Ariake Bay－present conditions of fisheries and research for its restoration－

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The 33rd UJNR Aquaculture Panel Symposium

Ecosystem and Carrying Capacity of Aquaculture Ground -for sustainable development of aquaculture and stock enhancement-

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Keynote of the symposium The role of the fisheries industry as a supplier of healthy food for human has become more important in recent years. Marine aquaculture and stock enhancement have been developed and can now compensate the reduced productivity of the wild catch.

Aquaculture creates impacts on the surrounding environment and ecosystem in various ways. Intensive feeding fish-farming often results in adverse effects on both the fish farm itself and the ecosystem beneath and around the fish farm through changes such as oxygen deficiency, generation of hydrogen sulfide, and blooms of harmful plankton.

On the other hand, non-feeding aquaculture and stock enhancement of seaweeds and shellfish potentially prevent eutrophication by removing nutrients and particulate organic matter from the surrounding water. The integration of fish farming with non-feeding aquaculture is therefore a useful approach to mitigation of the environmental problems associated with marine aquaculture.

To achieve sustainable development of aquaculture, we need to deepen our understanding of the environmental problems associated with aquaculture activities, especially their effect on the ecosystem and carrying capacity of aquaculture ground. In this symposium we would like to discuss future perspectives of sustainable and responsible aquaculture, particularly in regard to the natural environment and ecosystem, methods of managing aquaculture grounds, and new approaches to integrated aquaculture management.

Ariake Bay － present conditions of fisheries and research for its restoration －

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This theme is one of the symbol of a microcosm that includes many complicated issues related to social and scientific problems in the coastal fishery in Japan.

In Ariake Bay, the event occurred in 2000-2001 that the Porphyra (Nori) culture suffered from

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huge damage of discoloration by the environmental change for worse.

Many factors are included, such as oceanic condition, decreasing of current speed, rise of water temperature, reduction of concentration of nutrients, weakened wind blows, much rain by typhoon and after that sunshine lasted for a long time, and artificial matters, reclamation, dam, pollution etc. So briefly I introduce the research to restore the environment and fisheries production being done in the bay.

What is Ariake Bay?

Ariake Bay is located in northwestern Kyushu Island and a nutrient enriched productive sea. Its area is about 1700 square kilometers. The bay is semi-enclosed, being connected to the East China Sea through the narrow Hayasaki-Seto Strait. The bay environment is strongly influenced by the environmental conditions of the East China Sea (Fig. 1).

The main features of the bay are tidal flats, a large tidal range and enriched with nutrients. The tidal flats cover about 20,000ha along the coast of the Bay. Western part of the Bay is muddy sediment and eastern part is mainly sandy sediment due to the current direction counterclockwise.

Looking at from historical aspect, as the bay is shallow and flat tides are distributed widely, the reclamation had already begun in Shogun period to ensure the increase of food and protect their houses and farm from disaster. And after the world war two it was getting rapidly to solve the scarcity of food with the advance of technology. Until now about 26,600 ha, about 57% of the flat tide, had been reclaimed.

One more feature of the bay is the large tidal range. Fast tidal currents and strong vertical mixing have been observed in the bay due to the large tidal range (the maximum is about 6m) and shallow water depth (mean depth is 20m). Such a mixing process promotes oxidative decomposition of organic matter in the bottom layer and brings the regeneration of nutrients up to the surface from the bottom. This nutrient cycling provides a high productivity and has prevented bottom-water hypoxia in the inner part of the bay.

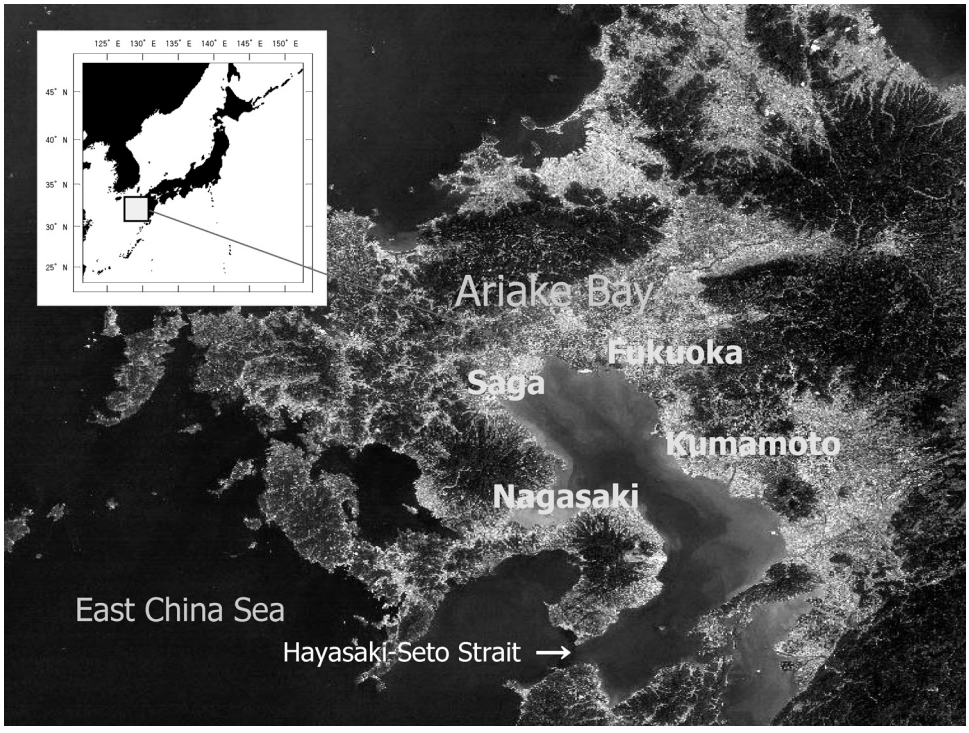

Fig. 1. Ariake Bay and adjacent area in north western Kyushu Island

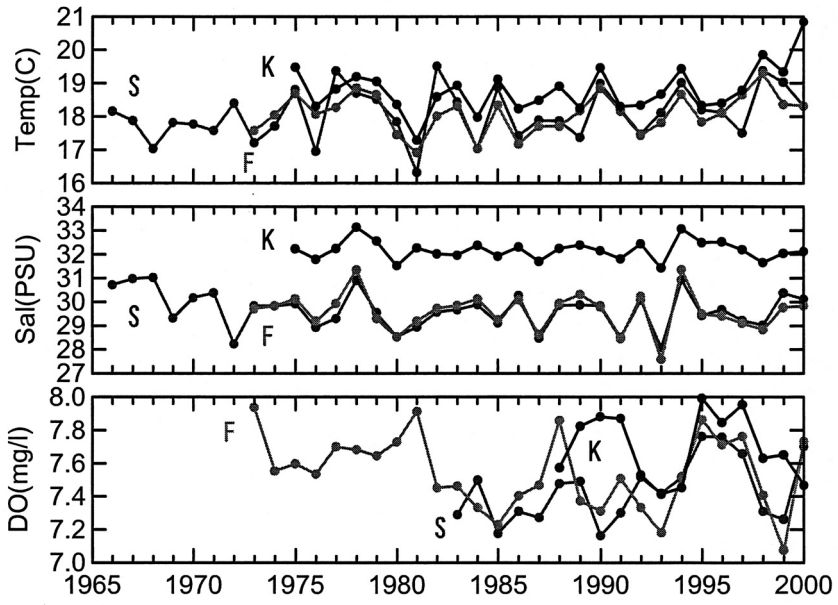

Fig. 2. Fluctuation of temperature (SST), salinity (PSU) and DO (mg/l) in Ariake Bay.
F : Fukuoka S : Saga K : Kumamoto

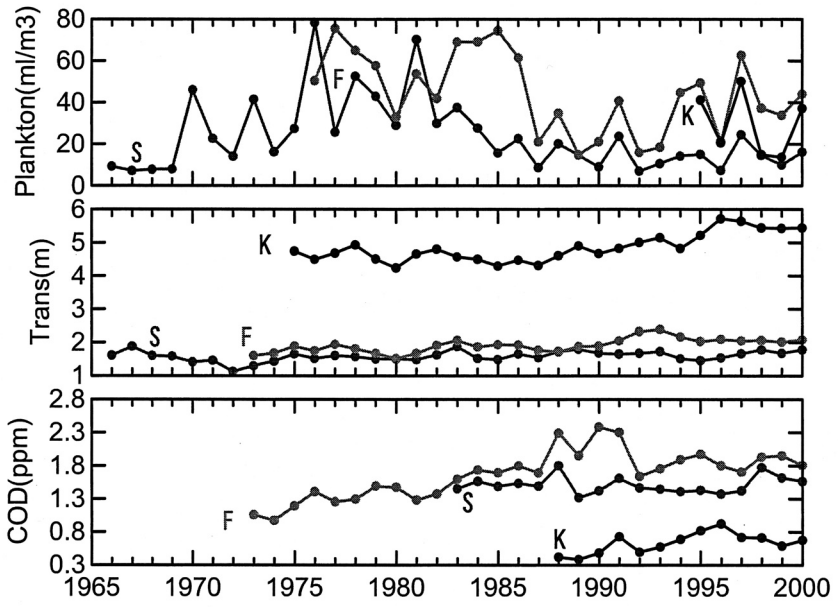

Fig. 3. Fluctuation of plankton (ml/m^3), transparency and COD in Ariake Bay.
F : Fukuoka S : Saga K : Kumamoto

Long term fluctuation of environmental indices

Water temperature is a well-used environmental parameter for fisheries grounds, higher water temperature than a normal year has been recorded at the bottom of the bay in recent years (Fig. 2).

The transparency has also been increasing. The area of muddy sediment has extended to the western part of the bay, where the sediment was formally sandy. Furthermore, COD is gradually increasing, implying the deterioration of the bay environment (Fig. 3).

The total number of the occurrence and the days of appearance of excessive algal blooms are rising in recent years. Particularly *Rhizosolenia imbricata* was appeared as a dominant species for a long time from September in 2000 to January in 2001. The reduction of nutrients by the algal bloom affected to the discoloration of Nori is estimated as one of the most important factor so far.

The tidal range has become also smaller, resulting from a decrease of the area of the tidal flats especially during neap tides. Moreover, hypoxia is formed in the inner part of the bay from early summer to late fall and the concentration of dissolved oxygen falls drastically especially during neap tides (Fig. 4).

Fluctuation of fisheries

1) Bivalves

The catch of bivalves was large and the major part of the fisheries in the bay. The amount of the catch reached more than 80,000 tons in the 1970s. Since then, however, the production of short-necked clam (*Ruditapes philippinarum*), jack-knife clam (*Sinonovacula constricta*) and pen shell (*Atrina pectinata*) has been diminishing. The catch fell to the level of 30,000 tons early in the 1990s, and it has further fallen to less than 20,000 tons in recent years (Fig. 5).

Following causative factors for decreasing yields of bivalves are considering;

1) Over fishing
2) Environmental deteriorations
   a. Reductions in dissolved oxygen contents in water column
   b. Blooms of toxic micro algae

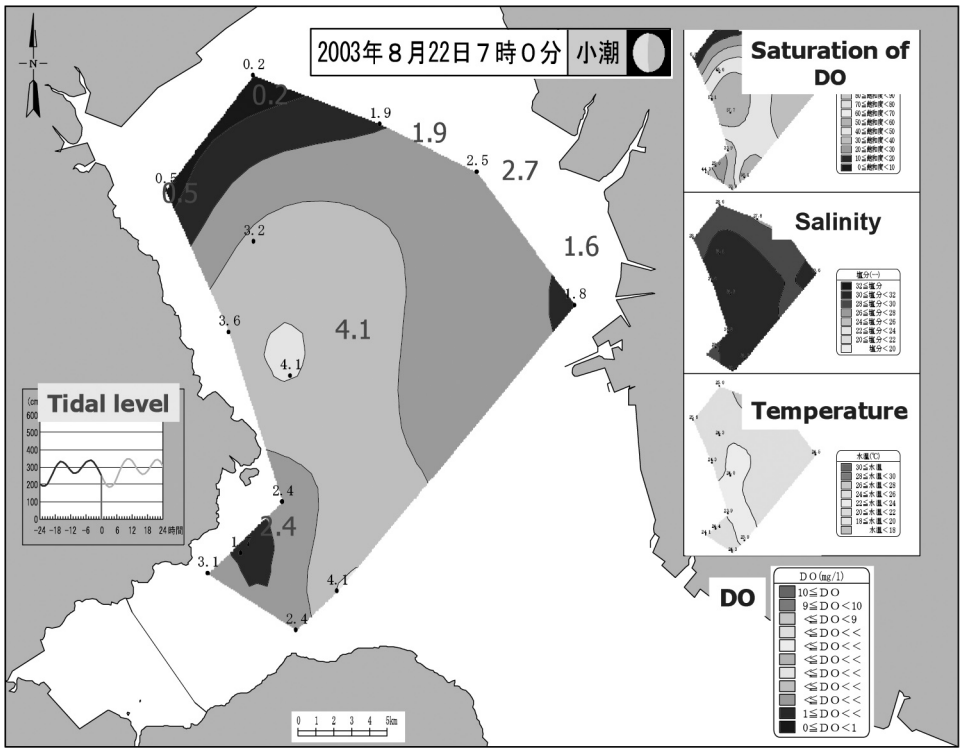

Fig. 4. Distribution of dissolved oxygen (mg/L) of bottom layer (−0.2～0.5m) at neap tide at 07:00 on Aug. 22, 2003.

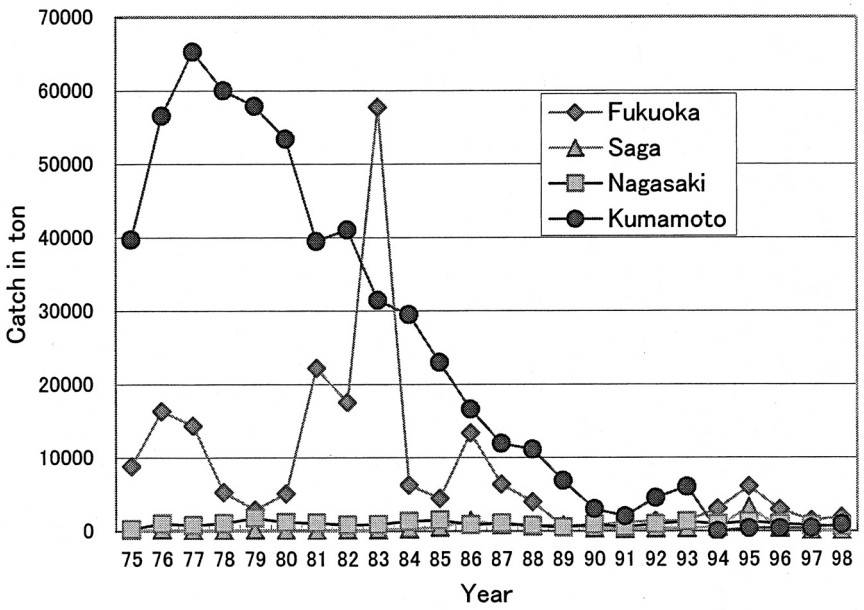

Fig. 5. Fluctuation of the catch of jack-knife cram in Ariake Bay

c. Unsuitable sediment conditions for larval settlement

3) Impact of predation

a. Predator such as crabs and rays

4) Outbreak of diseases

a. Protozoan and viral diseases

Particularly, mass mortality due to hypoxia was reported for jack-knife clam in the aquaculture grounds. And the predation by the ray, which inhabitants generally in southern waters, has also reported to be causing serious damage to the bivalve stocks.

One species of ray, *Aetomylaeus flagellum*, which eats two to three hundred of jack-knife crab per day was caught to decrease the damage more than eighty tons in 2003 in the bay.

2) Nori

The Nori production has been increasing since 1960's, and it reached 60,639 ton in 1970, 92,913 ton in 1980, 121,732 ton in 1990, and it reached the maximum of 168,250 ton in 2001. The production of cultured Nori in the bay occupies about 40% of the total amount of Japan. And its economic value is estimated about 40 to 45 billion yen in recent years.

However, discoloration of cultured porphyra was widespread in the winter of 2000-2001, damaging the porphyra production. The discoloration was thought to be caused by a shortage of nutrients as a result of the unusual environmental conditions such as a large amount of precipitation in the fall, longer daylight hours far exceeding normal years and repeated occurrence of atypical algal blooms. The production felt to 91,146 ton in that year. It showed the lowest value in the past 25 years (Fig. 6).

3) Fish and Crustacea

Commercially important fishes such as flat fishes, puffer and crustaceans such as blue crab are caught in the bay. However, their share in the total catch is small and the amount of catch has never exceeded 20,000 tons. Annual fluctuation is relatively small but a gradual declining tendency has also been noticeable in the 1990s (Fig. 7).

Present and future program

1. Monitoring

- Ocean environment (physical, chemical and plankton data)
- Harmful algal bloom (resting spore)
- Eggs and larvae distribution

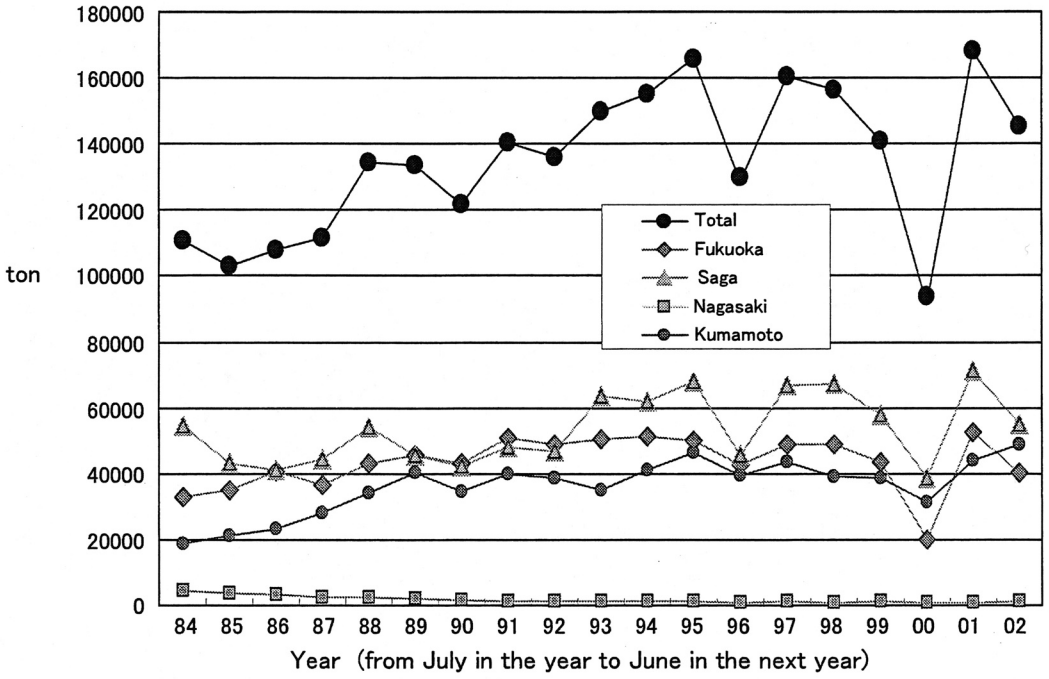

Fig. 6. Nori production in Ariake Bay

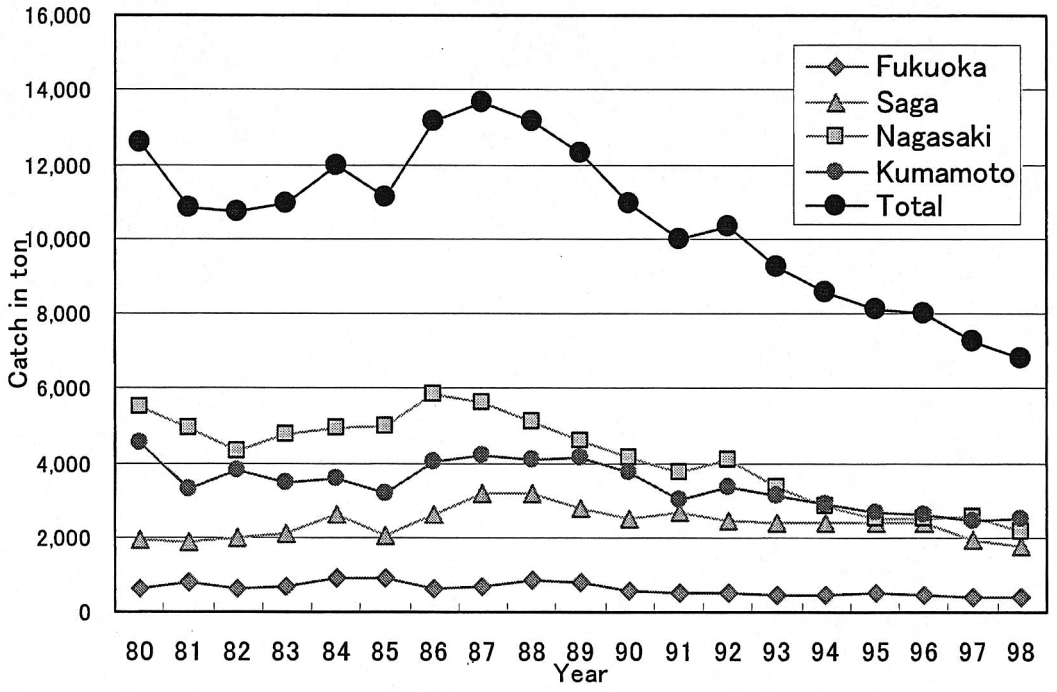

Fig. 7. Catch of the wild fish in Ariake Bay

・Hypoxia : mechanism of trigger technique of elimination

The bivalve catch and Nori production are undoubtedly the main fisheries production in the bay, but the production is not stable. Therefore, it is an important issue to restore the bivalve resources and to maintain the steady production of Nori. Additionally, it is requested to improve the

habitat environment, especially quality of water and sediment. It is known that the improvement of sediment quality can be achieved by irrigation and/or covering by sand. More investigation of the effectiveness and long-term persistence of these methods are necessary and also trying to develop more effective techniques to restore the sediment environment is needed. And also investigating formation mechanisms of hypoxia is proceeding in order to find where hypoxic conditions will form, when they will form, how large an area it will affect, what will trigger hypoxia, and how to eliminate it.

Other related research includes a development of techniques to prevent harmful effects of excessive algal blooms on cultured Nori as well as to predict an outbreak of excessive algal blooms.

2. Restoration

・Release of seeds (fish, bivalve, shrimp, crab)
・Breeding (algae)
・Sediment quality (irrigation, covering by sand)

We also have strong research programs on seeds for release including fish and shellfish, breeding of high-temperature, low-nutrient resistance Nori in order to restore fisheries resources and to maintain sustainable fisheries in the bay. So it should be continued to monitor the present status and to be developed some techniques on the restoration. And it would be considered to synthesize the carrying capacity and production in the bay.

References

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