1 percent of the total area shallower than 10 meters. Azuma (1981)⁶⁾ warned that in areas where eelgrass beds were prominent, rapid simplification of the animal community occurred when such an area was reclaimed. He also pointed out that serious decline in the eelgrass beds could be accompanied by reduction in catches of small shrimp, crab, red seabream and other species which depend on the eelgrass beds during their life cycle.

An indication of the response of fishery production to reclamation was also shown in Osaka Bay, where shellfish catch have rapidly declined and never recovered after integrated reclamation areas in the bay coast exceeded a certain limit⁴⁾.

AN ECOSYSTEM-BASED APPROACH TO COASTAL HABITAT EVALUATION

As an ecosystem-based approach to practical habitat evaluation, "Health examination for the coastal seas" is being discussed under the support from the Ship & Ocean Foundation since 2000. This project is still in its infancy, and first thing to be discussed is what environmental indices should be used for the evaluation/diagnosis in the ecosystem-based approach. I would propose in this paper that it is a promising way to focus on major ecosystem functions such as (1) buffering environmental changes, (2) material recycling, and (3) nurturing living resources. Species diversity could be one of good indicators for evaluating the function of buffering and the extent of ecosystem stability, while dissolved oxygen in the bottom water and other water/bottom quality parameters could indicate the smoothness of material circulation and the extent of self-regulation of the ecosystem. In addition, capacity of reproductive habitats, which is possibly quantified by total areas of tidal flats and seaweed/seagrass beds, may represent the

sustainability of fishery production.

The health examination for the sea will have two types of operation by analogy of that for human body. One is preliminary examination, in which using existing data and simple examination time-series analyses on oceanic conditions, water/bottom quality, habitat capacity, fishery yields, etc., and rough estimates of material budget will be made to grasp the outline of the ecological features. The other type is advanced examination to find out causes and effects behind the ecosystem changes. In this advanced stage, further specialized measurements and data analyses on physical-biological interactions and detailed material fluxes will be made. The environmental indices based on ecosystem functions mentioned above will be used in both examinations. It is further required to conduct several case studies to look at the feasibility of this type of approach. These may include Ariake Bay and/or Omura Bay in the Kyushu coast, both of which are apparently suffering from environmental degradation in recent years (Okawa M., pers. comm.)

FUTURE DIRECTION AND TASKS

As described above, the present situation in Japanese coastal waters does not provide an optimistic view for the future. Most areas are suffering from severe degradation of water quality and rapid losses of the coastal habitat.

It is needless to say that establishment of quantitative measures for evaluating ecosystem changes responding to human impacts is an important and urgent task. An intensive survey on the nutrient (nitrogen, in this case) budget of a tidal flat has been recently revealed a new aspect of the ecological functioning of the tidal flat ecosystem⁷⁾. Matsukawa demonstrated in this study that a tidal flat consists of both plankton and benthic ecosystems which diversifies the food web system and probably enables nutrients to reside long enough to be converted into particulate material through biological production. Some of the nutrients are thereafter removed by marine species such as shellfish and seaweed. The effective trapping and removal of nutrients contributes to maintaining high productivity on the tidal flat. Improved knowledge of such mechanisms in the natural system will help guide habitat conservation and restoration.

In this respect, a new method for assessing the human impact on coastal ecological systems related to fishery production has been proposed⁸⁾. There are also high expectations that ecosystem models will become a significant aid to the prediction of habitat changes and proper management of living resources (Hata, et al., in this volume, for example)^{9,10)}. However it has not yet

been incorporated as a practical tool for the impact assessment. Further development of this modeling technology would be promising. In addition, newly emerging analytical techniques such as those of a Sr/Ca ratio in the marine organisms has recently revealed a significant value of tidal flat nurseries for fishery resources in a quantitative manner¹¹⁾. This sort of scientific work will open the door to rational assessment of the ecological costs we might pay due to habitat destruction.

Another important task in the future is to monitor ecological changes on a long-term basis. Yuasa (1995)¹²⁾ presented an example of long-term monitoring of coastal fauna of benthic animals in a seashore region of the Seto Inland Sea (Fig. 2). The number of species observed at six stations showed rapid decline between 1960 and 1990. Inner stations started to decline earlier than outer ones. The number of species has not yet recovered even after enforcement of the Seto Inland Sea Conservation Law. Unfortunately, except for this study, there have been very few time-series data sets obtained on the ecological responses to change in the coastal water of Japan. It is therefore an urgent need to establish a well-designed and operational monitoring network for ecological properties in the coastal waters around Japan. Those biological and ecological databases will provide an important and common basis for verifying ecological models for the impact assessment, and contribute to adaptive management of various coastal habitats.

Fig. 2 Year to year changes in the number of species of coastal fauna collected at the seashore stations (Kashima, Tenno, Karuga, Kurose River, Nagahama, Tohama) in and around Kure Bay, Hiroshima from 1960-1990 (after Yuasa, 1995)

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