Environmental Problems and Environmental Management of Japanese Coastal Waters: An Ecosystem Perspective

Hideaki NAKATA
Associate Professor
Ocean Research Institute
University of Tokyo

presented at the
ESENA Workshop:
Energy-Related Marine Issues in the Sea of Japan
Tokyo, Japan
11-12 July 1998

ABSTRACT

The coastal marine environment of Japan is characterized by its high biological productivity, which contributes to generally high fishery yields. However, both the productivity of coastal ecosystems and coastal fisheries are being threatened by substantial changes in the coastal marine environment. This situation is making it increasingly imperative to take an ecosystems approach to management of the coastal marine environment. Pollution due to rapid industrial development and urbanization, and engineering project are the primary causes of the degraded condition of the coastal environment. The goal of this paper is to briefly describe some of the present environmental problems in Japanese coastal waters, especially in relation to the fishing industry, and to discuss mitigation and management of these problems from an ecosystem perspective.

TABLE OF CONTENTS

1. Introduction

Japan's coastal and neritic environments[1] are characterized by their highly diversified collection of ecosystems and high biological productivity. The high biological productivity in turn contributes to high-yielding coastal fisheries. Biological productivity and coastal fishery yields have been on the decline in recent decades, though. The sources of these declines are many. Some, for instance, are related to industrialization and urbanization, and some are related to fishing practices.

Traditional coastal fishery practices have generally maintained healthy productivity of coastal and neritic waters. However, the modern coastal fishery industry has contributed to the damage of coastal habitat and ecosystems through their fishing operations, and through overfishing and by-catch problems (Nakata, 1995). In addition, the overloading of organic materials, such as leftover food and fecal pellets from aquaculture grounds, have degraded the water and bottom area quality in semi-enclosed bays. As will be argued later in the paper, development of sustainable coastal fisheries have a key role to play in the conservation of the marine environment in Japan.

Fishing practices, however, are not the most serious threat to Japanese coastal and neritic waters. Industrialization and urbanization are more serious threats. In the postwar period, pollution caused by industrial development and urbanization, along with secondary effects of industrialization and urbanization such as red tides, oxygen depletion in bottom waters and oil contamination, have considerably degraded the coastal environment (Table 1).

Table 1: Frequency of Reported Fisheries Damage Caused by Water Pollution in Coastal Waters

Year	1980	1986	1987	1988	1989	1990	1991	1992
red tide	42	36	47	40	22	42	30	37
oil	137	66	59	66	71	48	43	52
others	32	23	34	28	25	27	17	15
Total	211	125	140	134	118	117	90	104

In addition, engineering projects, such as dredging, reclamation, and construction of marine facilities, have led to the loss of coastal nurseries and habitats. According to the Environmental Agency of Japan, the total loss of tidal flat lands between 1978 and 1988 was about 4,000 hectares, which is equivalent to about 8 percent of the existing tidal flat areas. Another source reported that about 40 percent of the tidal flats that existed in 1945 were lost by 1988 (Kikuchi, 1993). Since most commercially valuable coastal fish species spend their larval and juvenile stages in coastal nurseries such as tidal flats and seaweed beds, it is essential to preserve these areas to maintain the viability of the coastal fishing industry.

Concentrations of some pollutants in the marine environment have improved since the 1970s when enforcement measures were first undertaken in Japan. However, concentrations of other pollutants, including some heavy metals and organic contaminants (e.g., PCBs, PAHs and TBTs), have increased. (Tanabe, 1995).

On top of the above problems, in recent years some of the shallow seas in the northern part of Japan have been suffering from a phenomenon known in Japanese as "isoyake" (or sea desert). Isoyake occurs when sublittoral marine algae such as *Eisenia bicyclis* (Phaeophyta) are replaced by dense crustose coralline red algae, resulting in rapid reduction in productivity and biodiversity (Taniguchi, 1991). Although the exact cause of isoyake has not yet been identified, there is an urgent need to develop methods to restore the original marine forests of *E. bicyclis* in isoyake-affected areas.

In a global context, sustainable use of renewable marine living resources is indispensable for the future development of human society. In general, economic development aims to maximize short-term benefits, whereas maintenance of ecological integrity aims to maximize long-term benefits. Sustainable development seeks to balance economic goals with ecological integrity. This applies to sustainable development of coastal waters as well as other air, land, and water resources. An optimal development strategy should consist of both the short-term goal of raising production efficiency and the long-term goal of restoring and maintaining ecological quality. It is not easy to put this into practice, though.

In Japan there is growing interest in pursuing sustainable development by restoring and/or enhancing the proper ecological functioning of aquatic environments. Pilot projects have recently been started which aim to restore or create fishery industry-related coastal habitats (Nakamura, 1991; Itosu, 1993). However, most of these projects focus mainly on engineering solutions to productivity enhancement, not ecologically-based solutions. The goal of this paper is to briefly describe some of the present environmental problems in Japanese coastal and neritic waters, primarily in relation to the fishing industry, and to discuss mitigation and management of these problems from an ecosystem perspective.

2. Environmental Problems in Japanese Coastal Waters

2.1. Dissolved Oxygen Depletion

Among the factors controlling environmental carrying capacity of coastal living resources, dissolved oxygen (DO) concentration is the most critical (Nakata, 1991). In Japan the formation of DO-depleted waters near the bottoms of some hypereutrophicated bays have significantly affected the benthic living resources of the bays. When nutrient loads from the land are small, eutrophication can increase fishery production, and fishery catches can contribute to the removal of organic products from the bays. However, when nutrient loads exceed a certain limit there emerge negative feedback processes. Eutrophication is succeeded by rapid growth of phytoplankton (outbreaks of red tide, etc.). This leads to an increase in the organic flux to the bottom waters. Increased organic inputs in turn deplete the bottom waters of oxygen. And this further accelerates eutrophication through nutrient regeneration from the bottom sediments. Ultimately, DO depletion damages the habitats of fishery resources, and inhibits removal of organic products.

Annual changes in nutrient loadings from the land around Osaka Bay—a bay representative of a heavily urbanized region in Japan—from 1955 to 1982 show that both nitrogen and phosphate loadings to Osaka Bay rapidly increased until the early 1970s . In the early 1970s phosphate began to decline, but nitrogen maintained an increasing trend. There is concern that the difference in the phosphate and nitrogen loadings could lead to problems which may affect biological production in the bay due to a change in the overall nitrogen-phosphate ratio. In general, primary production in the bay seems to have increased in response to increased nutrient loading. This may enhance the production of pelagic (open ocean) fish, while benthos (dwelling on or in bottom sediments) and demersal (dwelling at or near the bottom) fish production may start to decline owing to DO deficiency (Kurimoto and Kuramoto, 1992). With regard to demersal fish and shellfish, responses to increased nutrient loading are different according to species (Joh, 1991). Catches of mantis shrimp and flat fish declined in proportion to phosphorus loadings which exceed 14 tonnes per day, while those of octopus, shrimp, and crab started to decline at smaller phosphorus loadings (less than 5 tonnes per day).

Although the exact mechanisms of such qualitative changes in the fishery catches has not yet been clarified, it should be noted that of the commercially most valuable species, first demersal fish, and then shellfish populations, decline at a rate corresponding to the extent of eutrophication, and may be replaced by less commercially valuable small pelagic fish populations. In fact, in the Seto Inland Sea, of which Osaka Bay is a part, fishery catches of higher-priced demersal species, such as red sea bream, kuruma prawn and octopuses, show a declining trend in the first and second phases (1963 to 1975) of the eutrophication process, while lower-priced pelagic and mesopelagic plankton feeders, such as sardine, anchovy and sand lance, rapidly increased during the same period (Tatara,1981). Although it is necessary to look at the combined effects of eutrophication and increased fishing efforts toward capturing higher-priced fish species, these above trends probably illustrate an alteration in catch composition due to the effects of eutrophication.

As another example of change in fish species composition, in the innermost part of Tokyo Bay most macrobenthic species disappear during the period when DO depletion is observed on the bottom during the summer, and azoic (lifeless) areas can often be found in late summer. Furota (1991) pointed out that these azoic or almost azoic bottom conditions tend to be found under a DO concentration of less than 2 milligrams (mg) per liter on the bottom. This suggests that a 2 mg per liter DO concentration is a cutoff limit for survival of macrobenthic populations in the innermost part of Tokyo Bay. As a result of strict enforcement of laws controlling waste water since the 1970s, water quality in Tokyo Bay has gradually improved, and fauna in the bay, including commercially valuable species, have correspondingly increased to the increase in DO levels (Shimizu, 1988). However, according to a numerical model estimate of the DO balance in Tokyo Bay required to maintain the DO concentration above 2 mg per liter all year round, the present nutrient loading into the bay must be reduced by nearly 50 percent (Kuramoto and Nakata, 1991).

A striking example of the recovery of animal species that were on the verge of extinction is that of Dokai Bay located near the western entrance to the Seto Inland Sea (Yamada et al., 1991). This bay suffered from excessive water pollution caused by industrial and chemical wastes during the first half of the century. However after enforcement of wastewater laws in the 1970s, water quality improved, and most animal species recovered. The commercial fisheries of kuruma prawns (*Panaeus japonicus*) which had been abandoned earlier were even restarted in 1983.

2.2. Loss of Tidal Flats and Seaweed Beds

One of the most serious causes of deterioration in the quality of Japanese coastal waters is the loss of tidal flats and seaweed beds. Tidal flats and seaweed beds are localized zones of high biodiversity where pelagic and benthic ecosystems interact. The high biodiversity contributes to high biological productivity. Coastal engineering works such as reclamation projects and dredging are mainly responsible for the loss of these areas. More than 80 percent of the coastline of Tokyo Bay between 1950 and 1988 has been reclaimed since the Second World War, mainly for the industrial development, and the remainder is still threatened by development (Ishikawa et al., 1991).

The loss of tidal flats and seaweed beds, in addition to directly affecting biodiversity and bio-productivity, has exacerbated eutrophication problems because these areas play a significant role in the removal of nutrients and organic materials. Horie (1991) proposed that water and bottom quality can be improved by restoring the habitats (i.e., the tidal flats and seaweed beds) of benthic animals.

Parallel to the loss of tidal flats, seaweed beds, such as eelgrass (*Zostera marina*) beds, have also rapidly disappeared. According to the Nansei (formerly Naikai) Regional Fisheries Research Laboratory, approximately 53 percent of all the original eelgrass beds in the Seto Inland Sea were lost by 1965. Furthermore, half of the remainder disappeared between 1965 and 1971, and by 1971 eelgrass beds occupied only 2.1 percent of the total area shallower than 10 meters. Azuma (1981) warned almost 20 years ago that in areas where eelgrass beds were prominent, rapid simplification of the animal community occurred when such an area was reclaimed. He also pointed out that serious decline in the eelgrass beds could be accompanied by reduction in catches of small shrimp, crab, red seabream and other species which depend on the eelgrass beds during their life cycle.

2.3. Isoyake (Sea Desert)

Coastal reef areas in the northern part of Japan have suffered from isoyake in recent decades. Isoyake is characterized by a replacement of sublittoral brown algae, such as *Eisenia bicyclis*, the most typical species in marine forests along the Pacific coast of northern Japan, by less productive crustose coralline red algae. *E. Bicyclis* marine forests are known for their diverse animal communities. They serve as feeding habitat for commercially valuable marine species including sea urchins, and abalone and other reef fish.

The cause of the isoyake phenomenon is as yet unknown. One hypothesis is that it is caused by overgrazing by sea urchins (*Strongylocentrotus nudus*). Other hypotheses included competition for substrate with other algae, hydrographic changes such as temperature changes which affect the physiological conditions, and water pollution. A project was started in 1997 by the Japan Fisheries Agency to investigate the isoyake phenomenon and its possible biological and ecological causes. Independent of the cause, though, there is pressing need to restore marine forests areas devastated by isoyake so as to enhance their functions as marine nurseries and habitats (Taniguchi, 1990; 1991).

2.4. Pollution Due to Toxic Chemicals

(1) Heavy metals: The loading of heavy metals such as Hg, Cd, and Pb into coastal waters began around 1900, slowly increased in the decades before the Second World War, rapidly increased during the period of economic recovery and boom growth after the war, and began to taper off beginning in the 1970s. Heavy metal contamination peaked around 1970, corresponding to the peak loading from the land. The situation has improved in recent years; however the concentration levels are above background values of deep sediment samples.

(2) Oil: As compared to the period prior to 1975, there have only been a few incidents of major oil spills. This is probably due to the enforcement of regulations. The annual change in total weight of tar balls recovered at seashore monitoring stations by the Maritime Safety Agency of Japan significantly declined in early 1980s (Seko, 1994). This same trend is detected in the amount of drifting tar balls at the sea surface. Despite these trends, the recent oil spill from the Russian tanker *Nakhodka* in the Sea of Japan in January 1997 revealed the lack of a systematic response strategy for oil spills. It is urgent that a predictive and operational model be developed for preventing environmental damage caused by oil spills.

(3) Organic contaminants: Organochlorine compounds such as PCB (polychlolinated biphenyl), DDT (an organochlorine insecticide) and HCH (hexachlorocyclohexane) are known to be highly toxic and have a strong tendency to bioaccumulate, particularly in higher trophic levels of a marine food web. This is why the distribution and the effects of these substances on marine ecosystems have been of great concern in recent years. As far as the marine environment is concerned, these substances (which tend to be used on land surfaces) find their way to the sea and end up being accumulated in the sediment and in organisms which live in coastal waters (Tanabe and Tatsukawa, 1981). Even after the production of these substances was prohibited, their concentrations in the marine environment have only diminished very slowly.

In addition to organochlorine contamination pollution, there are newly emerging problems with other toxic chemicals such as TBTs (tributyltin-compounds), PAHs (polycyclic aromatic hydrocarbons), and dioxins. The Environmental Agency of Japan has been engaged in continual monitoring of these contaminants since the 1980s, particularly TBTs and dioxins. Preliminary results indicated that contamination by these toxic chemicals has expanded (Tanabe, 1995).

(4) Plastic wastes: Recent investigations by the Japan Fisheries Agency revealed that about 60 percent of the drifting debris in the North Pacific were made up of plastic wastes. Plastic wastes in Tokyo Bay made up more than 80 percent of the total debris collected with a demersal seine. The plastic wastes were mainly composed of various daily use articles, and rope and fishlines used by the fishing industry. It has been suggested that the plastic wastes injure marine animals either when swallowed or when animals become tangled with the debris.

3. Coastal Marine Habitat Engineering

Enhancing global food production in a sustainable manner is a high priority given the rapidly increasing human population. Since expansion of production on land is limited, many people are looking to the oceans, especially the coastal seas, as a food supplier in the future. If coastal areas are to be future sources in the future, their productivity will need to be enhanced through coastal habitat engineering designed in accordance with ecological principles.

As is indicated by the data presented in this paper, the present situation in Japanese coastal waters does not provide an optimistic view of the possibility of the regional seas of Northeast Asia being a greatly enhanced food resource in the future. Most areas are suffering from severe degradation of water quality and rapid losses of the coastal habitat. During the period of high economic growth in the 1960s and 1970s, the Japanese coastal environment, particularly around urbanized areas, was severely damaged. Vast economic growth was accomplished but at the cost of ecological degradation of coastal waters. Times have changed, and some attempts have been made in recent years to restore the coastal ecology. These efforts are aided by the field of coastal habitat engineering which includes such tasks as reef placement, marine afforestation, and upwelling enhancement (Nakata, 1995). Another effort is development of technology for pumping up deep, clean, nutrient-rich water. A pilot plant for utilizing deep water for aquaculture production is now operating in Kochi, on the southern Pacific coast of Japan. Knowledge about the structure, function, and impact of ecosystem enhancement measures and artificial ecosystem creation is still very fragmentary. More effort needs to be made to collect high-quality quantitative data relative to such manipulations of the environment.

Among various future tasks related to habitat technology, priority should be given to the restoration and creation of coastal nurseries such as tidal flats and seaweed beds. These areas play a very important role in the reproductive potential of most valuable fisheries resources. In this respect, it is imperative to investigate the ecological features of the natural system before designing artificial habitats. In fact, an intensive survey on the nutrient (nitrogen, in this case) budget of a tidal flat has recently revealed a new aspect of the ecological functioning of the tidal flat ecosystem (Matsukawa 1990). Matsukawa’s study demonstrated that a tidal flat consists of both plankton and benthic ecosystems which diversifies the food web system and probably enables nutrients to reside long enough to be converted into particulate material through biological production. Some of the nutrients are thereafter removed by marine species such as shellfish and seaweed. The effective trapping and removal of nutrients contributes to maintaining high productivity on the tidal flat. Improved knowledge of such mechanisms in the natural system will help guide habitat technology development.

A similar study showed the potential of artificial seaweed beds to remove nutrients from Tokyo Bay (Yamaguchi, 1993). It was estimated that the rates of nitrogen removal by large brown algae, such as arame (*E. bicyclis*), could amount to more than 20 percent of the total nitrogen load from the land if artificial seaweed beds were constructed to the maximum area extent possible in the bay. It should be noted, however, that large brown algae will not be able to grow and survive in Tokyo Bay if water quality remains high in turbidity and pollutant concentrations. This indicates that the first priority for making full use of artificial seaweed beds is to reduce the amounts of nutrients and pollutants in the bay to below a certain critical level. This suggests that production enhancement can only be achieved in tandem with the restoration of the entire ecological system.

Another important task related to coastal marine habitat engineering is to monitor ecological changes on a long-term basis. Yuasa (1995) present a recent example of long-term monitoring of the coastal fauna of benthic animals near Kure-city in the Seto Inland Sea. The numbers of species observed at six monitoring stations show rapid decline between 1960 and 1990. Inner stations started to decline earlier than outer ones. The number of species has not yet recovered even after enforcement of the Seto Inland Sea Conservation Law. Unfortunately, except for this study, there have been very few time-series data sets obtained on the ecological responses to change in the coastal waters of Japan. It is therefore urgent to establish a well-designed and operational monitoring network in the coastal and neritic waters around Japan.

Besides monitoring, computer simulation and other modeling and assessment efforts form are part of coastal marine habitat engineering. Soon after the enactment of the Basic Environment Law in Japan in November 1993, a national Environmental Impact Assessment Law was enacted. The objective of the Environmental Impact Assessment Law is to ensure that adequate consideration of environmental preservation is given in the implementation of projects. The law will enter into force in June 1999. Basic technical guidelines are now being prepared for the environmental impact process. An important task is to establish appropriate methods for the rational assessment of all possible risks to the marine coastal environment. A new method for assessing the human impact on coastal ecological systems related to the fisheries production has recently been proposed (Nakata and Hirano, 1989). Ecosystem modeling, however, has not yet been incorporated as a practical tool for this assessment, although there are high expectations that it will become a significant aid to the prediction of habitat changes and proper management of living resources (Nakata, 1991).

4. Ecosystems Approach to the Marine Environment

The Basic Environmental Plan, established by in 1994, outlines the government’s overall and long-term policies through the middle of the 21st century in environmental conservation. This plan sets the following four long-term objectives: to establish a socioeconomic system fostering environmentally sound cycling of substances, to ensure harmonious coexistence between nature and human beings, to build a society where all parties participate in environmental conservation activities, and to promote international environmental efforts. These objectives apply to conservation and restoration of the marine environment, as well as other areas.

To put these objectives into practice will require a new and integrated approach to the coastal environment in Japan. In short, it will require an ecosystems approach. Examples of new practices that will need to be a part of this ecosystems approach include, for instance, mutual cooperation between researchers working on working on land-related issues and sea-related issues in absolutely essential. This is especially true since the most productive areas in coastal waters are found in the zone between land and sea, i.e. tidal flats, estuaries, surf zones, etc. It has been pointed out in relation to seaweed bed construction in Tokyo Bay that cutback of material loading from the land into the bay is a prerequisite for utilizing the ecological functions of the seaweed bed to intake and remove excessive nutrients in the bay.

Another instance of the ecosystems approach is that fishermen engaged in coastal fishery and aquaculture activities must take actions to preserve and restore forests in watersheds neighboring their fishing grounds. Intact forests will contribute to maintaining the quantity and quality of the water discharged into the sea. This in turn may result in production enhancement of coastal fishing grounds. In fact, there is a history in Japan of forest reserves along the seashore being owned by fish associations (uotsuki-rin). However, their area has been reduced from 54,000 ha to 28,000 ha during the last four decades. Modernization of society has accelerated the collapse of traditional communities linking forestry and coastal fishery. Proof that reversing the trend will improve fishery catches it the example of the coastal fisheries catch near Cape Erimo in the southeastern part of Hokkaido Island which began to increase about 20 years after the establishment of a seashore forest.

In order to achieve the goals outlined in the Basic Environmental Plan, it is absolutely essential to realize that human beings are an integral part of the biosphere, sharing its limited energy and resources with other living beings. In this respect, Takahashi (1992) points out that an evolutionary switch in socio-cultural thinking is required. He postulates a switch from rule by modern technocrats, who base their choices on advanced high technologies, to rule by a new generation of “ecocrats”. These ecocrats prefer to maintain natural ecosystems on a sustainable basis in conjunction with utilizing their productivity. A technology and social system based on an understanding of ecosystems will forward the goal of realizing sustainable exploitation of the blessings of marine environment.

5. References

Azuma, M. (1981) Importance of Zostera beds as nursery ground for juvenile inshore fishes. In: Seaweed Beds, Japan. Soc. Sci. Fish. (ed.), Koseisha-Koseikaku, Tokyo, 24-56 (in Japanese).

Furota, T. (1991) Survival and population maintenance of macrobenthic animals in inner Tokyo Bay. Bull. Coast. Oceanogr., 28, 160-169 (in Japanese).

Horie, T. (1991) Functions of coastline features on water quality improvement. Bull. Coast. Oceanogr., 28, 152-159 (in Japanese).

Ishikawa, K., Y. Matsukawa and A. Wada(1991) A summary of "Symposium on Proposals for Restoration of Environmental Conditions in Tokyo Bay"., Bull. Coast. Oceanogr., 28, 170-173 (in Japanese).

Itosu, C. (1993) Marine innovation for fisheries in Japan. Proceedings of the Second International Conference on Fisheries and Ocean Industrial Development (FOID) for Productivity Enhancement of the Coastal Waters, National Fisheries University of Pusan, Feb.1993, 11-22.

Joh, H. (1991) Change of marine environment of Osaka Bay due to coastal development. Bull. Coast. Oceanogr., 29, 3-12 (in Japanese).

Joh, H. (1992) Field studies in Osaka Bay. In: Fishing Ground Capacity for Artificial Impacts, T. Hirano (ed.), Koseisha-Koseikaku, Tokyo, 49-68 (in Japanese).

Kikuchi, T. (1993) Ecological characteristics of the tidal flat ecosystem and importance of its conservation. Japan. J. Ecol., 43, 223-235 (in Japanese).

Kuramoto, T. and Kata (1991) Numerical simulation of the formation and movement of an oxygen deficient water mass in Tokyo Bay. Bull. Coast. Oceanogr., 28, 140-151 (in Japanese).

Kurihara, Y. (1988) A logic of ecology in relation to conservation and utilization of ecosystems. In : Ecology and Ecotechnology in Estuarine-Coastal Area, Y. Kurihara(ed.), Tokyo University Press, Tokyo, 289-305 (in Japanese).

Kurimoto, Y. and T. Kuramoto(1992) Improvement techniques for marine environment in the enclosed bay. Proceedings of the First International Conference on Fisheries and Ocean Industrial Development (FOID) for Productivity Enhancement of the Coastal Waters, National Fisheries University of Pusan, Feb.1992, 37-51.

Matsukawa, Y. (1990) Behavior of nitrogen and phosphorus in estuaries. Bull. Coast. Oceanogr., 28, 43-48 (in Japanese).

Matsumoto, E. (1983) Behavior of heavy metals in coastal waters. In: Marine Environmental Science, T. Hirano (ed.), Koseisha-Koseikaku, Tokyo, 168-177 (in Japanese).

Nakamura, M. (1991) Artificial habitat technology in Japan-today and tomorrow. In: Recent Advances in Aquatic Habitat Technology, M. Nakamura, R.S. Grove and C.J. Sonu (eds.), Japan-U.S. Symposium on Artificial Habitats for Fisheries Proceedings, Tokyo, June 1991, 11-19.

Nakata, H. (1991) Potential utility of ecological modeling for fish abundance studies. In: Recent Advances in Aquatic Habitat Technology, M. Nakamura, R.S. Grove and C.J. Sonu(eds.), Japan-U.S. Symposium on Artificial Habitats for Fisheries Proceedings, Tokyo, June 1991, 95-104.

Nakata, H. (1995) Production enhancement and its implications for the restoration of marine biodiversity in the coastal waters of Japan. FAO Fisheries Circular, 889, 1-32.

Nakata, H and T. Hirano(1989) The use of the structural model for the assessment of environmental impact on coastal fisheries: principles and procedures. Nippon Suisan Gakkaishi, 55, 273-278.

Sasaki, K., Y. Matsukawa and T. Suzuki(1988) Analysis of mechanism of eutrophication by a box model. In: Studies on Fisheries Oceanography, Japan. Soc. Fish. Oceanogr. (ed.), Koseisha-Koseikaku, Tokyo, 238-252 (in Japanese).

Seko, Y. (1994) Oils and fats. In: Considering marine Environmental Problems, Oceanogr. Soc. Japan (ed.), Koseisha-Koseikaku, Tokyo, 33-36 (in Japanese).

Shimizu, M. (1988) Distribution of benthic fishes and shellfishes in Tokyo Bay. Bull. Coast. Oceanogr., 25, 96-103 (in Japanese).

Takahashi, M. (1992) A new direction of coastal sea research. Proceedings of the Workshop 1992 on Ocean Research Program, Coastal Sea Sub-Group, Yokosuka, Sep.1992, Japan Marine Science and Technology Center, 145-154.

Tanabe, S. (1995) Historical trend and present status of marine pollution by toxic contaminants since 1975. Bull. Coast. Oceanogr., 32, 137-144 (in Japanese).

Tanabe, S. and R. Tatsukawa (1981) Behavior of man-made organics in the coastal and estuarine environment. Bull. Coast. Oceanogr., 19, 9-19 (in Japanese).

Taniguchi, K. (1990) Marine afforestation of "Arame", Eisenia bicyclis (Laminariaceae, Phaeophyta). Bull. Coast. Oceanogr., 27, 167-175 (in Japanese).

Taniguchi, K. (1991) Marine afforestation of Eisenia bicyclis (Laminariaceae, Phaeophyta). NOAA Technical Report, NMFS, 102, 47-57.

Tatara, K. (1981) Advancement of eutrophication and fishery product in the Inland Sea. Bull. Jap. Soc. Fish. Oceanogr., 38, 42-49 (in Japanese).

Yamada, M., R. Takeuchi, S. Sueta, K. Kido, Y. Yabumoto and Y. Yoshida (1991) Recovery of aquatic animals in Dokai Bay, Northern Kyushu, Japan. Mar. Pollution Bull., 23, 201-207.

Yamaguchi, M. (1993) Algae. In: Tokyo Bay - Environmental Changes During Recent 100Years, N. Ogura(ed.), Koseisha-Koseikaku, Tokyo, 61-77(in Japanese).

Yuasa, I (1995) Alarm bell from the change of coastal marine ecosystem. The Human and Environment, 21, 73-79 (in Japanese).

Endnotes

[1] Technically, "coastal" is defined as the environmental zone which lies between the high tide mark and the low tide mark, and "neritic" is defined as the environmental zone which lies between the low tide mark and a depth of about one hundred fathoms (or 200 meters). However, the term "coastal" is used in this paper in both the restricted sense given above and in the general sense of referring to the marine environment which lies along the coastline of a body of land.