水研センター研報，別冊第1号，13－18，平成16年
Bull. Fish. Res. Agen. Supplement No. 1, 13-18, 2004

The decline of Manila clam stock in Tokyo Bay

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Abstract The fisheries production of Manila clam in Chiba Prefecture, which amounts to more than 90 % of the total clam production in Tokyo Bay, markedly declined to below 20,000 metric tons (mt) in 1979, after reaching 70,000 mt at its maximum in the late 1960s. This is mainly because of the large-scale reclamation of the shallow tidal areas where clam fisheries were intensively operated. However, the clam production keeps gradual decreasing even after the cessation of the series of reclamation in 1979. The periodical monitoring of clam stocking density shows decreasing of clam production since 1985 seems to be associated with the poor occurrence of wild juvenile clam. In Kisarazu Area, which is the largest Manila clam producer in Tokyo Bay, production is stably maintained between 5,000 and 6,000 mt since late 1980s, in spite of the stocking density of juvenile clam (4-11 mm in shell length) declining from 68 to 12 inds/m^2 during this period. It is probably due to 2,000-3,000 mt of the transplantation of the seed clam (>20 mm) from other area in Tokyo Bay and other prefecture. On the contrary, in Northern Chiba Area, where the clam fisheries relies only upon wild clam stocks without any transplantation, the clam production has sharply declined from around 10,000 mt in late 1970s to 800 mt in 1999 reflecting directly the poor occurrence of wild juvenile clam. The cause of the substantial decline of the wild juvenile clam is still not known.

Key words: Manila clam, Tokyo Bay, stock decline, early life cycle, coastal development

Along the coast of Tokyo Bay, the clam fisheries and culture have been operating in the tidal and shallow water area since before the World War II. Before 1960s, harvested species were mainly hard clam, Manila clam, surf clam, blood cockle, Pacific oyster, and others. However, at the present, only Manila clam and surf clam dominate the bivalve fisheries production.

The annual production of Manila clam in Chiba Prefecture, which occupies most part of the production in Tokyo Bay, reached its peak in late 1960s over 70,000 mt (Fig. 1)*[2]. Then the production declined markedly to below 20,000 mt mainly because of large-scale reclamation of coastal area, where the clam fisheries intensively operated. However, the clam production is only about 8,000 mt in 1999 as a result of continuous and gradual decline even after the cessation of the coastal development. This recent decline in Manila clam production is the major problem of the clam fisheries in Tokyo Bay; however, the exact mechanism responsible for the decline is still not well understood. In this manuscript, I show the details of this problem and several probable factors responsible for this decline.

2003年6月12日受理（Received on June 12, 2003）
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*[2] Statistics of fisheries and culture production of manila clam are quoted from Annual Statistic Report of Agriculture, Forestry and Fisheries in Chiba.

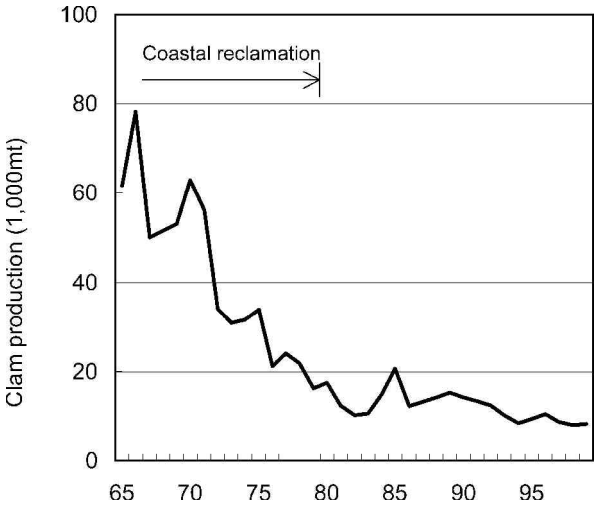

Fig. 1. Annual production of Manila clam in Chiba Prefecture after 1965.

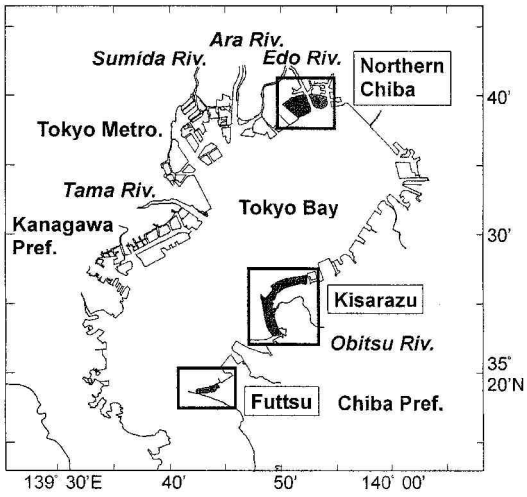

Fig. 2. Culture and fisheries area of Mania clam in Tokyo Bay.

Culture and fisheries areas in Tokyo Bay

Three major areas of clam culture and fisheries in Tokyo Bay, Northern Chiba, Kisarazu, and Futtsu, are located east coast of the bay in Chiba Prefecture (Fig. 2). Each of them has somewhat different operating patterns from the other. For instance, the production in Kisarazu is mainly based on the transplanted clam from outside of the area, while in Northern Chiba production relies only upon its domestic clams that naturally occur. This is due to their historical customs of fisheries as mentioned later, probably being formed through decades under their natural environment and reproductive characteristics of the clam.

Recent variations of Manila clam production in these two areas show quite different patterns; drastic declining in Northern Chiba and relative stability in Kisarazu.

Northern Chiba

Northern Chiba is located in the bottom inside of Tokyo Bay. West, east and North of the area are surrounded by reclaimed land, and Ichikawa Sea Route divides the area into west and east. The bottom level of this area is almost 0 to −2 m in tidal level; the bottom surface is not completely exposed to air even while ebb tide.

As the production in this area relies only upon naturally occurring clams, the clam production has relatively large fluctuation (Fig. 3). With fluctuation, the clam production tends to decline in these years, especially in 1990s. The production in 1999 is only about 800 mt.

Despite recent poor production, fishermen do not transplant any seed clams except during small-scale experimental culture trials. This is because that the naturally occurring clams were so abundant in this area that they did not have to use any stock enhancement for a long time. And also because, this may be the pri-

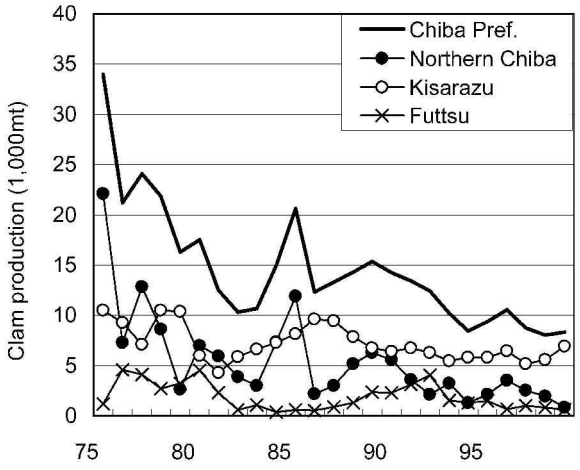

Fig. 3. Annual local production of Manila clam in Chiba

mary reason, the transplantation is highly risky for them economically, as the frequent mortality will collapse the plans of the clam growing and harvesting in this area.

In this area, unpredictable accidental mortality often have occurred. Some of them were caused by Aoshio (blue tide), upwelling of the oxygen-deficient seawater from the bottom of the subtidal zone. When the strong wind blows in the direction from the land to off shore during spring and fall, bottom seawater comes up as the counterbalance of the surface seawater that moves away to offshore (Kakino *et al.*, 1987).

Ichikawa Sea Route, which runs through the middle of the area, is connecting to Edogawa Flood Control Channel. When the water level of Edogawa River rises beyond a certain level due to the heavy rain, such as the case in the typhoon, the floodgate is opened and a great deal of muddy fresh water flows out. Then the salinity of seawater reduces extremely for days, and the mud deposits more than 10 cm in thickness in certain cases and covers the bottom surface for weeks or months. During 15 years from 1985 to 1999, any mass mortality was absent only 6 years in this area (Kakino, 2000). In addition to the mortality of the adult clam by smothering and burying, the mud deposition may inhibit the new recruitment of clam larvae.

Furthermore, population density sharply declines in winter every year (Fig. 4). In 1994-1998, the clam density reached annual peak in summer season, more than hundreds ofinds/m^2, and decreased to below 100 inds/m^2 in winter. Winter mortality is considered to be caused by complex interaction among several factors (Chiba Pref. Fish. Exp. Stn. and Chiba Pref. Fed. Fish. Co-op. Union, 1998). Firstly, the reduction of clam viability by the low temperature and low food condition in winter. Secondly, disturbance of the bottom surface by the stronger wave action in this part of the season. This is related to the subsidence of the land level due to drawing up large volume of ground water during coastal development. By the reduction of the land level, large wave directly reaches deep inside the shallow area. Besides these factors, the predation by some kinds of mallard, which migrate to this area during winter, is also an important factor (Chiba Pref. Engineering Dept. and Chiba Pref. Enterprise Dept., 1999).

Until mid 1990s, the population density of the total clam was constantly above 400 inds/m^2 in spite of the mortalities. That was due to the quick recovery of clam stock after the mass mortality. However, the clam density began to decline rapidly after late 1990s, and it still continues. In particular, the low density of juvenile clam after 1990s is characteristic feature of this area (Fig. 5).

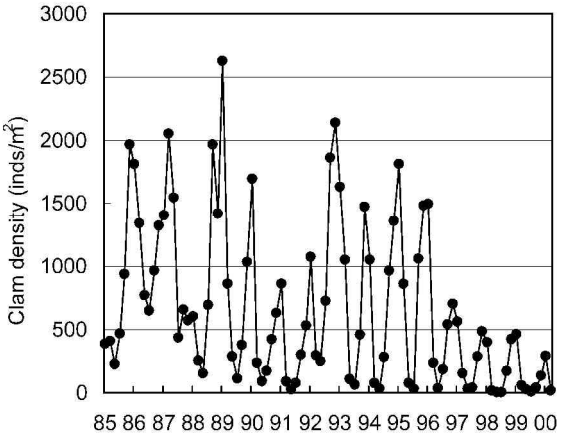

Fig. 4. Seasonal change of the stock density of Manila clam in Northern Chiba.

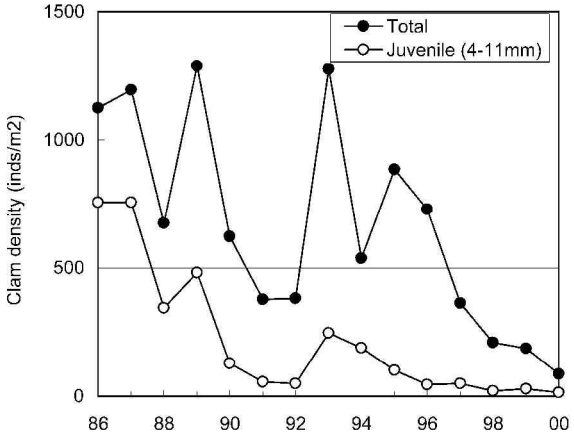

Fig. 5. Changes in the stock density of Manila clam in Northern Chiba.

Kisarazu

The culture and fisheries ground in Kisarazu, which is located in the east coast of the central Tokyo Bay, is the tidal area of bottom level −2 to +1 m in height. The clam production in this area is the largest in Tokyo Bay. The major production of clam in this area relies upon transplanted seed clams. As the density of naturally occurring juvenile clams is relatively low, there remains large tidal area that is used for culture.

The clam production from the transplanted plot from 1986 to 2000 is about 4,000 to 6,000 mt and that from naturally occurring plot is 200 to 1,100 mt. Thus, production from naturally occurring plot is only 6 to 25 % of that of transplanted plot. After 1986, the annual amount of transplanted seed clam, which is introduced from other clam-producing district in southwestern Japan, is 2,200 to 5,000 mt. The shell size of transplanted clam was about 20 mm in length. Recently, the clam size of 25 to 30 mm, which is the minimum size of the clams circulating the commercial market for the human consumption, is used as the seed. This reflects the decline of naturally occurring juvenile clams all over Japan.

The density of naturally occurring juvenile clams in Kisarazu decreased from about 70 to 10inds/m^2 during 1989 and 2000 (Fig. 6). Despite that, the stable total clam production in this area is supposed to be owing to large amount of the seed transplantation. The period of consistent decline of juvenile clam is common to that of Northern Chiba.

Factors common to Northern Chiba and Kisarazu

I think I can indicate some of the probable factors responsible for the decline of clam stock as local and common factors (Table 1). As mentioned above, the poor occurrence of wild juvenile clam is common characteristics to these two areas. Therefore, I am paying attention to the early stage of the life cycle of the Manila clam in Tokyo Bay.

Table 1. Probable factors responsible for the decline of clam

1 Local factors (Northern Chiba) • Accidental mortality by blue tide (upwelling of oxygendeficient seawater) • Accidental mortality by river flood • Winter mortality
2 Common factors to the areas • Reduction of entire habitat by the coastal reclamation • Contraction of the effective spawning period • Larval mortality due to oxygen deficient seawater

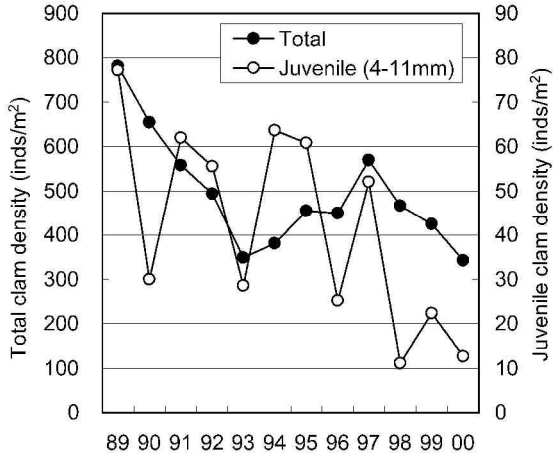

Fig. 6. Changes in the stock density of Manila clam in Kisarazu.

One of the most important factors influencing the decline of clam stock may be reduction of the habitat area (Fig. 7). Results of the investigation in 1945 and 1985 show that nearly 90 % of the tidal area was lost.

Manila clam has the spawning period in warm water season; May to October in Tokyo Bay. Newly hatched larvae have a strong negative geotaxis, and 2 to 4 weeks of swimming period until settlement. From the results of the studies on the seawater current, the larvae, which are spawned at the coastal area, may be dispersed and transported throughout the bay, and mixed during the swimming period. The bay area may play an important role as the habitat of the larval stage for the Manila clam

population in Tokyo Bay. While the shallow or tidal coastal area has reduced greatly in the past few decades, the bay area is almost constant. The reproductive potentiality of the Manila clam in Tokyo Bay is reduced by decline of the total fecundity of the adult clam. Furthermore, the larvae dispersed all over the bay have much less chance to get back to the scattered shallow areas where they can settle.

Manila clam has two peak periods of gonadal maturation in a year; spring and autumn in Northern Chiba. While the fecundity of clam seems greater in spring spawning (Toba *et al.*, 1993), adult density in spring is very low because of the winter mortality. The clam population in Northern Chiba may not spawn effectively in spring season.

The peak spawning period of Manila clam in Kisarazu is suspected to be once in a year during summer months from the observation of the seasonal changes in condition factor. And the transplanted clams that have different seasonal reproductive patterns from native clams may influence the low peak values of condition factor in the clam population in Kisarazu.

Three peaks of the larval density were recorded in post summer months, August, September, and November at the adjacent points of Northern Chiba from May to December in 2001. The peaks of postlarval density, smaller than 0.4 mm in shell length, were observed 2 to 4 weeks after the peaks of larval abundance. In Kisarazu as well, the peaks of the larval and postlarval density were observed in post summer months during 2000 and 2001. Substantial spawning and postlarval recruitment for the clam population may contract to post summer in Tokyo Bay in these years.

During the warm water season from May to October, the bottom layer of the large part in bay area is covered by oxygen-deficient seawater (Ishii, 2003). The thickness of oxygen-deficient layer often grows more than several meters especially in north bottom side of the bay. Although the thickness of oxygen-deficient bottom layer gets lowered temporally by the stormy weather, it builds up quickly again under the calm weather within few days. Thus, oxygen-deficient seawater lies intermittently during whole warm water season. As the larval swimming activity is markedly reduced in oxygen-deficient seawater, continual appearance of oxygen-deficient layer may affect the survival of larval population in Tokyo Bay for months.

Conclusion

I suspect that not only the sharp decline of Manila clam production before late 1970s in

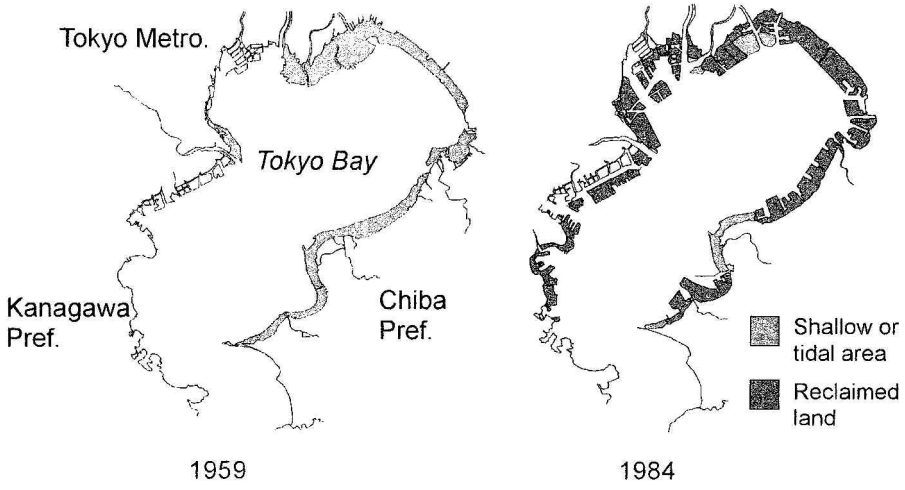

Fig. 7. Reduction of the clam habitat in Tokyo Bay during 1959-1984.

Tokyo Bay but also the gradual decline afterwards may be affected by the series of the coastal reclamation that ceased in 1979. One of the marked and common characteristics of the clam populations in local areas during latter period is continual decline of the recruitment of natural juvenile clams. Reduction of adult population, contraction of reproductive period, larval mortality caused by oxygen-deficient seawater, and reduction of shallow or tidal area for larval settlement may involve poor recruitment of juvenile clam. Temporal mass mortality including adult population caused by the blue tide, river flood, low temperature and wave action, predation by the birds seems to accelerate the decline of clam stock.

The ecological impact on the clam population by the artificial modification of their habitat and hypertrophication of the bay area may appeare through certain period as long as more than 20 years. Unfortunately, however, as mentioned before, the exact mechanism responsible for the decline is still not well understood.

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