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Changes in Fishery Resources in Relation to Water Environments in Osaka Bay

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ABSTRACT

An attempt was made to analyze the relationship between the change in the quantity of fishery resources and the change of phosphorus load deposited into Osaka Bay. The phosphorus load had steadily increased from 1955 to 1975, then decreased slowly towards the 2000s. The major benthic fishery organisms, such as octopus, shrimp and crab, mantis shrimp, tongue-fish and right-eye flounder, were employed to examine the characteristics of change in fishery resources in relation to water environments of Osaka Bay. Excluding shrimp and crab, catch amounts showed a largely equivalent response to phosphorus load in the bay. The results presented here demonstrate that a close relationship exists between phosphorus emissions and benthic fishery resources in Osaka Bay.

Keywords : eutrophication, oligotrophication, phosphorus load, fishery resources

INTRODUCTION

As shown in Fig. 1, Osaka Bay is located at the east end of the Seto Inland Sea, and is a semi-enclosed bay with urban areas including Osaka and Kobe in the catchment. With the development of urban areas, the nutrient load to the sea has increased, causing organic pollution symbolized by the frequent occurrences of red tide (Imai et al. 2006). In order to improve the organic pollution, a total effluent control system was introduced by legislative regulation in the Seto Inland Sea.

As a general principle, primary production in the sea is closely correlated with the nutrient load (Nixon 1992). Furthermore, fishery production is proportional to the primary production in its fresh water and marine systems (Nixon 1988). It is surmised that a change in the nutrient load would have major impacts on fishery production in Osaka Bay.

With emission load of phosphorus as an indicator of the inflow load of nutrient, Joh (1991) reported relations between catches of the main benthic fishery organisms and phosphorus load in Osaka Bay. Corresponding to the change in phosphorus load, the catch of these benthic fishery organisms showed the characteristic patterns. However, these analyses were conducted based on fishery data from the period when eutrophication had advanced. In the present paper, the authors tried similar analysis using data before and after 1975, when eutrophication or oligotrophication had progressed according to increase or decrease of the phosphorus load.

MATERIALS AND METHODS

Indicator of nutrient level

Monitoring data on seawater nutrients in Osaka Bay, which defines primary production, exists only for the period after 1972. Accordingly, the emission load of phosphorus in Osaka Prefecture was used as an indicator of the nutrient level of seawater. On the basis of the pollutant load factor by Nakatsuji (2002) and Joh (1991), the phosphorus emission load was estimated for every five years from 1955 to 1975. For later than 1979, we used the emission load calculated every five years by the Osaka Prefectural Government for total volume control. Where the figure for annual load was required, it was determined by interpolation from the five year-interval values.

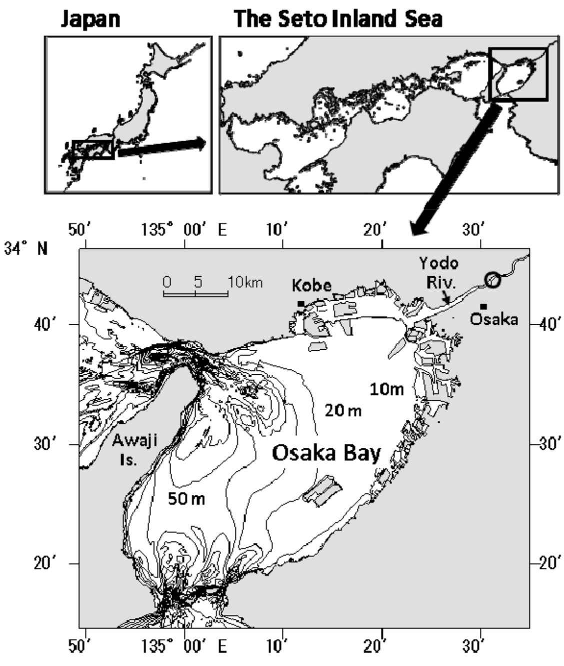

Figure 1 Map showing the location of Osaka Bay, Japan. The lower map shows isobath diagram, numbers show water depth in meters. The open circle indicates Osaka Prefectural Government water quality observation points in the Yodo River.

Indicators of fishery resources

There are two types of fishery resources in Osaka Bay. One is migratory wandering fish resources such as sardine. The other is resident fish resources which are considered to complete their full lifecycle in Osaka Bay. The latter are commonly caught in the trawl. Following to Joh (1991), the major benthic organisms such as octopus, shrimp and crab, mantis shrimp, tongue-fish and right-eye flounder were employed to examine the relationship between marine benthic fishery resources and nutrient load in Osaka Bay. Statistical data from the Ministry of Agriculture, Forestry and Fisheries of Osaka Prefecture was used for the catch volume of fishery organisms from 1955 to 2005. We regard the amount of fish catch in Osaka Bay as basically reflecting the quantity of fish resources of the bay, since the fishery in the Seto Inland Sea is well developed and the fishery resources are thought to be harvested fully using a variety of fishing gear (Tatara 1981).

RESULTS

Figure 2 shows the long-term variation of the phosphorus emission load in Osaka Prefecture area. Phosphorus load increased sharply since 1955. It then began to decrease gradually after reaching its peak in the 1970s. In 2009 it was reduced to the previous level of 1955. The phosphorus load occurred in land area flows into the sea, mainly through rivers. Water discharge of the Yodo River accounts for 64% of the total river discharge into Osaka Bay. The phosphorus concentration of Yodo River water is measured by the Osaka Prefectural Government at the observation station in Fig.1. Figure 3 shows the correlation between the phosphorus emission load and the annual average phosphorus concentration in the Yodo River water. The high coefficient of determination suggests that the phosphorus concentration in the river water is dominated by the emission load amount in the land areas. Figure 4 shows annual changes in the phosphorus concentration of Yodo River water and the phosporus emission load in Osaka Prefecture. Phosphorus concentration in the river water decreased in accordance with the decreasing estimated phosphorus emission load since 1976. From these results, the following things were shown. The phosphorus emission load in land areas has been reduced from 1975, suggesting that the actual phosphorus inflow load into the sea have also been reduced, and the 2009 phosphorus load was reduced to the same level as in 1955.

The relations between phosphorus load and annual catches of the main resident species are shown in Fig.5. In the case of the mantis shrimp, being particularly resistant among crustaceans to organic pollution from sediment, the catch quantities increased with increasing phosphorus emission load. As the load began to decrease in the mid-1970s, the catch was found to decline as well. For tongue-fish and right-eye flounder, the peak fishery amount was observed to be at the period when phosphorus emissions were around 10t/day. In contrast, the octopus catch declined sharply in response to increased phorsporus emission load, and was observed to trend upwards as the load decreased.

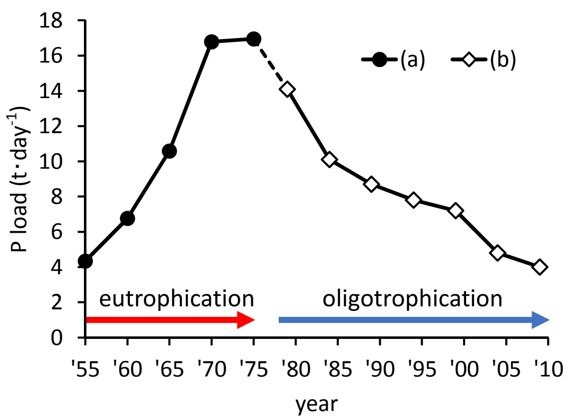

Figure 2 Long-term variation in phosphorus emission load in Osaka Prefecture. Polygonal line (a) shows data based on the pollutant load factor (Nakatsuji 2002), and polygonal line (b) shows data estimated by the Osaka Prefectural Government.

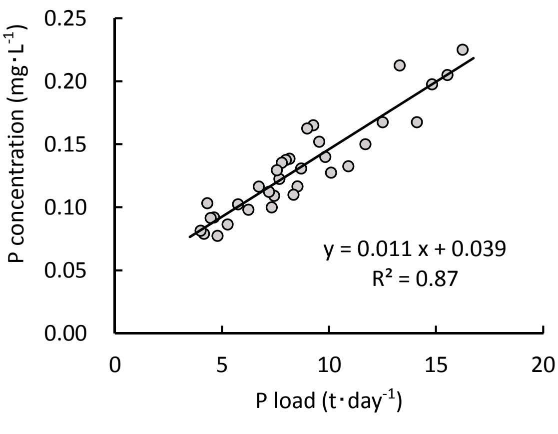

Figure 3 Correlation between phosphorus emission load in Osaka Prefecture and annual average phosphorus concentration in Yodo River water. The period of data is from 1976 to 2009.

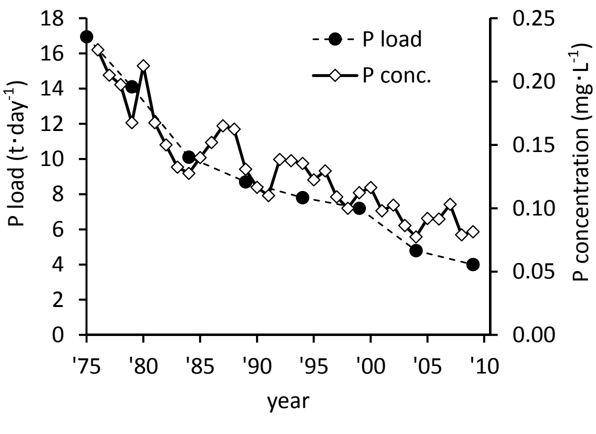

Figure 4 Changes in annual average phosphorus concentration of Yodo River water and phosphorus emission load in Osaka Prefecture.

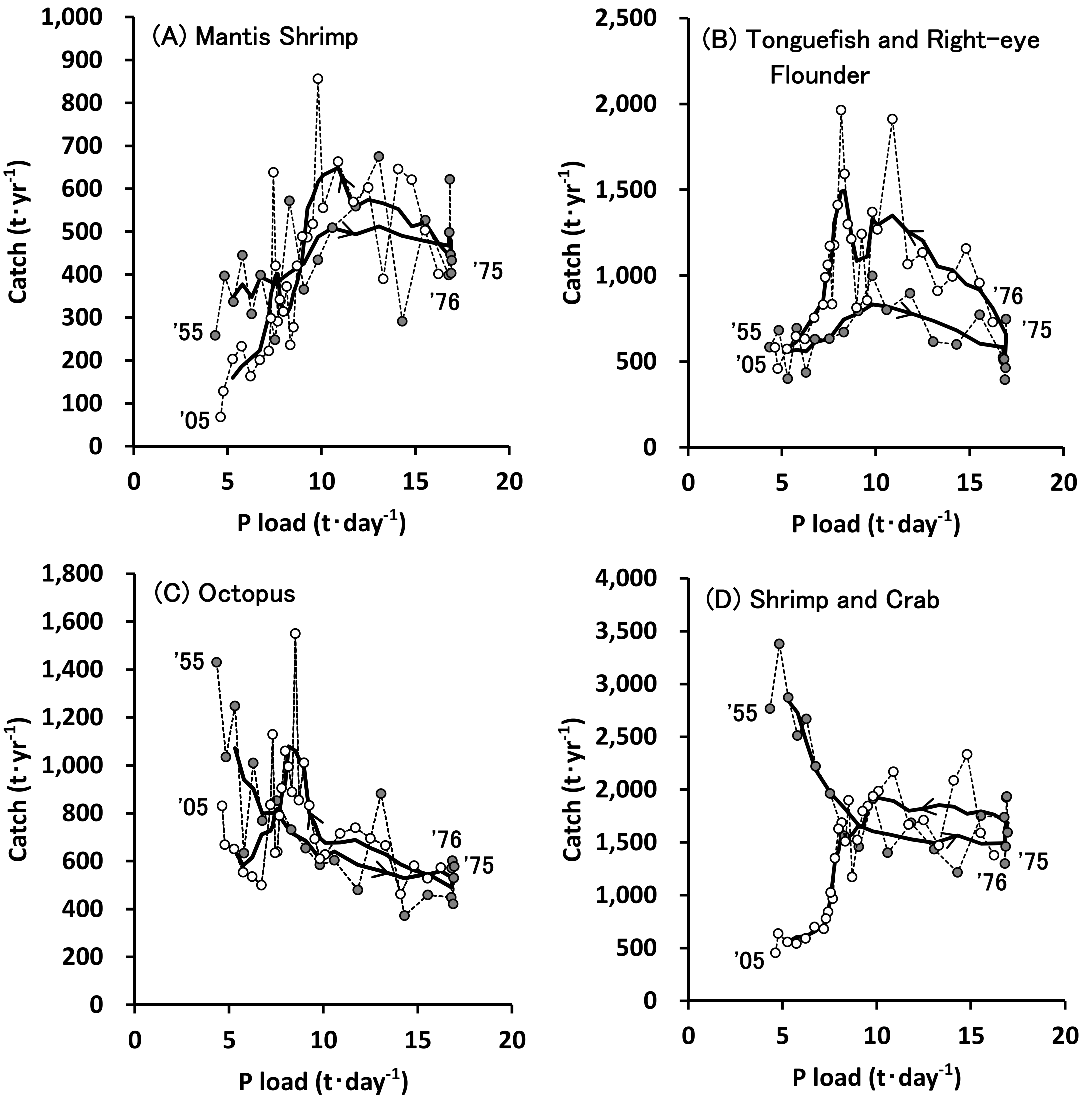

Figure 5 Relations between phosphorus emission load and annual catches of benthic fishes and shellfishes. Solid circles indicate data from 1955 to 1975, and open circles indicate data from 1976 to 2005. Four figures show (A) Mantis shrimp, (B) Tonguefish and Right-eye flounder, (C) Octopus, (D) Shrimp and Crab, respectively. The thin dotted line shows the trajectory of each catch, and the bold solid line follows the trajectory of a 5-year running average.

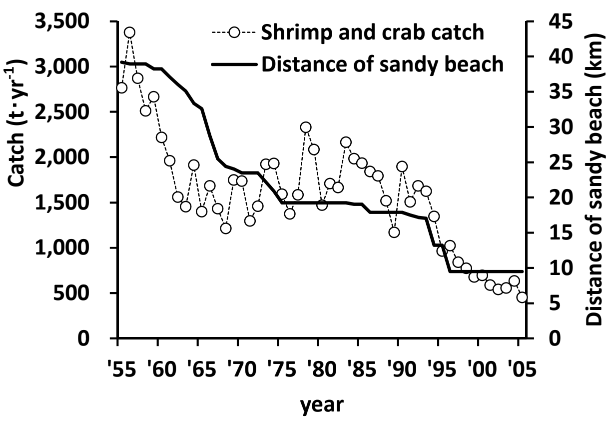

Figure 6 Change in annual catches of shrimp and crab, and that of distance of sandy beach in Osaka Prefecture.

The catch of shrimp and crab, sensitive to organic pollution in sediments, also fluctuated depending on the emission load. However, since the mid-1990s catches of shrimp and crab have once again decreased rapidly, showing a different response pattern to the one observed for octopus.

DISCUSSION

A close relationship is observed between the catch of these benthic fishery organisms and the phosphorus emission load. As Joh (1991) also pointed out, it is possible to remark that the load of phosphorus dominates the benthic fishery resources based on the following two assumptions. (1) Trends in catches and phosphorus load largely reflect the transition of fishery resources and the nutrient load from land areas, respectively. (2) The nutrient load from land areas is a major environmental factor controlling the long-term trends of fishery resources, while contributions of other factors are negligible.

However, shrimp and crab catch amounts have not recovered, despite the reduction in phosphorus emission loads to the level when they were abundant. This suggests the possibility that factors other than reduced nutrient load from land areas are acting dominantly in recent years. Figure 6 shows changes in the annual catches of shrimp and crab, together with the length of sandy beach in Osaka Prefecture (Ariyama, H., unpublished data). The annual catch of shrimp and crab decreased in pace with decreasing distance of sandy beach. When shrimp and crab are juvenile, most of them utilize shallow waters including sandy beaches. Thus, the decline of sandy beach availability since the 1990s has been considered as possible negative impact on shrimp and crab resources.

On the other hand, the annual catch of octopus, mantis shrimp, tongue-fish and right-eye flounder have changed depending on the increase or decrease of the phosphorus load. For instance, octopus declined when the phosphorus nutrient load was relatively high, but was observed to trend upwards as the load declined. Mantis shrimp, tongue-fish and right-eye flounder peaked when phosphorus load was high. These phenomena suggest that the response pattern to phosphorus load is different from taxon to taxon (taxon based on the catch statistics), reflecting their physio-ecological characteristics such as the resistance to organic pollution of the sediment.

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