DEVELOPMENT OF ECOSYSTEM MODELS IN THE SETO INLAND SEA FOR FISHERIES MANAGEMENT

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Fisheries in the Seto Inland Sea is suffering from big problems such as eutrophication caused by fresh water inflow from a densely populated basin, destruction of tidal marshes and seaweed beds caused by coastal construction works, and over-fishing caused by fishery itself. For the sustainable development of fisheries, a quantitative estimation of biomass is required. The traditional way of estimating fishery resources quantitatively was based on population dynamics only for the object species. This method focused on estimating the effect of fishing pressure on an object species based on characteristics such as the growth ratio and the death ratio which were assumed to depend only on that species. In reality, the growth ratio and the death ratio are also affected by grazing by other living organisms, the amount of food available, and the other environmental conditions. For this reason, a "model" that takes into consideration not only the object species but also the system that contains that species into consideration is required for a comprehensive quantitative assessment. In this report, we apply the Water-Sediment Quality Model (WSQM) that focuses on water quality and the Shallow Sea Ecological Model (SSEM) that focuses on living organisms to the Seto Inland Sea, and examine the effect of reduction of nutrient loads from land.

WSQM: Water-Sediment Quality Model

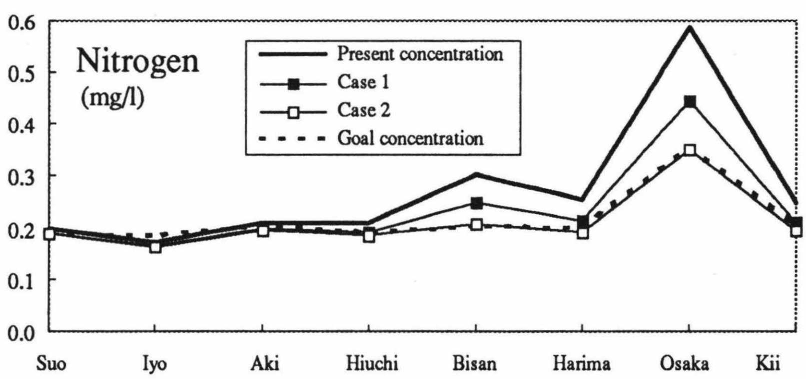
WSQM is an ecosystem model that describes the interaction between the water column and the bottom sediment (Ukita et al., 1986). It models the processes by which plankton are produced from nutrients in the water column, die and finally sink into the bottom sediment as detritus, which dissolves into the water column again accompanied by oxygen consumption. The purpose of the model is to reproduce an observed seasonal change of water quality, especially chemical oxygen demand (COD) and dissolved oxygen (DO). We divide the Seto Inland Sea into 8 boxes. The water column of each box is divided into two layers, a five meter thick surface layer and a bottom layer. The water exchange rate between the boxes is obtained based on a current simulation that is calibrated with observed salinity. The driving functions are water temperature, light intensity, and nutrient loading from the land area. The nutrient load for each year is obtained by interpolating the five year data.

SSEM: Shallow Sea Ecological Model

SSEM is intended to assess the impact on ecosystems and fisheries in shallow sea areas caused by coastal construction works (Sekine et al., 1991). Because SSEM is programmed using an object oriented programming language, Smalltalk, it can model a

complicated ecosystem flexibly and quickly. SSEM has special features such as fish movement by preference of environmental conditions and competition among many species. In this calculation, SSEM uses the same box features and driving functions, such as water exchange, nutrient load etc. , as WSQM. The components in calculations are two species of pelagic fish, two species of demersal fish, two species of benthos, a phyto plankton and a zoo plankton. Each fish and benthos has three life stages, juvenile, young and adult.
A model which is based on the food chain, such as SSEM, tends to give larger fish catches when there is a larger nutrient load from the land area. However, an increase of nutrient load does not always cause an increase of fish catch in reality. It is unclear whether this is the result of the water quality deterioration or the increase of fishing intensity caused by high demographic pressures in these areas, which is also the cause of the increase of nutrient load. The mechanism by which an excess nutrient load exerts a negative influence on fish catch is not obvious. In this model, the negative effect of an excess nutrient load is taken into account by adopting oxygen deficiency in the calculation. The DO concentrations used in this calculation are obtained from WSQM.

Simulation of the effects of nutrient load reduction



Reduction ratio	Suo	Iyo	Aki	Hiuchi	Bisan	Harima	Osaka	Kii
Case 1	0.1	0	0	0.2	0.3	0.3	0.3	0.3
Case 2	0.1	0	0	0.1	0.8	0.3	0.55	0.1

"Case 1" is the case in which the load reduction is limited to a maximum of 30% (= 0.3, in the tables), the maximum that the people in the catchment area can be expected to accomplish. "Case 2" is the case in which there is no limit to the reduction effort people can carry out. The goal concentration used here was presented by Nagai et al. 1997.

Figure 1. Nutrient load reduction rates required to accomplish the goal concentration presented by Nagai et al. 1997.

Figure 1 shows the nutrient load reduction ratios for each region needed to accomplish the goal concentrations of nitrogen obtained by using WSQM. "Case 1" in Fig. 1 is the case in which the load reduction is limited to a maximum of 30 %, the largest reduction rate we assume people in the catchment area can accomplish. The figure shows that in Hiuchi-Nada, Bisan-Seto, and Osaka Bay, 0.3 (even with the maximum 30%) nitrogen reduction still will not be enough to achieve the goal concentration. "Case 2" is the case in which we assume no limit to the amount of effort possible for nutrient load reduction. We can see that a lot of effort will be necessary to achieve the goal especially in the area from Bisan Seto through Osaka Bay.

Figure 2 shows the change of benthic biomass caused by the nutrient load reduction by using SSEM. In Osaka bay, benthic biomass becomes more than two times larger in spite of a 55% nutrient reduction, whereas in the western part of the Seto Inland Sea there is little change in biomass. This is the effect of oxygen deficiency.

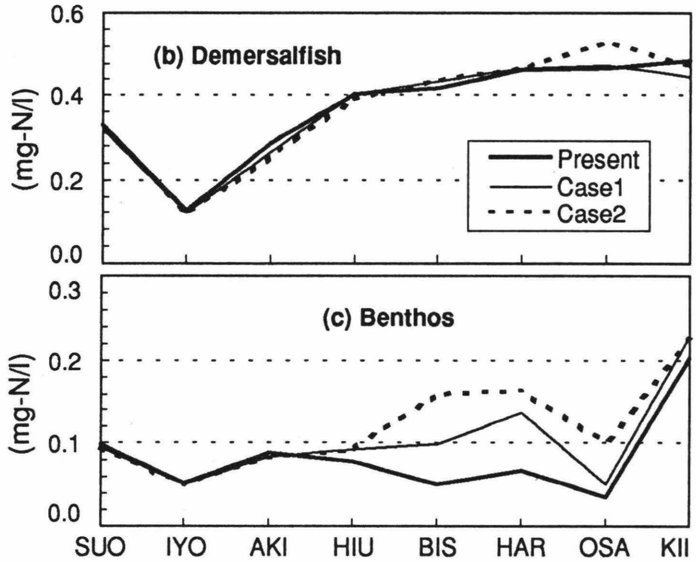


Figure 2. the change of benthic biomass caused by the nutrient load reduction.

Further study

By using WSQM and SSEM we have simulated another aspect of the effect of nutrient load, oxygen deficient water mass. The models are able to explain the distribution of the catch of benthic organisms to some extent. The effect of nutrient load reduction on biomass can also be evaluated by the models. However, although we can use the models to *calculate* the biomass change, we cannot say whether they are a reliable results at the present. There still remain many factors we have to consider. For example, we divided fish into just four categories. But in reality, there are many species of fish with different modes of life. When the environmental conditions change, the species composition may change at the same time, and that could cause big differences in the calculations. Although SSEM can treat such aspects by incorporating detailed information on each species in the model explicitly, an enormous amount of information will be required to do that. Moreover, we have not considered other important environmental impacts on biomass such as extinction of tidal marshes and seaweed beds with the model yet. Thus the models are still premature, but we think it could be an important step for the biomass evaluation that incorporate influences of environmental changes. This is an interim report on progress towards that goal.

Acknowledgment

This research was supported by the Nippon Life Insurance Foundation.

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