An Important Problem for Oyster Farming in Enclosed Coastal Waters

YOSHIO SUGAWARA and KENJI OKOSHI
Department of Biotechnology, Faculty of Science and Technology, Senshu University of Ishinomaki, Ishinomaki, Miyagi, 986 Japan

Originally, oyster farming was performed at enclosed coastal waters where nutrient salts-containing rivers streamed in from the land, such as Matsushima Bay in Miyagi Prefecture. However, many-sided use and pollution of such coastal waters caused reduced productivity and mass mortality. As the results, such an original oyster farming was forced to be changed into so-called off-shore culture, seeking for more clear sea water, as well as changes in the culture method from rack method to raft method and further to long-line method. Commercial value of oysters, however, is now decreasing considerably, because easygoing off-shore culture taking no account of biological characteristics of oysters has yielded new problems, such as a so-called "oyster with residual eggs" caused by abnormal reproduction and growth and a type of shell formation called "shell chamber formation", in which empty layers are formed in a part or most of a shell. In this paper, history of oyster farming will be summarized, current problems will be made clear and then future direction for coastal water oyster farming will be discussed from the viewpoint of (1) biological characteristics of oysters, (2) safety as sea-food materials and (3) maintenance of coastal waters as aquatic environment.

Sea food has always been an important item of Japanese diet. Oyster farming is being performed in various districts ranging from Hokkaido to Kyushu, and oysters of 90% of the total production in Japan are produced in Hiroshima, Okayama and Miyagi Prefectures (Fig. 1). Specific oyster farming methods have been developed independently, reflecting characteristics of fisheries and economic structure of each district (Korringa, 1976).

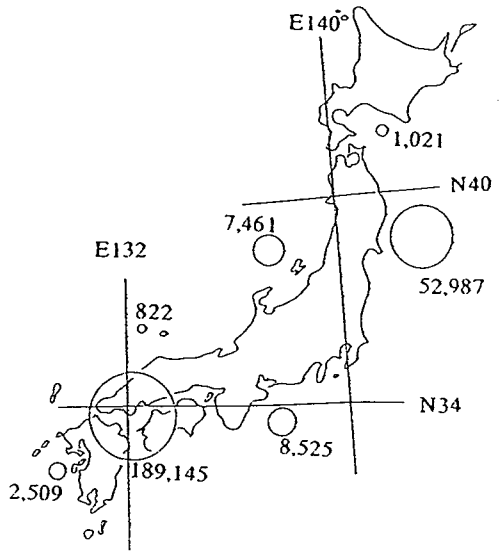

Fig. 1. Regional production of oysters with shell in Japan, in tonnes.

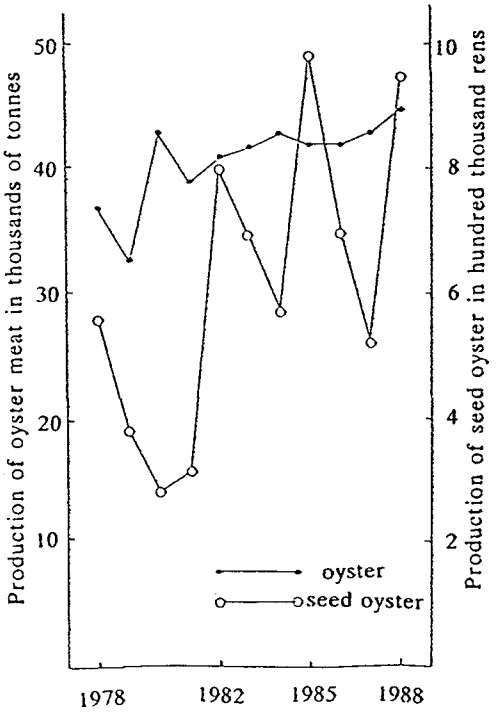

Fig. 2. Production of oyster meat and seed oyster in Japan.

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Oyster farming in Miyagi Prefecture

There are 40 or more oyster shell mounds in peripheral areas of Matsushima Bay. It can easily be considered that a large number of oysters had been obtained from the bay, though these mounds were formed over a long period of 4,000 to 5,000 years started in the early Jomon period until the beginning of the historic era. Such being the case, oysters have been used as relish by people from time immemorial, but are now being produced artificially in a large scale because naturally produced oysters are not enough to satisfy the demand.

In former days, oyster farming at a sea area was a peaceful sight, such as harvest by making racks or rafts at an enclosed calm coastal waters. Nowadays, however, farming sea areas have been expanded through changes in the farming method from the simple hanging method to a raft method and further to a long-line method, in order to use sea areas more effectively like the case of the changes in the living environment on the land, thus rendering possible oyster farming at high seas which was once considered impossible (Imai, 1977).

Naturally, marine environmental condition is an important factor for oyster farming. Recently, however, pollution of enclosed waters has been increasing, thus making rearing at inner area impossible at many bays. In consequence, in concert with the rush out of the farming into high seas with the improvement of farming technology, the rearing ground has been moving from the inner area to the mouth and further to the outside of the bay. At coastal waters of Sanriku district where waves are high, rearing grounds of oyster, *Crassostrea gigas* have been expanded outside of bays by applying a long-line culture method.

The present state of oyster farming in the whole areas in Miyagi Prefecture is that the number of oyster-farming private enterprises and the amount of the production have recently been increasing slightly due to the increasing demand and state cost, but with serious problems such as aging of rearing grounds due to repeated use of the same ground and reduction of the productivity due to extended rearing period caused by dense culture. Consequently, it is difficult to expect sharp increase in the oyster farming in this prefecture (Fig.2).

Naturally, production of seed oyster which are important for the oyster farming is related closely to the biological conditions of an oyster itself, such as maturation, discharge of eggs or sperm, fertilization, development, planktonic stage and settlement, as well as oceanographic factors such as water temperature, salinity, tides and topography, and feeding conditions, because oyster larvae grow up through planktonic life and perform metamorphosis and settlement (Sugawara, 1984). In other words, Matsushima Bay has been the one where all of these conditions were satisfactory.

Production of seed oyster at Sendai Bay had once been dependent upon oysters cultured at Matsushima Bay as adult stock of planktonic larvae until 1950's. After that, however, main adult stock for the collection of seed oyster has been changed to late spawning groups at farming ground near the Oshika Peninsula, because the mass mortality of oysters occurred in 1960's at Matsushima Bay has caused drastic decrease in the number of cultured oysters. In addition, delayed spawning season caused by changes in the strength or speed of Oyashio and low water temperature in summer has often been resulted in poor harvest of seed oyster.

Problems of oyster farming

In spite of the long history of oyster farming and active studies on biology of oyster, development and improvement of oyster farming techniques is now in a stagnant state due to the reduction of the number of farming grounds triggered by the recent remarkable modernization of cities and creation of lands and water pollution originated from industries, fisheries processing industries and agricultural chemicals. In addition, as described above, aging of farming ground due to repeated production processes, especially deterioration of environment of coastal farming ground, resulted in the necessity of replacement of farming facilities along with the introduction of intensive farming, thus delaying the rate of growth and fattening and the spawning season. Such a fact makes planned spat collection unstable, because the season of spat collection is

delayed and repeated collection of seed oyster becomes impossible, and such an unstable collection of seed oyster becomes the cause of a vicious circle of further delaying the growth and fattening.

Next, biological characteristics of oysters are described taking temperature and oyster races as examples. Generally in oysters, period for the brooding of eggs becomes short and the number of spawning times becomes small as they migrate from high water temperature seas in southern districts toward low temperature seas in northern districts and, in the same manner, the size of reproductive organs and the number of eggs per one spawning increase. At the same area, the time of spawning and sperm-release is slightly early in oysters who inhabit surface layers compared to deep layer-inhabiting ones, and larger individuals brood higher numbers of eggs and mature early. AS illustrative data, a temperature at which 80 to 90% or more of fertilization rate can be obtained after the discharge of eggs and sperm by *Crassostrea gigas* is 15 to 30.5 ℃, and a temperature at which 80 to 90% of fertilized eggs reach D-shape larvae through normal progress of division and development after the fertilization is 19 to 27℃. At the lower limit of these temperature ranges, however, a delay in the progress of development and a decrease in the setting rate are observed. Similarly, salinity also imparts effects of changing the rate and ratio of development, growth and fattening.

Regarding the oyster races, Imai and Sakai (1961) have performed breeding studies by collecting samples of *Crassostrea gigas* from various districts in Japan, performing pure line and varietal crossings for three generations and hanging the resulting breeds into sea waters at farming grounds in various districts and found that growth, shell morphology, mortality during rearing, releasing time of eggs and sperm, glycogen contents and taste varied depending on the local type of oysters. They have also reported that crossing between these local varieties was achieved easily and any of the shell morphology, growth and glycogen contents in F_1 hybrids showed intermediate properties of the parents. The representative varieties of *Crassostrea gigas* in Japan, Miyagi race and Hiroshima race, have each own characteristics and Miyagi race is fitted for use in northern districts in Japan while Hiroshima race is fitted for use in southern districts. Though actual numbers are not clear, seedings of Hiroshima race are now being applied to oyster farming due, mainly, to the fact that the mortality of Hiroshima race was low compared to that of Miyagi race when the production of seed oyster was poor or mass mortality occurred at Matsushima Bay.

The first problem arisen under such present situations is the structure of shell chamber (Okoshi *et al.*, 1987) which caused no problems when oysters had been sipped in shucked forms. Elucidation of the cause of shell chamber formation is now a pressing subject to be solved. It has so far been revealed that there are some farming grounds with oysters having greater number of shell chambers, while such a number is small at certain grounds which located relatively enclosed-type waters with gentle farming water surface (Okoshi *et al.*, 1986). In addition, a possibility has been suggested that the formation of shell chambers is related to the environment of farming ground and used seed oyster. As the second problem, application of Hiroshima race adapted to the southern warm waters to the northern cold waters has resulted in a disturbance in ovaries, that is a residual egg which appears in and after autumn in Hiroshima race caused by the great changes in the living environment. Such a residual egg development has not been observed in Miyagi race.

From a distribution point of view in terms of the popularization of and increasing demand for half-shell oysters, such a shell chamber formation and an oyster with residual eggs which appears early in winter have been reducing commercial value of oysters. At least, application of Hiroshima race to northern waters must be examined at an industrial scale. With regard to the amount of products, oyster farming has been growing satisfactorily since 1950's, but environmental deterioration of farming grounds in each district has resulted in the diversification of techniques from the collection of seedings to harvest and increase in the manpower. Especially, disordered introduction of varieties has disturbed technical system of oyster farming and resulted in the creation of many problems. In other words, since each farming ground has each own environmental characteristics in terms of shell growth and flesh fattening and there are many varieties having local characteristics in Japan, it is important to find proper

capacity of facilities and proper farming system by applying these characteristics rationally.

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