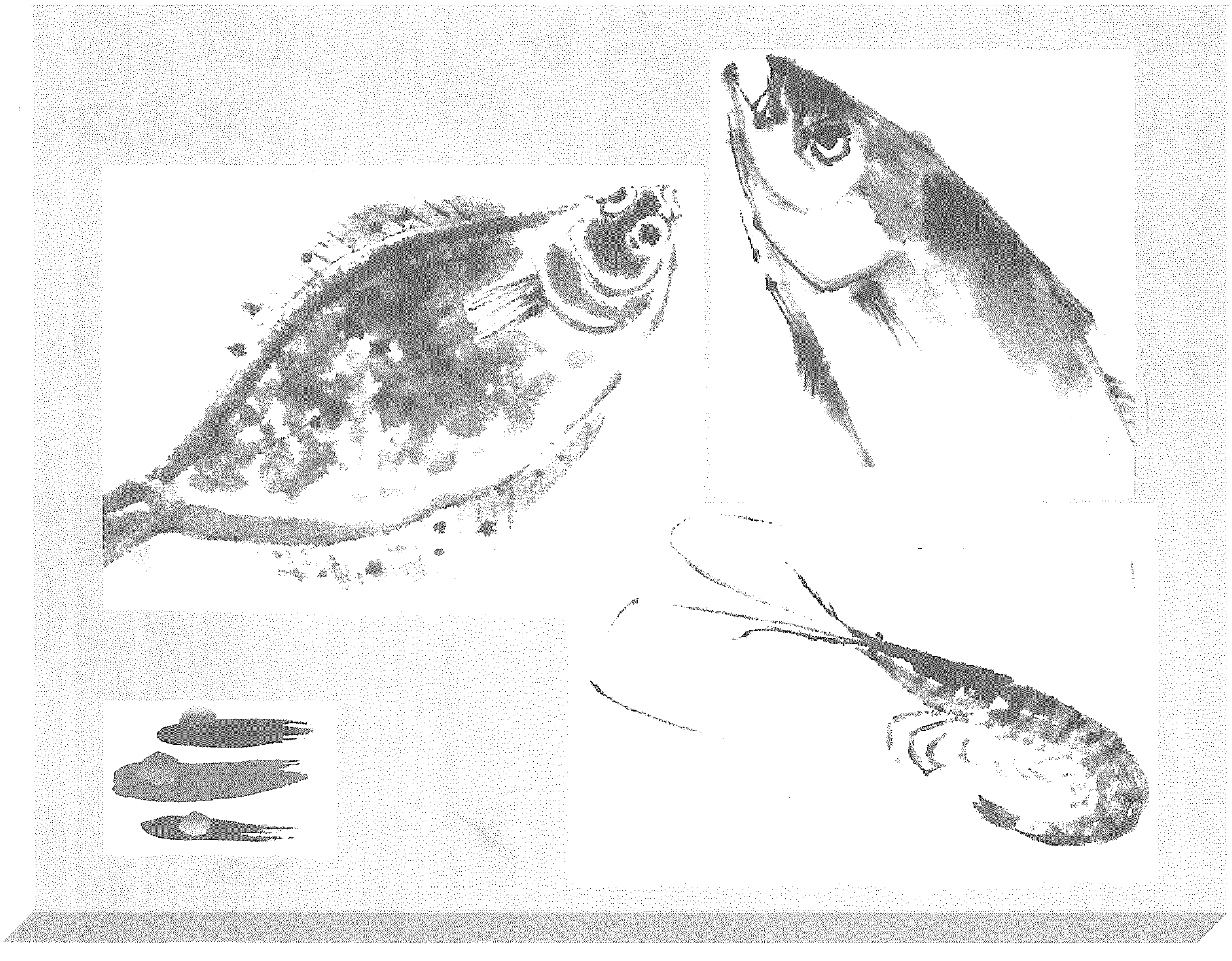
FAO Fisheries Circular No. 943

FIRI/C 943
ISSN 0429-9329

MARINE RANCHING: GLOBAL PERSPECTIVES WITH EMPHASIS ON THE JAPANESE EXPERIENCE



Food and Agriculture Organization of the United Nations

FAO Fisheries Circular No. 943 FIRI/C 943

MARINE RANCHING: GLOBAL PERSPECTIVES WITH EMPHASIS ON THE JAPANESE EXPERIENCE

FOOD AND AGRICULTURE OF THE UNITED NATIONS
ROME, 1999

PREPARATION OF THIS DOCUMENT

The International Conference on Sustainable Contribution of Fisheries to Food Security resulted in the Kyoto Plan of Action that calls for a rapid transfer of technology and know-how in enhancement of inland and marine waters. As part of the implementation process of the Kyoto Plan of Action, Ishikawa Prefecture, in cooperation with the Fisheries Department of FAO, the Fisheries Agency of Japan, the Japan Sea-farming Association, Marino-forum 21, and others convened an International Symposium on Marine Ranching, 13-16 September, 1996, Kanazawa, Japan (See Appendix 1, 2 and 3). This Circular is an unedited collection of the presentations of this Symposium, which have been assembled by the FAO Inland Water Resources and Aquaculture Service, Fishery Resources Division.

The assistance ~~of the~~ Fisheries Department of Ishikawa Prefecture, and especially the work of Messrs M. Miyahara and A. Shikida, is greatly appreciated.

FAO Inland Water Resources and Aquaculture Service, Fishery Resources Division.
Marine ranching: global perspectives with emphasis on the Japanese experience.
FAO Fisheries Circular. No. 943. Rome, FAO. 1999.252p.

ABSTRACT

This circular reports on the status of marine ranching programmes throughout the world, with a special emphasis on the enhancement work ongoing and planned in Japan. The papers contained herein represent the proceedings of the International Symposium on Marine Ranching, 13-16 September 1996, in Kanazawa, Japan. They address the variety of issues that are necessary for responsible and cost-effective marine ranching. These issues include, *inter alia,* technical concerns with producing and releasing large numbers of hatchery fish and invertebrates, habitat improvement, genetic resource management and biodiversity conservation, socio-economic evaluation, fishery management, technology transfer, criteria for success, and the multidisciplinary approach required for a successful ranching programme. The marine ranching programmes of Japan, the world leader in this type of fishery management, are extensively reviewed by Japanese experts.

CONTENTS

MARINE RANCHING: PRESENT SITUATION AND PERSPECTIVE

Masaru Fujiya
Chairman
Marine Ranching Development Research Group
Marino-Forum 21

BACKGROUND

The world's population each year has continued to increase by about 100 million persons, for a growth rate of 1.7% or 1.8%. According to the estimate by the Food and Agriculture Organization of the United Nations (FAO), in 2050 the world's population will exceed 10 billion, twice the present figure (about 5.8 billion) (Figure 1). Even if the present rate of per-capita food consumption continues, twice as much food production will be required.

Looking at the geographical distribution of the world's population, most people live in Asia, followed by Africa, Europe, and North America.

In Asia, both China and India have the highest populations, together exceeding 3 billion persons. This is almost half the world's total.

Inasmuch as Japan exists in the midst of a "Satiation Era" wherein the country is satisfactorily supplied with food, it is difficult to come to grips with the idea of a developing food crisis. Nevertheless about two-thirds of the world's population even now suffers from food shortages. To improve these people's daily lives to international dietary levels, several times as much food will be necessary to nourish the coming population explosion.

Concerning global food-production capacity, it is most important to supply protein according to the three nutritional essentials: protein, carbohydrates, and fat. There is, however, a limit to the production of protein on land. Some regions have already reached the limit in protein production. Marine production is thus extremely important as a protein source.

Continents such as Eurasia, Africa, North and South America, and Australia, where huge undeveloped areas still remain, have possibilities for the agricultural production of carbohydrates. In these continents, advanced-technological development for agricultural production in dry areas is likely to enable grain production in significant quantities. Such technology includes land improvement by antiflood afforestation, river improvement, desert fertilization, and plant-rearing technological development.

The foregoing, however, does not apply to protein production on land. Stock raising with compound feed, such as is conducted in Japan, needs eight kilograms of feed for the production of each kilogram of beef; and two kilograms of feed per kilogram of chicken. This will be become extremely illogical because food will be desperately short in fifty years. South and North America and China have adopted this raising method. It is difficult to think about production methods other than making use of natural or cultured grass.

The same applies to fisheries. I would like to explain present-day intensive food-supply aquaculture by the example of yellowtail. Six to ten kilograms of feed should be prepared for producing one kilogram of yellowtail. This is extremely unproductive and consideration is required for the future. If no feed is developed that humans cannot possibly use, such aquaculture cannot survive. Accordingly, future aquaculture should depend on shellfish or seaweeds, which need not be fed.

From this viewpoint, for rational protein production by fisheries, there are great possibilities for sea farming and marine ranching, especially to produce fish and seaweed by capitalizing on natural productivity. This is the meaning of developing marine-ranching technology.

It is said that we cannot hope for any significant future food increase without effective measures for world fishery production, which is about 100 million metric tons. Marine ranching can be one of the effective countermeasures to solve future food problems.

With food shortfalls in mind, in December 1995 in Kyoto the Japanese government convened the International Conference on the Sustainable Contribution of Fisheries to Food Security, with the cooperation of the FAO. This conference examined the extent and means by which fisheries can contribute to the supply of food resources. Especially mentioned was protein, which is becoming scarce in the face of the explosive population increase under way as we move into the new century. Five-hundred and twenty-two participants came from 95 countries, among which 23 countries dispatched ministerial-level representatives. Eleven international organizations and nine international NGOs were also represented. It was the world's greatest international fisheries conference.

Estimated by the conference's subcommittee was the world marine-product supply-and-demand situation. At the main session it was reconfirmed that fisheries contribute importantly to food security through food provision, employment, and income production. The Kyoto Declaration was adopted, proposing that countries cooperate in preparing for future food shortfalls.

To be controlled under international standards are appropriate resource-management measures and adequate promotion of coastal and inland-water fisheries, intensive aquaculture, and the marine-product trade.

Behind such an international conference, countries, both developed or developing, are highly interested in the sustainable contribution of fisheries because of worries about food shortfalls for which no positive countermeasures exist. Japan, which in fisheries has the world's most advanced technologies and industrial abilities, is expected to contribute internationally to avoid the near future's inevitable world food crisis.

Fishery Present Situation in Japan

Looking at the animal-protein supply in Japan, fishery products comprise 41% of the whole, followed by meat (32%), milk and dairy products (15%), and chicken eggs (12%). We thus significantly depend on marine products.

Japan's fishery production, after peaking at 13 million metric tons in the latter eighties, experienced annual decreases and eventually hit the bottom with fewer than 8 million metric tons in 1995. Looking at the transition in fishery production by category, pelagic and offshore fisheries have undergone remarkable diminutions, while coastal fisheries gained slight increases and inland fisheries remained more or less stable.

For the present, Japan needs at least 10 million metric tons of marine products. We supplement shortfalls with imports, which reached 4 million metric tons in 1995. The major exporter to Japan is the United States, which supplies 18% of Japan's total marine-product imports. China, Taiwan, Korea, and Thailand follow as leading exporters to Japan.

Mainly imported are so-called "highly valued" fish, such as shrimp, then, tuna, salmon, trout, crab, and cod as ingredients for minced-fish meat products.

Population increases and improved living standards in developing countries contribute to raise global marine-product consumption. The world's total fishery catch has been stable at around 100 million metric tons. Consumption for food has been increasing and has recently exceeded 70% of the total catch.

In many nations, whether developed or developing, marine-product demand has been on the increase. This trend is especially remarkable in Pacific countries and in North America, while a slight decrease is seen in Middle and South America and Africa.

Nevertheless as a whole it can be said that marine-product consumption has been increasing.

Taking this situation into consideration, the present exporting countries will have fewer marine products for export in the near future because of rising domestic demand. As a result it will probably become extremely difficult for Japan to import marine products. The ensuing shortage of about 4 million metric tons, which are now imported, will have to be harvested from within Japan's 200-nautical-mile offshore waters.

Fortunately, Japan has the world's seventh largest extent of territorial waters, with the greatest productivity. The United States has the world's largest offshore zone, followed by Australia, Indonesia, New Zealand, Canada, Russia, and then Japan (Figure 2). Most of the zones, however, belonging to these countries are not necessarily utilized because polar seas comprise large portions.

Japan's 200-nautical-mile zone encompasses climates ranging from frigid to tropical. Most of the area belongs to the temperate zone and is blessed with mild weather. Japan is expected to make the best use of these waters.

Sustainable fisheries should be established by appropriate fishery management to secure a sufficient harvest.

Large-catch fish, the basic food, depend upon natural resources. Resources should therefore be not only utilized but also increased by the establishment of sustainable fisheries under judicious management.

As for the artificial cultivation of useful coastal marine resources, which should be the core of the "From hunting fisheries to farming fisheries," will be cultivated by sea-farming and marine ranching. Most of technologies that have been developed for intensive or extensive aquaculture and sea farming are elemental technologies for marine-ranch development. Fishery-engineering technologies for the purpose of environmental improvement have also been remarkably developed. It is hoped that from now more rational use will be made of such technologies, including marine-ranch complexes on a larger scale, combining technologies that have already been developed.

Many kinds of marine biological resources have yet to be utilized as food. Inasmuch as outstanding technologies for using or processing marine resources have recently been developed, it is important to make use of unused resources by utilizing these technologies. Some fishery catches, which have thus far not been satisfactorily used, should be considered for practical utilization.

For reasonable and efficient marine biological resources, it is requisite to maintain the prevailing ecological system, and it is essential to conserve the marine environment. It is therefore important to manage the environment from an individual point of view in physiology as well as ecology. Elaborate consideration should be accorded this issue.

New Era With the United Nations Law of the Sea

In 1996 Japan will ratify the United Nations Law of the Sea. Japan will thus become responsible for the resource management of sustainable fisheries throughout its 200-nautical-mile offshore zone.

The basic policy for this resource management grants exclusive jurisdiction in the coastal 200-nautical-mile area to each country, with the obligation of establishing a Total Allowable Catch (TAC). Each nation must provide measures for preserving and managing biological resources. Japan will join resource management, using direct-catch control.

Some spokesmen have insisted that the operation of pelagic fisheries within another country's 200-nautical-mile zone is a vested right to be enjoyed by all other nations, as well. From now on, however, we should request permission to fish in such countries' territorial waters, with negotiations taking into consideration new concepts that assign to the sovereign power exclusive jurisdiction over offshore resources. Furthermore, in Japan's 200-nautical-mile area, foreign fishing vessels have been permitted to fish pursuant to agreements between Japan and China, Korea, or Russia. Such fishing will not be permitted in principle, and the area will be exclusive for Japanese fishing vessels. After enactment of the Total Allowance Catch, foreign fishing vessels' entry must be considered under a new concept. Restriction in principle, however, must be carefully considered because of the importance of maintaining international amity.

Under this basic policy, as a specific form of the TAC system for focused resource management, the whole of Japan's 200-nautical-mile zone shall be provided as exclusive. This means that the area is established and applied as an economic offshore zone where foreign fishing vessels are in principle denied entry for fishing.

With these measures Japanese fisheries in the coming century will face important reformation. For this purpose it is possible that the present irrational fisheries and catches will be regulated. Such reformation should be extremely purposeful because fisheries perform vital role in Japan's food supply.

Making the most of these measures, we should pay attention not to imperil our future food supplies. Japanese coastal-resource cultivation and fishery management must carefully consider distribution economics, such as stable fish prices.

From the above viewpoint, rational resource management is indispensable. For example, coastal trawling, which has been criticized as an illogical fishing method, is likely gradually to be abolished. For increasing the future food supply, ongoing intensive aquaculture in relation to food supply will be subject to review regarding its extreme irrationality.

World fisheries of the new century are expected to be reformed significantly into management-type fisheries. Effective fishing methods will be needed to ensure sustainable fisheries for cultivating useful coastal marine resources with natural productivity to make use of technologies that will be developed in the future. Japan will also follow this world trend and put it into practice.

We are thus at a time when we must promote the development of Japan's 200-nautical-mile zone and ensure stable fishery production by cultivating useful coastal resources.

Basic Idea of Marine Ranching

For the promotion of Japan's 200-nautical-mile offshore development, the Fisheries Agency has executed numerous useful measures such as the construction of artificial reefs and useful-fish releases. Projects include coastal fishing-grounds improvement and sea-farming. Each effort has reaped substantial results.

These measures have been conducted in individual efforts, and more reasonable results are expected for the future. It is illogical, however, to expect that every measure will be conducted in idealistic form.

From now on, regarding the individual results obtained as elemental technologies, it is necessary to strive for more effective results with reasonable combinations and management based on technology. In this sense, marine-ranching is one of the concepts presently attracting the highest interest and expectations.

Most of the technologies developed in intensive or extensive aquaculture or sea-farming can be evaluated as elemental technologies for marine ranching. Fishery-engineering technologies intended for environmental alteration have also been outstandingly developed. For the future of marine ranching, complex marine ranches of larger scale should be created by combining all existing individual technologies. These available technologies should be utilized as major elemental technologies for future marine ranching.

Taking the present technological standards into consideration, fewer technological issues stand in the way of future marine-ranch development. The Marino-Forum 21 has in particular enabled cooperation among industries, universities, and national and prefectural governments. It is encouraging that information exchanges and technological cooperation are promoted within all technological domains including fisheries, and that technological development is enabled based on a wider basis.

Moreover, the fishery system should be revised so that it can be rationalized immediately in anticipation of the coming era. Many issues exist in connection with marine ranching such as establishment of piscary, adjustment of fishing-area use, interest distribution, and coordination with sport fishers.

Concept for Marine Ranching

It is difficult for us to understand with our senses the image of marine ranches. Therefore, let me compare marine ranches with those on land. There are different kinds of conventional ranching, such as livestock pasturage in huge expanses in America and Australia making use of natural pasture, large-scale nomadic sheep raising in Mongolia, and small-scale cattle raising with cultured pasture or compound feed in small stables in the mountain and remote villages of Switzerland or Japan.

Each ranching method is based on a different idea, but all of them are skillfully accomplished with high productivity, making the most of the socioeconomic background and climate of each location.

It is essential rationally to improve production by making use of nature and human wisdom. The same thing applies to marine ranching. In the ocean's broad expanse the concept is even more grand, and is different from ranching on land.

For example, before the birth of the concept of marine ranching, salmon releases were conducted in the sea. This is the equivalent of the large-scale ranches on land. Furthermore, intensive fish aquaculture with net cages corresponds to small-scale ranches with stables. Other than these, several technologies developed in intensive or extensive aquaculture and sea-farming can be evaluated as ranching technologies. Considering the coming food shortage apropos to the future population increase, intensive aquaculture predicated upon feed that humans themselves can consume will gradually have to be reduced or even abolished. Accordingly, shellfish and seaweed, which need not be fed, will be the main items for future intensive aquaculture.

As a trial to make use of the habitual characteristics of fish and to control their activities through training, audio-signal-training technology was developed for porgies or other species. It was used for improving the remainder ratio of released juvenile around a release location. Marine ranching focusing on audio-signal training has already achieved results as one stage for complex-type marine ranching targeted for future refinement.

It has long been known that carp kept in a pond perceive the approaching footsteps of feed-bearing humans, and gather in anticipation. Porgies in Tainoura Bay, Chiba Prefecture swim to the surface and approach boats if the boaters tap the boat sides.

It is not that carp and porgies have such a habit in nature. It is nothing but a habit ingrained by repeated training that they can obtain food when people approach or tap the sides of boats.

This kind of learning is effective with other kinds of fish. They gather at the feeding place when perceiving sounds or vibrations, learning by repetition of artificial sounds and subsequent feeding.

Recently, fish-seed-production technology in sea-farming has improved in both quality and quantity. Many healthy seeds have been released. Unless we are blessed, however, with favorable geographical and oceanographic conditions, many of the fish become scattered in a comparatively short period postrelease and possibly are caught before they mature. To avoid such inefficient results, we should see that the released juveniles stay within the release area where it is possible for humans to maintain a degree of control.

If fish, at the time of seed production or nursing, are released into an area where an audio-signal-training system is installed, and if sounds and feeding are continued for a time according to the training schedule, it is possible to train the released fish to remain for several years in the release area, given favorable environmental conditions. Even if the trained fish are scattered, the dispersion is less than with untrained fish. It has already been proven that fish are likely to reside within several miles of the release point.

Regarding the physiological influence of training, feeding efficiency is improved by advance audio-feeding notice. The same effect in promoting gastric-juice secretion in fish as seen in higher animals is expected, and the improved digestion efficiency of feed is also perceived in trained fish.

Focusing on this technology, by combining environmental-alteration technology, especially elemental technology for artificial reefs, undersea afforestation, and also in some cases of artificial fertilization, it becomes possible to make more efficient use of released fish.

From proven results and from studies it is highly recognized that not only released fish but also natural fish inhabiting the vicinity become trained. They remain in the vicinity of the audio-signal training system. More efficient fishery effects can thus be expected.

Technical Background of Audio-Signal Training

Summary of fish characteristics for sound and learning methods

Fish have superb sensibility for sounds. The perceivable frequency among fish is within the audible frequency range possessed by humans. It is therefore possible to create audible sounds for fish without special consideration or equipment.

Various kinds of noise exist in nature under the sea. Most of the noise is in the frequency range of 400 to 1000 Hz. Because it is preferable to avoid this frequency band, the frequency between 100 and 300 Hz is used for learning. Experiments have proven the efficacy of 300 Hz intermittent sound. Learning for fish is conducted in combination with feeding and sounding.

Fish aptitude for audio signals and learning possibilities

Numerous experiments have been recorded about porgies' response to audio signals. Aptitudes were considered for audio-signal training among several kinds of fish, along with learning possibilities. As a result it is recognized that many kinds of fish can learn by audio-signal training in a comparatively short time, ranging from two days to two weeks.

Audio-signal selectivity among fish

In training according to a given frequency, it is difficult to use the training as technology unless the fish have selectivity for the sound. From experimental results, it is recognized that many kinds of fish including porgies have comparatively good selectivity for audio signals.

Influences of stress, such as impacts

In the technological process of marine ranching, significant stimulus or impact may be given to cultured fish in the course of transportation, transfer, or disease treatment. Loss or diminution of habit obtained by stressful learning is undesirable for fish. Accordingly, examination is necessary regarding impact responses. None of such responses is recognized to influence the learning results.

Sustaining memory obtained in learning

When using audio-signal training for marine ranching, it is problematical whether fish memorize the audio signal obtained in learning. It is possible for sounds to stop because of reasons such as equipment damage and bad weather. In most cases such suspension continues only a few days, but it can be ten days or more in inconvenient areas such as remote locations. Within this suspension period, audio-signal training will be in vain if the memory obtained in learning is lost. It is thus vital to maintain memory at least for several weeks.

The examination results for several kinds of fish prove that memory is retained for at least four months. It was concluded, however, that sound suspension during a comparatively short period, caused by equipment repair, does not hinder training results.

Trainable minimum growing stage

In audio-signal training with artificial seeds, a question exists regarding the growing stage at which learning is possible. Learning is therefore tried in every stage, beginning with the juveniles produced as seed, to examine the trainable minimum growing stage. As mentioned before, in terms of auditory-organ growth it is possible to train juveniles to grow into adult form. Accordingly, porgies of around 20 mm produced as seed have already proven possible to train. The methods are nearly similar to those for adults.

The Future Image of Coastal Marine Ranching

The ultimate in marine ranching for coastal areas is complex-type marine ranches combining existing elemental technologies and new technologies that will be forthcoming in the future.

The basic idea is as follows. Elemental technologies in biology and fisheries civil engineering developed in intensive or extensive aquaculture, including conventional sea-farming, should be utilized. An important element in such production is the carrying capacity of the water area. Accordingly, areas with unsatisfactory carrying capacity need technological improvements to increase the capacity.

Reasonably to combine carrying capacity and biological production, it is necessary to develop and apply biological behavior control, especially for fish, with technology based on learning.

While sea-farming is for useful life production, marine ranching means development of a specific coastal area. Marine-ranching projects are thus not uniform, but consist of establishing marine ranches that rationally combine elemental technologies. Response must be made to geographic and hydrographic characteristics, where the ranch is constructed, and the fishery form.

Future Marine Ranching Making Use of the Open Sea

It is already mentioned that salmon releasing as conventionally conducted can be compared with large-scale ranches on land. Many kinds of fish have habits similar to salmon. For example, I would like to talk about bluefin tuna. Bluefin tuna spawn around the Southwest Islands. Growing up, they migrate north near Japan, then reach the coast of California in large numbers. They mature along the American coast, then return to Japan where they are caught.

Taking advantage of this habit, it is possible to have similar results with salmon. Paying attention to this point, basic studies have been conducted and new knowledge obtained including patterns of group life in the Japan Sea, not only the Pacific Ocean. If mass production of bluefin-tuna artificial seed can be conducted based on these studies, bluefin-tuna ranching in the Pacific Ocean or Japan Sea is not a dream.

This concept for large-scale marine ranching making use of the open sea is expected to evolve with development of life-mode studies of useful fish.

Individually conducted on land ranches are technologies corresponding to the elemental technologies for marine ranches. It is significantly different from ranches on land for marine ranches to conduct such technologies in combined form. It is necessary to aim at complex-type marine ranching on a larger scale, combining existing elemental technologies in rational form. For this purpose, research and development, especially evidence and experiments, are essential.

Basic Form of Marine Ranching

Marine ranching is basically classified into two types. One is tentatively called the "harvest type." In this method, which is similar to agricultural cultivation, seeds are planted in the field and they are perfectly cropped when they grow up.

In fisheries, intensive aquaculture applies to this category of marine ranching. Examples of fish and seaweed intensive aquaculture and sea-farming include the release of tiger shrimp and blue crab seeds in tidelands; as well as the release of juveniles of scallops, little clams, and hard clams on the sea bottom or in tidelands, and harvesting in adult form. Seeds produced or nursed in hatcheries are thus released in the area and recaptured when they reach a suitable commercial size. In this case, release and harvest are repeated every season, and it is important to improve the fishing area, to preserve the environment, and to recapture in an efficient manner (Figure 3).

The other marine ranching type is tentatively called the "recruit type," whereby seeds released into the area settle there for proximal reproduction. In this case, similar to the total-harvest mode, seeds produced or nursed in hatcheries are released in the area. The released fish are expected to grow up, to mature, to spawn, and to hatch in the fishing area for natural reproduction under appropriate fishery management. In this case, not all the grown-up fish are recaptured, and an appropriate number of adult fish are retained as natural brood stock. Release is to be suspended after new resources are established. Satisfactory fishery and fishing-area management will then be conducted for maintenance of new resources (Figure 4). In general, the development of marine ranching aims at this recruit-type method. Even when released fish mature, it is impossible to recapture all of the fish and it is not difficult to make the brood stock remain in the release area. It is important for fishing-area improvement and maintenance to establish facilities where fish maturing and spawning are promoted.

Basic Elements for Marine Ranching

The basic difference between sea-farming and marine ranching is that the production of useful lives is improved in sea-farming, and specific sea areas are developed in marine ranching. Accordingly, marine ranching is established, taking full advantage of the characteristics of the area, and scientifically and reasonably combining elemental technologies. Four basic elements are involved as follow.

Fishing area development and alteration (field development)

With a selected specific area, taking advantage of the geographical characteristics of the waters, socioeconomic and technological background, and existing technologies obtained by the fishing personnel of the peripheral area, marine ranches are established combining each elemental technology. The most important element governing the production is the carrying capacity of the area in terms of fishery civil engineering. If the water area has an unsatisfactory carrying capacity, it is necessary to perform physicochemical environmental alterations, such as making use of fishery civil engineering technology and artificial fertilization technology for increasing the capacity. Especially effective measures include the construction of artificial reefs, construction of sandy beaches, tidelands, and fairways, undersea plowing, aquatic afforestation, and artificial-fertilization technology.

Healthy seed production and release (seed production)

Diverse technologies should be used, especially technologies for brood stock rearing, artificial hatching, nursing, and juvenile release, which have been developed in studies of intensive or extensive aquaculture, sea-farming and marine ranching.

Rationally to combine carrying capacity and biological production, it is necessary to apply technologies ranging from learning to the behavior control of living organisms, especially fish.

Fishing-area-environmental preservation

Attention should be paid to preserving the environment. This can be done by applying the technologies developed for managing water quality of the fishing area and peripheral water area, by regulating sea-bottom pollution, and by removing toxic substances. It is especially necessary to pay attention to the influence of toxic substances upon juveniles, the chronic toxicity of low concentration, and the bio-accumulation of toxic substances. From the fishery point of view, area management should pay attention to the specific important living organisms in the area where they are nursed and reared.

Appropriate fishery management

Important issues include to cooperate with sport-fishing enthusiasts and with fishery businesses for leisure activities. Application should be made using the technologies developed for management-type fisheries. Improvement laws should be enacted, and important water areas such as seed-release areas should be protected.

Considering present scientific standards, we have fewer technological problems to hinder the future development of marine ranching.

The largest problem that needs immediate resolution in the future is to revise the fishery system to respond to the new era. Many problems exist, including the establishment of piscary according to marine-ranch construction, coordination in fishing-area usage, interest distribution, and cooperation with sport-fishing people (Figures 5 and 6).

Environmental surveying and its purpose

It is preferable to conduct future core coastal development based on the marine-ranching concept, scientifically aggregating elemental technologies that have been developed through intensive or extensive aquaculture and sea-farming. It is vital to understand the oceanographic environment from the point of view of organisms; and from the vantage of installation and complete operation of facilities, equipment, devices, and units to manage and operate marine ranches.

The following items are pointed out for general surveys essential to grasp the oceanographic environment.

Geography

It is extremely important to know geography to understand the life habit of habitat groups, as well as knowing the conditions for installing facilities, equipment, devices, and units.

Meteorology

Because meteorological conditions are intimately related to water-life habits and ecology, examination is needed using reference materials covering as long a period as possible. If necessary, physical surveying is also required.

Oceanographic conditions

The same applies as above. Inasmuch as oceanographic conditions are importantly related to water-life habits and ecology, examination should be made employing reference data about tides, waves, current direction, and current velocity. If necessary, physical surveys are also requisite.

Water quality

Coastal-development success depends on water quality. Careful surveying is required. The survey should be conducted at various depths, not only on the surface. Surveys are performed regarding water temperature, salinity, transparency, water color, pH, COD, DO, nutrients, suspended substances (SS), floating, fine soil, and fine sand.

Sea-bottom conditions

Surveying is required to determine physical characteristics such as particulate distribution and sludge-sediment quantity; and chemical characteristics such as COD, ignition loss (IL), sulfide, and heavy metals.

Biota

Plankton: zooplankton and phytoplankton, including jellyfish, headfish, juveniles, and larva
Nekton: fish, squid, and octopus
Benthos: all fauna living at the sea bottom
Epizoa: fauna and flora attaching to underwater structures
Submarine forest: the area where seaweeds proliferate, and seaweed species

Relationship Between Water Quality and Life

Water temperature

In general, fauna are classified into homoiothermal and pokilothermal. Homoiothermal fauna are limited in kind, such as mammalia and aves, and have the ability to maintain body temperature. Most kinds of fauna, including all species of fish, belong to pokilothermal species and are sensitive to changes in water temperature.

Poikilothermal species divide in two: eurythermal, easy to adapt to temperature changes; and stenothermal, difficult to adapt.

Thermophile species prefer warm environments and psychrophile like chill. Most animals have a most appropriate temperature for existence. Remarkable deviation from this range influences physiological ecology.

Salinity

In general, hydrocole fauna are classified by salt adaptability in two categories: euryhaline and stenohaline. Euryhaline fauna have adaptability for salinity in a wide range. Some species can exist in habitats ranging from coastal brackish areas to offshore locations with high salinity. One variety can also inhabit coastal locations heavily diluted by freshwater. Generally, the organisms inhabiting coastal waters or land-bounded bays can be classified as this category. Stenohaline fauna are sensitive to salinity changes. Most of those that migrate offshore or into the open sea fall under this category. Accordingly, this species of fauna is not necessarily suitable for coastal farming or intensive aquaculture. As in the case mentioned in the paragraph concerning water temperature, these organisms have suitable salinity for habitation and it is necessary to the greatest possible extent to maintain their appropriate range.

Nutrients

Phosphate, nitrate, and silicate are examples of important nutrients. These are the sources of water productivity and essentials for plant production.

Phosphate is in lighter supply on shore. It is a by-product of animal corpses and is mainly consumed in phytoplankton production. The substance is of lesser content in warm-current areas and greater in cold-current waters. Rises and falls in plankton production have a correlation with the dissolved quantity of phosphate. These variations are often a restricting factor for basic production in ocean areas. In general, phosphate content rises in winter and diminishes in spring, summer, and autumn.

Nitrate is abundantly available on land, and in the sea is supplied from animal cadavers. Nitrate has diverse sources such as the synthesis of free nitrogen with nitrogen-fixing bacteria. Nitrogenous compounds are likewise supplied in air discharged with rain. Nitrate is consumed by plant production, mainly by phytoplankton. Accordingly, variations in plankton production are correlated with the dissolved quantities of nitrate. In general, nitrate is more abundant in winter, and in sparser supply in spring, summer, and autumn.

More silicate exists as compared with phosphate or nitrate. It is mainly supplied on land, and most is consumed by diatoms.

Water color

Color changes naturally according to plankton production, and the colors differ according to plankton type. An extreme example is the red tide. Otherwise water color may significantly change with the inflow of industrial waste or sewage. Water color is mostly useful as an index for wastewater distribution.

pH

The pH changes naturally changes the carbon dioxide gas arising from the production of seaweed and phytoplankton. pH changes with the inflow of industrial waste or sewage, and is useful as an index for wastewater distribution.

Dissolved gas

The three major gases are oxygen, nitrogen, and carbon dioxide. Oxygen and carbon dioxide play especially important roles in biological production.

Light

Light has a close relationship with biological physiologic actions. The quantity of light penetrating the water has an intimate affinity with phytoplankton proliferation, as well as with zooplankton and fish production. The depth of light penetrating the sea is influenced by transparency and water color.

Water flow

Water flow causes great modifications in the distribution and organization of water temperature, salinity, nutrients, and dissolved gases; as well as in animal form and life habits. Flow types include wind waves, swells, tidal flows, and currents.

Relationship Between Sea-bottom Conditions and Organisms

Sea-bottom quality, along with its physical form, has a close relationship with benthos' growing and proliferation, and is thus extremely important for fisheries. The sea-bottom consists of lead, gravel, sand, mud, and clay--or the substances in which these components are mixed. The sea-bottom possesses different smells, color, and viscosity under diverse environmental conditions.

Benthos especially in coastal areas frequently shows the indicator of environmental pollution.
A polluted sea-bottom influences organisms mainly through physical means such as water-pollution substances sinking or sedimentating in sludge, sand mud, and clay and remaining in fish or seaweeds. Chemical influences are caused by pollution substances aggregating or sinking in the water. Sea-bottom pollution has almost the same influence as water contamination.

Synergistic Action of Toxic-Polluting Substances

The coexistence of physicochemical components or different kinds of chemical components exerts more influence than do individual components. For example, the synergistic action of increased temperature and toxic substances significantly raises toxicity. If copper and zinc coexist, their combined toxicity is ten times that of their individual toxicity.

Bio-accumulation

Twenty years ago, considerable deformity appeared in artificially hatched juvenile salmon. Subsequent study revealed that this was caused by DDT accumulated in the brood stock and transferred into the eggs during egg-formation within the brood stock's body. As a result, the presence in the water of minor quantities of chloric pesticide was detected and eventually prohibited. This type of contamination is now regulated.

Heavy metals have also raised many problems regarding bio-accumulation. One example is "Minamata disease," which was caused by eating fish laden with concentrated mercury. Recent shellfish toxicity that has frequently been found all over Japan is said partly to be caused by poisonous substances in toxic plankton accumulated and concentrated in the shellfish. Accordingly, for future environmental management, the accumulation of low concentration should be taken into consideration. The accumulation of low concentration is considered to follow the following three routes.

Food-chain accumulation

In the ecological system, the food chain is usually considered to follow several stages. As an extreme example, the food chain is said to be concentrated at roughly 250-fold in the plankton stage, at about 500-fold in the small-fish stage that takes such plankton, and at about 80,000-fold in the upper stage of piscivorous fish or aves.

Oral concentration

In many cases, fish-feed efficiency is one to six-tenths. On average this means that about eight kilograms of feed are required for each kilogram of growth. If substances easy to accumulate exist in the feed, toxicity is concentrated eight times for each food-chain stage. For example, a three-stage food chain gives a concentration of about 500 times.

Respiratory concentration

If trout are fed with a chloric pesticide of extremely slight concentration mixed in the water, it is possible that for a few weeks 70,000 times as much toxicity will be concentrated in the trout's livers as in the water. Fish metabolism usually requires about 300 mg of oxygen per hour for each kilogram of fish weight. Fish secure their necessary oxygen via gill respiration. If oxygen in the ratio of 10 mg per liter is dissolved in the inhabited water, the fish, to ingest the oxygen necessary for metabolism, must gill-filter roughly 30 liters minimum per hour per kilogram of fish weight. This is the equivalent of 720 liters of water per day. In this case, not all oxygen dissolved in the water after passing the gills is absorbed, so a greater quantity of water should actually be filtered. Accordingly, if a substance that is easily absorbed is mixed in the water, the substance is absorbed in the fish with extreme rapidity. It is thus possible that in a single day the absorbed-substance concentration reaches hundreds of times the concentration in the water.

Although the route of a toxic substance entering the fish body is apt to be considered as oral absorption through feed, in some cases respiratory absorption through the gills may be more significant.

Survey for Special Products

In general, as a basic idea for environmental preservation to maintain the ecology of a given water area or sea, it is preferable to conduct management focusing on the area's organisms that have the least resistance.

If any rare organisms inhabit the area, careful countermeasures should be taken such as environmental management by establishing water-quality standards corresponding to the organisms' life habits. Furthermore, where organisms exist that are industrially important, it is necessary to manage the environment apropos to their life habits.

In this context, using Hiroshima Bay as an example, it is important to conduct environmental management taking into account oysters, a local specialty.

Measures have included devices to protect specific organisms from environmental pollution. It is especially important perfectly to protect the least-resistant stage during the lives of such organisms.

Oysters, after ovulation, spermatization, fertilization, hatching, and the floating-larval period, grow up attaching to a rocky beach or quay. Generally, shellfish have extremely strong resistance following completed shell formation, but the least resistance is at the floating-larval stage. In this stage, oysters have one-thirtieth or one-sixtieth the resistance possessed by adult shells. Accordingly, for the future maintenance of Hiroshima Bay oysters, we should preserve the habitat in which floating larva can healthily grow. For this purpose it is necessary to take countermeasures with this point in mind, when we consider Hiroshima Bay's ideal water quality.

The areas where similar concern should be exercised are dispersed throughout the Japanese archipelago. Environmental management for water and sea-bottom quality is vital, focusing on the characteristics of each area.

Protection Area Establishment

Establishment and management of "nursery areas"

In recent technologies it is regarded as favorable to obtain the healthy seed naturally or from sea-farming centers; and then to nurse, to release, and to manage the juveniles with methods suitable for each species' life habit. The zone for implementing such measures is called the "nursery area." The periphery, the "fishing zone," is demarcated for fisheries or sport fishing. For nursing, audio-signal training is recommended, the same as for "sanctuary areas." Postrelease, for a given time and area, it is necessary to enhance the survival rate around the release site by fishery management using protective methods such as fishing prohibition and catch-size restrictions. Taking into consideration the life habits of the released fry and the relative situation, the range of the "nursery area," where protection is required, should be designated as a useful area for everyone concerned with fisheries and sport fishing (Figure 7).

Establishment and management of "sanctuary areas"

For the enhancement of useful marine resources, the area with specific species for cultivation is designated for resource supply as a "sanctuary area" (the area where perfect protection is required). In this area, more substantial results are expected with rational nursing of seeds and intensive release. Adequate juvenile protection is the primary concern.

The peripheral area, established as a "fishing zone," is comprehensively utilized for resource cultivation with environmental preservation and appropriate management of fisheries and sport fishing.

Constructed in the sanctuary area are nursing facilities for audio-signal training. Fry with audio-signal training are released intensively in this area. Most of the released fry gradually move and disperse as they grow. Accordingly, induction, resident, nursery, and spawning reefs are installed in the peripheral fishing zone for residence and recruit of the released fry. This fishing zone is open for commercial fisheries. Fish dispersion can be largely prevented because fish trained with audio signals are highly likely to remain in the vicinity of release points.

This area is also an attractive fishing zone for sport fishermen. So, part of the area is open for them as a "Sport fishing rocky beach," "Sport fishing strand," or "Sport fishing beach." Thus, the area is also expected to be utilized for recreational purposes, managed to coexist and flourish with commercial fisheries (Figure 8).

Facility Specifications

Behavior control with audio-signal training aims at improvement of the percentage of released fish surviving or remaining in the peripheral fishing area. In nursing with audio-signal training, artificial seeds are given training in the area's tank or net cage. They are then released into the facilities with feeding in conjunction with audio signals, or into the area with protection/nursery reefs. The fry are thus gradually accustomed to nature. For efficient catching or recapturing, the remaining percentage of adult fish is improved by installing residential reefs. Efforts are also conducted to grasp oceanographic-environmental conditions. In general, oceanographic observation includes items related to oceanographic physics such as water temperature, current conditions, wave height, wind conditions, temperature, weather, humidity, sunshine strength; and to factors related to oceanographic chemistry such as salinity, nutrient concentration, and pH.

All of the foregoing items are important regarding the marine-ranching environment. Sensors are installed in marine-ranching facilities with floating or staking structures. This facilitates the data collection necessary for marine-ranching management. Different data items are required for the objective species of marine ranching. Data are collected, not in uniform form, but case by case.

Audio Signal Training Advantages

Audio-signal training is a method for the behavior control of released fish. No results, however, can be expected in areas not satisfying the conditions as a habitat for the released fish. The effects expected by this system are as follow.

- The recapture rate is improved by reduction of the initial decrease of the released fish.
- The system helps the released fish become accustomed to the sanctuary or nursery area.
- From experiments conducted in diverse locations, it was recognized that released juveniles with audio-signal training have a much higher remainder rate around the released point than those without such training. The system is thus extremely effective in preventing released fry from scattering into a wider area.
- Automatic feeding is available by simple setting and operation. If we have telemetry devices, it is possible on land to collect the oceanographic environmental-condition data and to understand the fish-shoal-gathering situation.
- Adequate management of nursing, release, and fishing area enables improvement of the resource-managerial awareness of persons engaging in fisheries.
- Establishment of the protection area around the facilities enables resource management for individuals including sport fishermen.

Facility Components

Marine facilities

Design conditions

The facilities should endure the conditions regarding water depth, tidal range, wave height, wave cycle, tidal current, wind speed, and sea-bottom quality. Shown below are the functions and design conditions with which the facilities should be equipped.

i) Facilities should have a structure in which a divided net cage (basically 4 x 4 x 4 m) for nursing can be installed, and that enables feeding with audio signals with the net removed after fish release.

ii) Provided should be automatic feeding facilities, enabling feeding in several depths if needed.

iii) Regarding the automatic audio-signal-controlled feeding system on the sea, a shoreside marine station is installed at the marine facilities and ground stations at suitable locations. Remote-control operation should be available on land with radio telemetry. Data on water temperature and fish finding should be transmitted via this system.

iv) The following conditions should be provided for nursery management and smooth maintenance and management of facilities.
- No excessive expenses or efforts should be needed for postinstallation maintenance and management.
- Good operability should be ensured for feed loading, operators' entry and egress, equipment inspection, and line changing.
- The required longevity (usually seven years) should be satisfied.
- Installation and movement should be easy.

Audio-signal-controlled feeding device

Feed type: dry pellet and crumble
Feed capacity: 150 kg (maximum)
Feeding frequency: eight times a day at maximum; can be set at any suitable time
Sound frequency: intermittent sound of 300 Hz
Sound pressure: changeable to around 100 dB maximum

Determining the fish-shoal situation

A fish finder is installed to discern seeds' nursing, postrelease cultivation, and audio-signal training of naturally collected fish.

Safety countermeasures

Sign lamps should be provided to consider the safety of vessels sailing around the area. Lighting is provided if night operations are required.

Power supply

Commercial power should be used at the facilities in the direction from the coast where the land-power supply is available. Batteries, including those by solar power, should be applied at the remote sites. In this case, taking into consideration the sunning hours of the installation site, attention should be paid to avoid power shortages.

Shore facilities

For remote control of the marine facilities, devices with telemetry equipment are installed and operated on land. In most cases a 150 MHz-band controller/receiver is installed. Water-temperature calculation, fish-finding image display, and printout records are available with equipment that includes a personal computer, color monitor, color display, and color printer.

Peripheral-water-area facilities

To encourage the released seeds to remain and the adult fish to settle, various kinds of artificial reefs, such as induction, residence, and spawning reefs are installed for improving resource-cultivation efficiency.

Present Situation and Future of Marine Ranching

Since 1988 the Fisheries Agency has conducted projects for Coastal Fishery Development and Coastal Fishery-Promoting Structural Improvement. Marine ranches, which were established under these programs, as of the end of 1995 exist in 15 sites in eight prefectures. All the structures are buoy-system for porgy and black porgy.

Conversely, the marine ranches established from 1978 for experiments and study by the prefectures and Marino-Forum 21, or established as projects solely by prefectures, occupy 30 sites in 18 prefectures. They mainly have raft-type structures, some with buoy- or stake-type structures, species-specific for porgy, black porgy, flounder, jacoperver, hardtail, barfin flounder, flatfish, and bluestreak emperor. All of these marine ranches concentrate upon audio-signal training.

Good examples of marine ranches include the Bungo Channel Area of Oita Prefecture; Odanohama Beach, Oshima, Kesennuma-shi, Miyagi Prefecture; Mano Bay, Sadogashima Island, Nigata Prefecture; and Shiraishi Island, Kasaoka-shi, Okayama Prefecture.

Especially in Oita Prefecture, the flourishing marine ranches at Saganoseki, Usuki, Tsukumi, and Hodojima are integrated into the "Bungo Channel Marine Ranching Area." Each has two-kilometer-diameter release-point protection, where the audio-signal-controlled buoys are installed, and is established as a nursery area. Fishing areas are demarcated beyond the nursery area. The fishing areas are managed with man-made resident and induction reefs, with extensive aquaculture fields. Porgies are produced under appropriate fishery management. The released porgies mature, migrate, spawn, and reproduce (Figure 9).

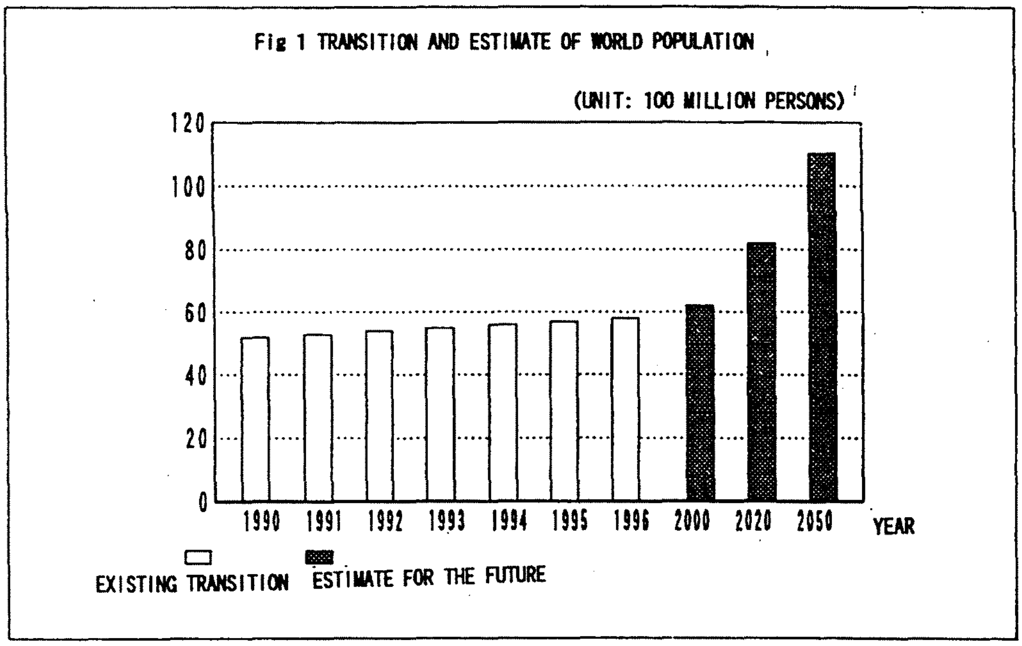
Porgy production in this area is increasing and achieving significant results; whereas in other areas without such countermeasures, diminished or stable production occurs.

Furthermore, in the marine ranches, one for jacopever at Odanohama Beach, Oshima, Kesennuma-shi; and the other for flatfish in Mano Bay, Sadogashima Island, the juveniles released after audio-signal training have demonstrated high percentages that remain proximal to the release point. These were superb resource-enhancement results.

In the marine ranch off Shiraishijima Island, Kasaoka-shi, new trials are expected for complex-type marine ranching conducted with grouper, porgy, black porgy, and black rock-fish.

For the future it is expected that wide-area-type marine ranching for Japan's 200-nautical-mile zone will become popular, making use of more advanced technology. With the nursing facilities in the nurseries or sanctuaries, juveniles can be efficiently cultivated by establishing artificial reefs for protection, growth, induction, etc. Fishing areas will be developed by constructing floating fish shelters, residential fish reefs, and artificial upwelling structures. Taking maximum advantage of advanced technologies such as observation aircraft and oceanographic-survey satellites, further development is expected by collecting information about fishery oceanographic conditions, and by installing marine stations and fishery oceanographic-observation buoys (Figure 10).

With these modern technologies, wide-area-type marine ranches for the 200-nautical-mile zone covering several prefectures will ideally be developed in the future. For this purpose further research and development should be required. I would like the researchers, engineers, and individuals engaging in fisheries to exercise wisdom and to strive vigorously for marine-ranch development.



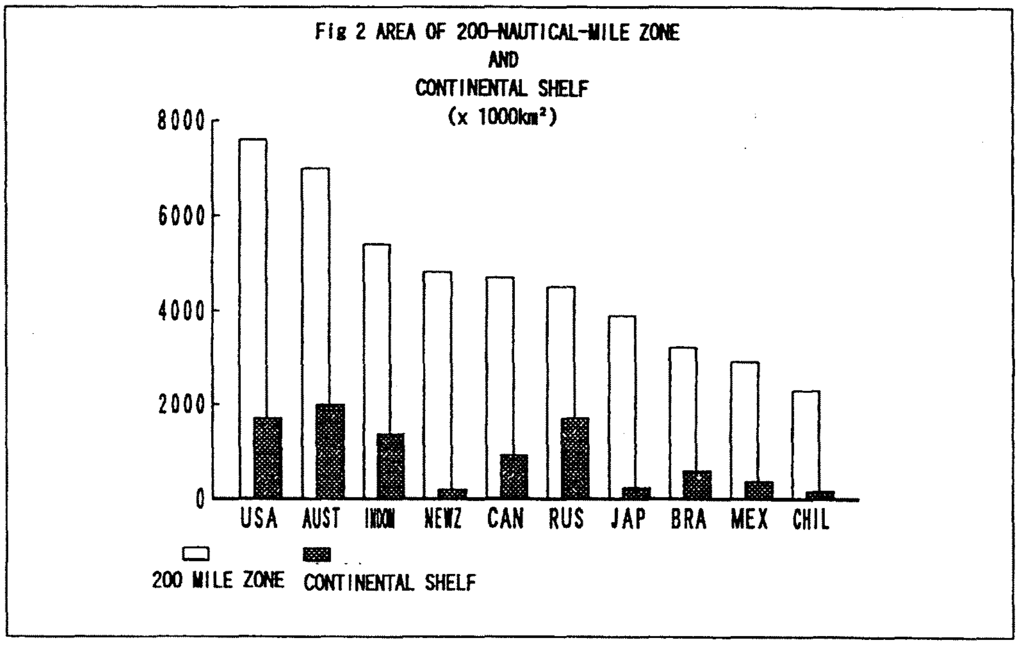


Fig.3 HARVEST TYPE MARINE RANCHING

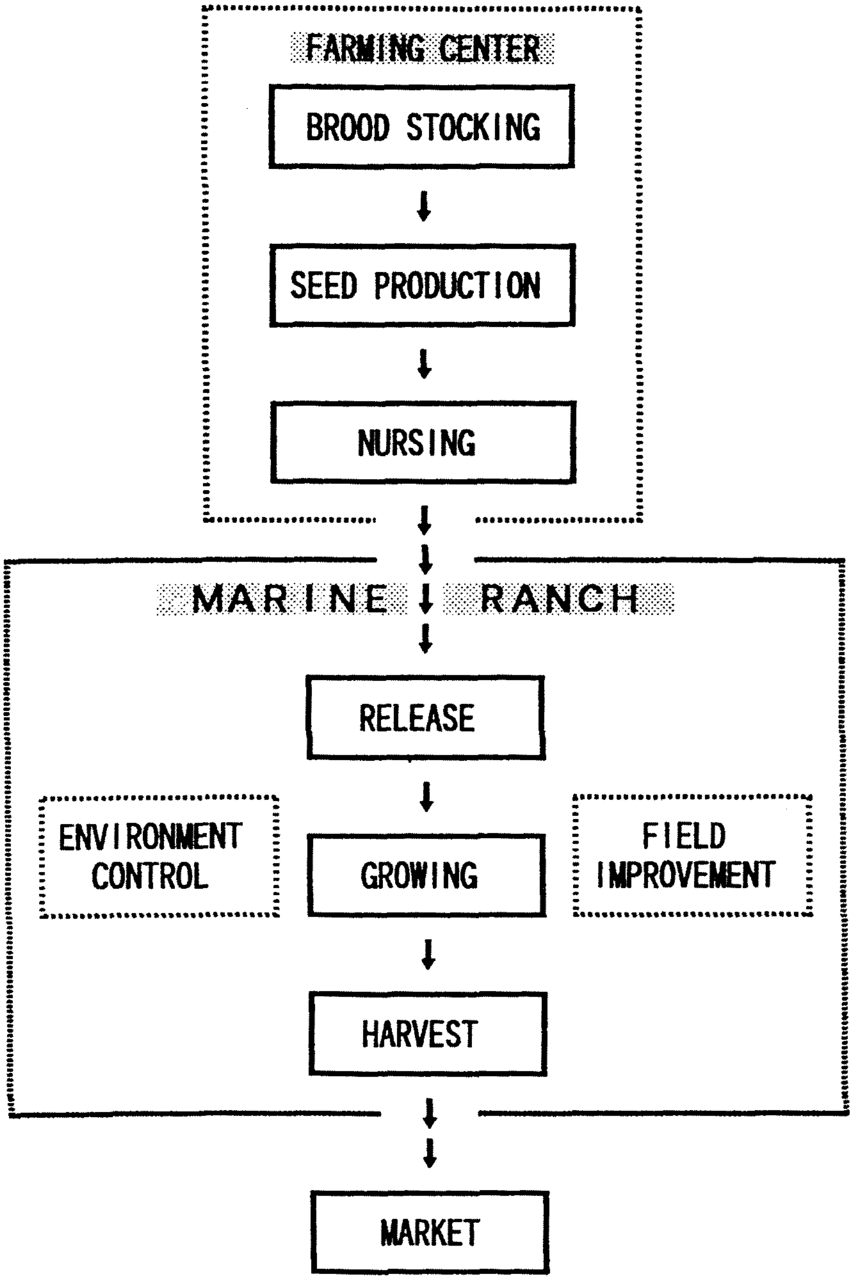


Fig.4 RECRUIT TYPE MARINE RANCHING

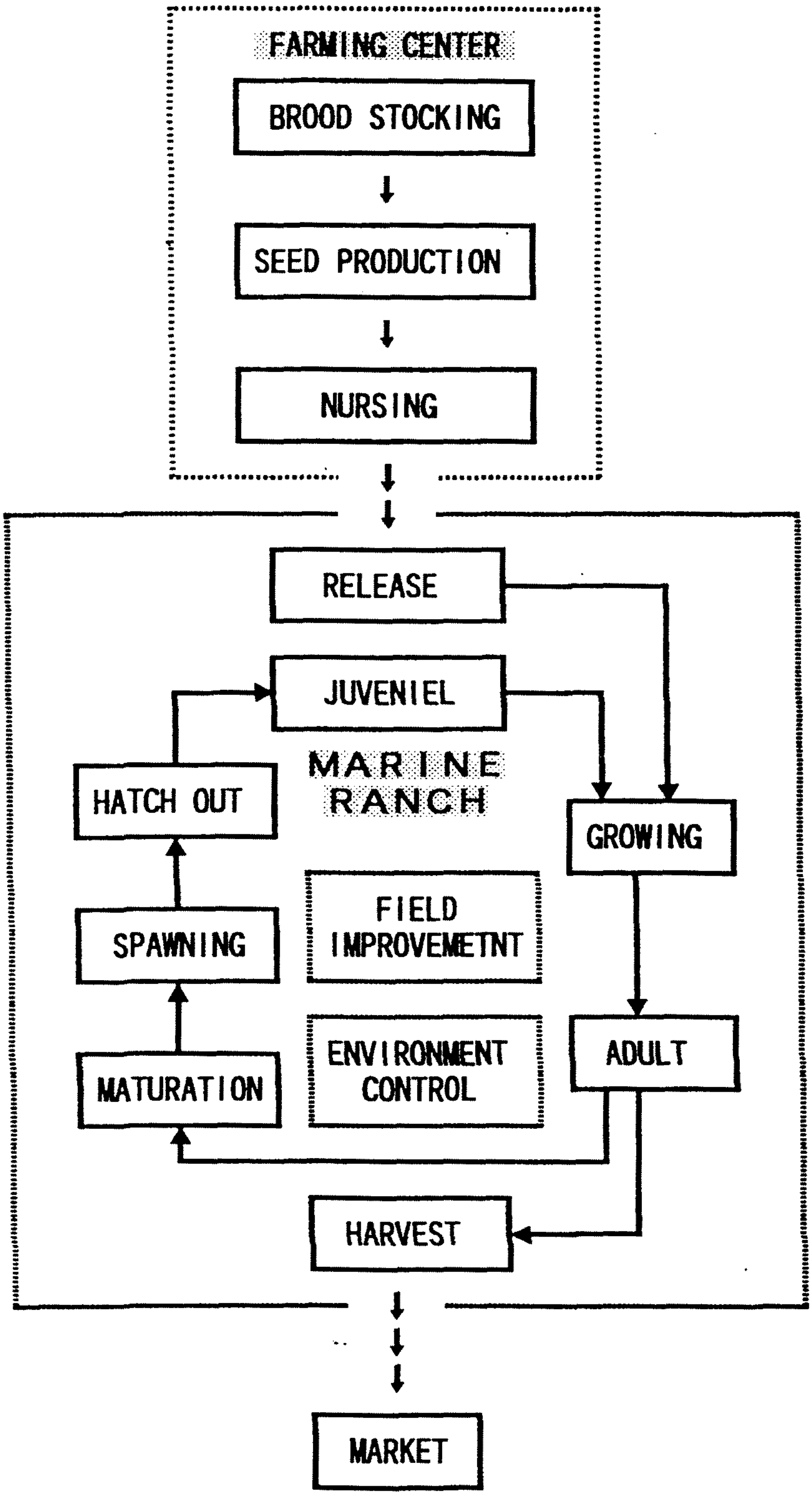


Fig.6 PROCESS OF MARINE RANCHING

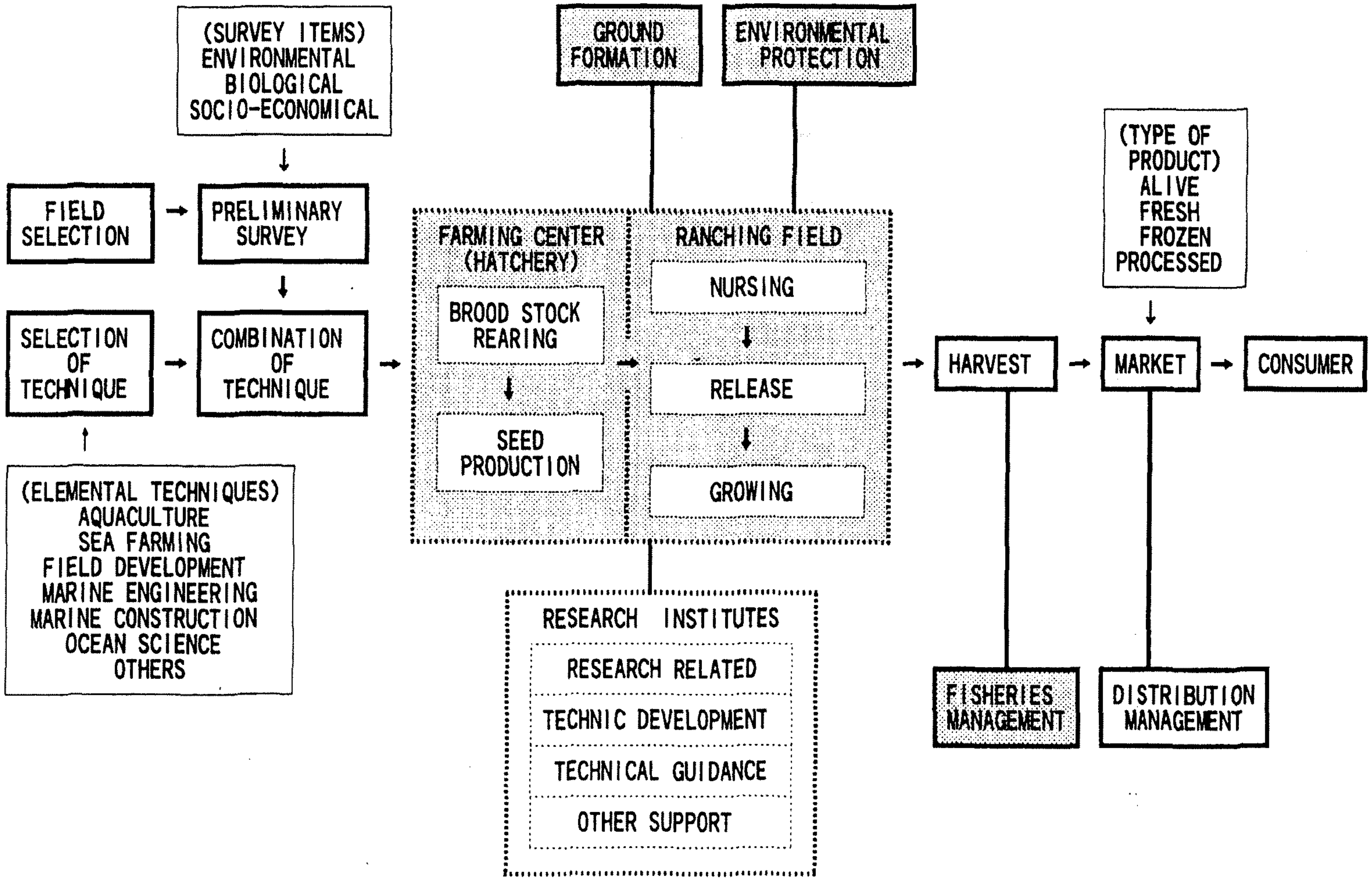


Fig.7 NURSERY TYPE MARINE RANCH MODEL

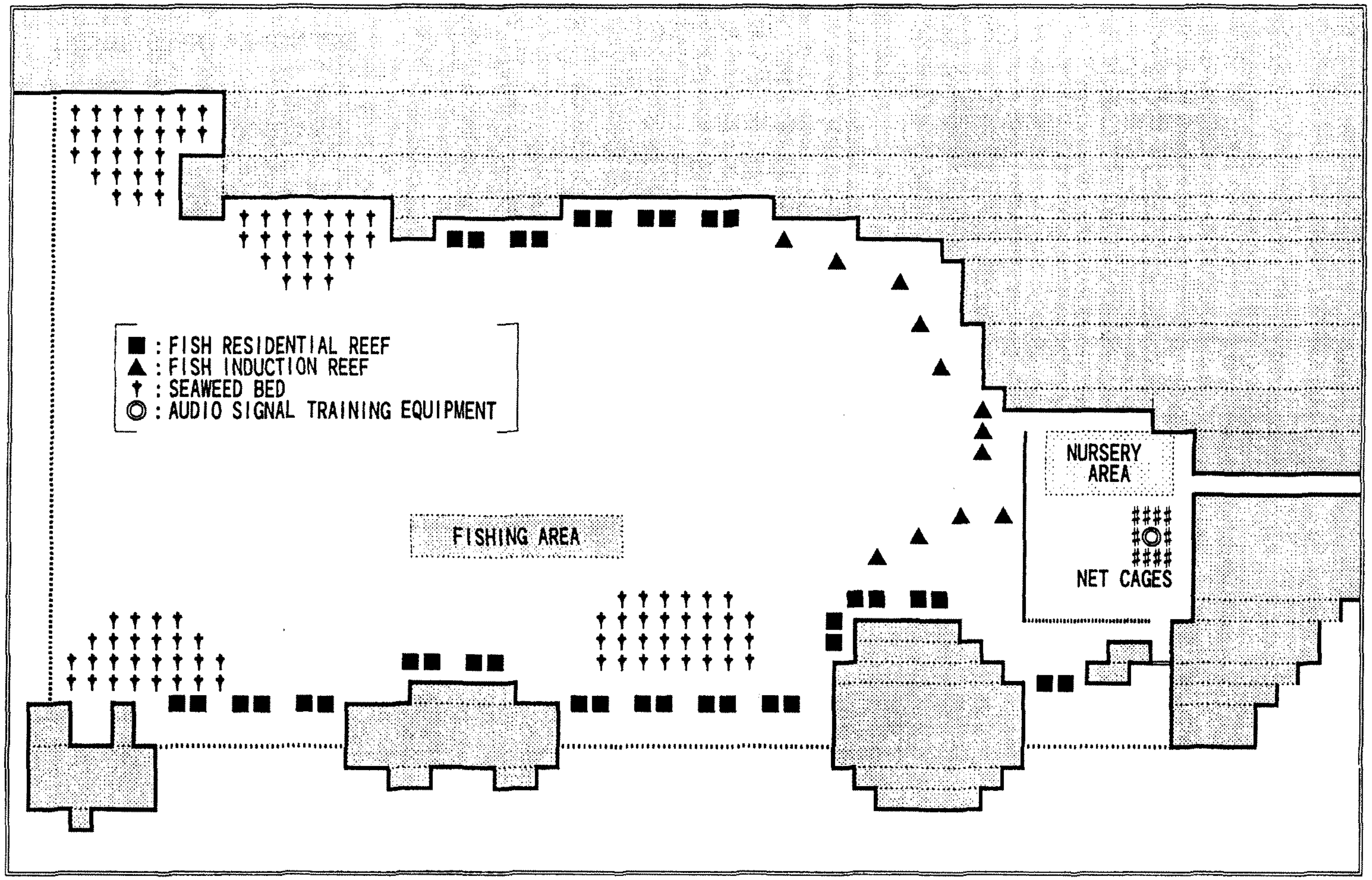
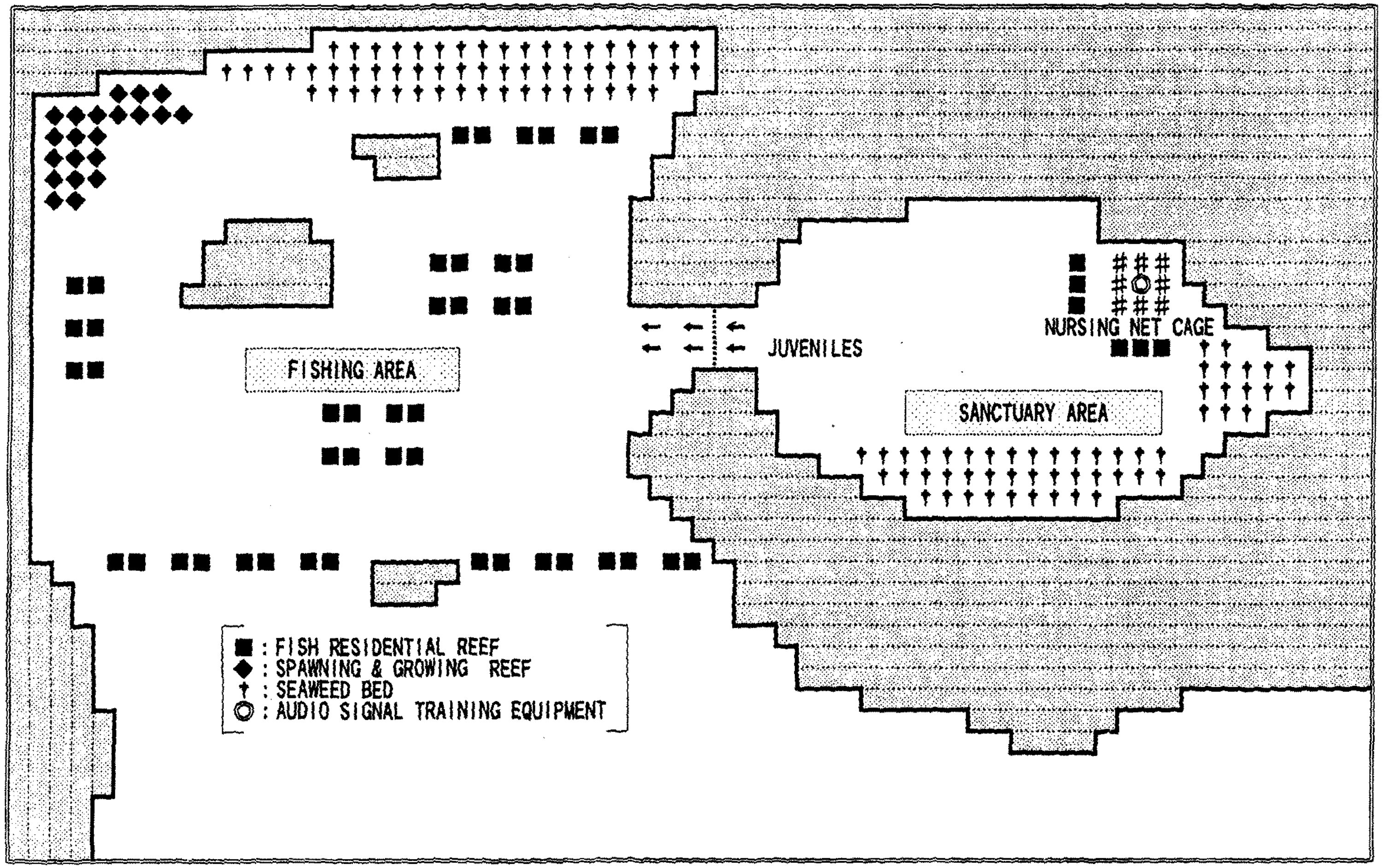


Fig.8 SANCTUARY TYPE MARINE RANCH MODEL



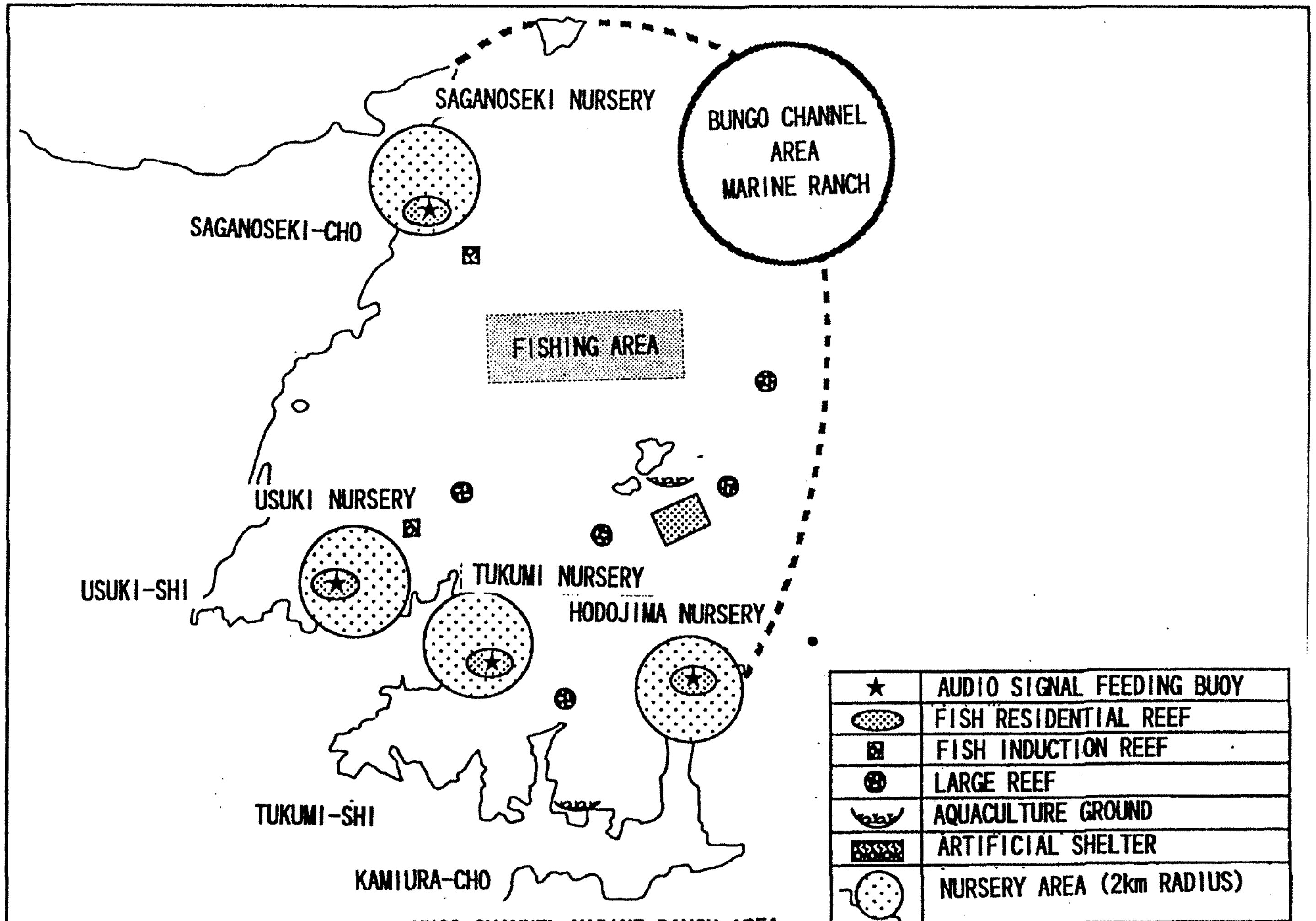


Fig 9 BUNGO CHANNEL MARINE RANCH AREA

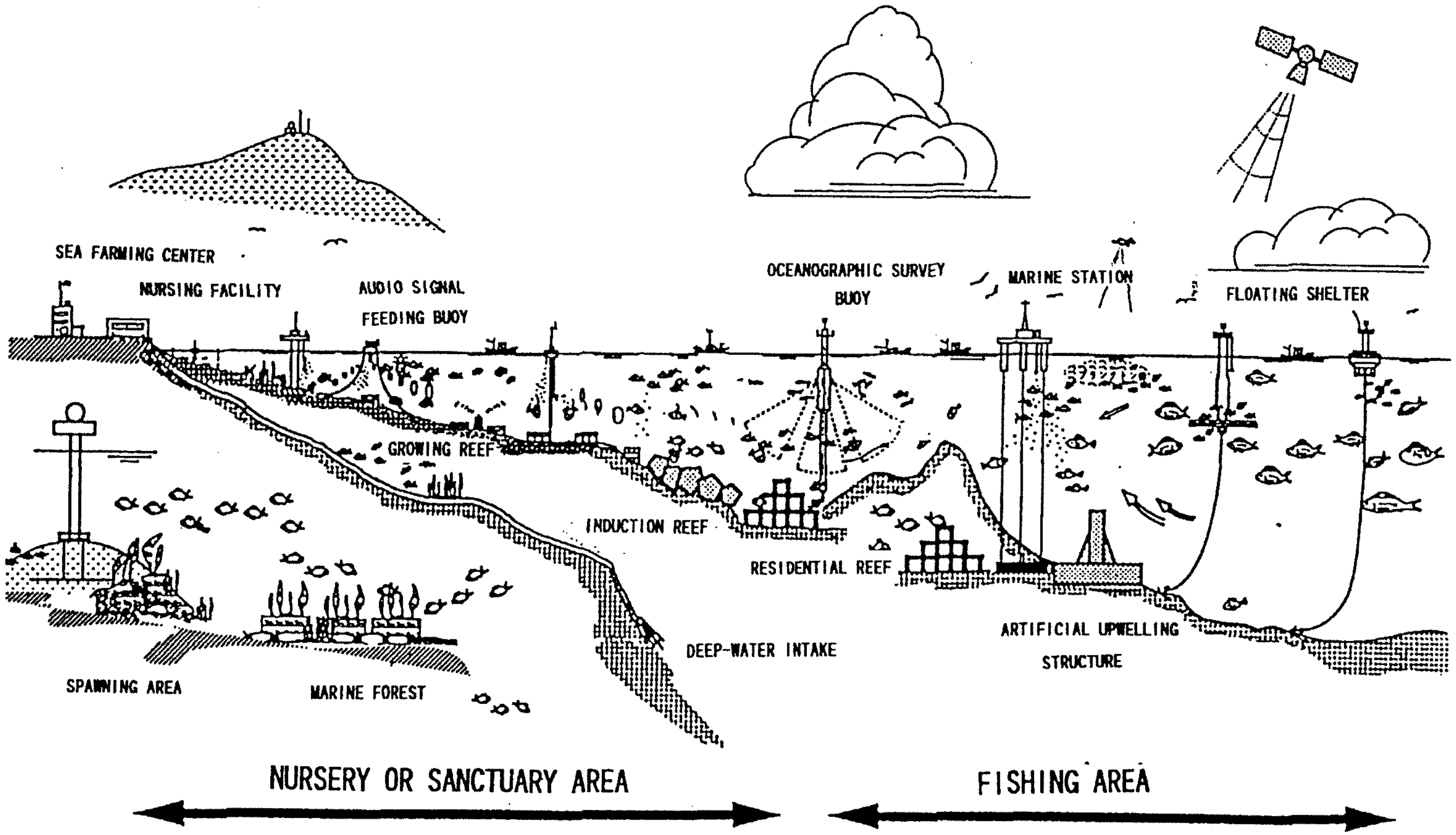


Fig 10 WIDE AREA MARINE RANCHING

MARINE RANCHING: CURRENT ISSUES, CONSTRAINTS AND OPPORTUNITIES

Devin M. Bartley
Fisheries Department
Food and Agriculture Organization
00100 Rome, Italy.

INTRODUCTION

With many of the world's capture fisheries overfished (Emerson 1994, FAO 1995b) and a growing demand for increased fishery production from an expanding human population (New 1991), enhancement of natural and man-made water bodies is seen as a mechanism to provide future food security and income. The use of hatcheries has been identified as a major component in these enhancement programmes by several international organisations involved with fisheries development (Lorenzen 1994, CGIAR 1995). The recently concluded Japan/FAO International Conference on Sustainable Contribution of Fisheries to Food Security resulted in the Kyoto that recognized the potential of fishery enhancement and marine ranching to restore depleted stocks and to increase food security; the Kyoto Plan of Action calls for " rapid transfer of technology and know-how in enhancement of inland and marine waters (Bartley 1995b, Japan/FAO unpublished report).

Three broad types stocking programmes have been identified (Cowx 1994): mitigation, augmentation and for community change. Mitigation stocking is to make up for loss of productivity due to anthropogenic perturbation to the environment. Numerous salmon hatcheries in North America and Europe were created as mitigation for lost spawning habitat as a result of dam construction. Augmentation stocking is designed to increase production of a particular stock that has either decreased, as in red drum fishery in the Gulf of Mexico (Rutledge 1989) and sturgeon fisheries in the Caspian Sea, or has been determined to be under the carrying capacity of the environment. Stocking for community change involves the introduction of a new species into a community to take advantage of an unfilled or underutilized niche, or to change the community structure towards a more productive endpoint, as in the case of Nile perch introduction to Lake Victoria, the striped bass in the western US, and numerous riverine fishes in Papua New Guinea. When stocking programmes are planned to be a permanent or long-term tool to increase fishery production for a specific constituency they are often called ranching programmes or in the case of sport fishing and put and take fisheries (Cowx 1994).

The use of hatcheries to create or augment fisheries has a history of controversy and mixed results (Petr 1989, Larkin 1991, Bartley 1995a). Hatchery enhancement of marine and anadromous fisheries has been criticized on the grounds that it is not effective, not cost effective, prevents alternative solutions from being implemented (McCall 1989), and that it endangers native aquatic resources (see references in Bartley et al. 1995 and Campton 1995). Hatchery enhancement of inland waters has not been as heavily criticized, and although there are numerous differences between marine and inland waters, many of the same issues and concerns are involved.

One reason for the failure of many past stocking programmes was the simplistic approach to the problem of decreasing fish-stocks (Baily 1991, Troadec 1991). There is now a greater appreciation for the inclusion of genetic and ecological principles in enhancement projects (Table 1 and Kent this volume). The International Council for the Exploration of the Sea (ICES) pointed out that often the reason for decreasing capture fisheries production are not well understood, therefore stocking may not adequately address the real problem.

However, advances in hatchery enhancement are appearing. Along with technological improvements in hatcheries, feed, disease prevention, etc., stocking projects recognize the importance of genetic stock structure, and the adaptation of subpopulations to certain habitats and are managing the hatchery releases accordingly (Waples 1991). Stocking projects are assessing ecological concerns, such as, size at release, release-habitat, habitat preference, habitat recovery, feed preference, juvenile fish movements, augmentation vs replacement and predator control (Leber et al. 1995, Kent et al. 1995, sand et al. 1991, Ikenoue and Kafuku 1992). Genetic resources are also being managed within hatcheries used for enhancement by attempts to increase effective population size, to select appropriate brood stock (Rutledge 1989, Allendorf and Ryman 1987, Bartley et al. 1995), or to create a better product through genetic modification (see for example Seeb et al. 1993, Jonasson et al. 1994).

It is the purpose of this document to review the main issues regarding hatchery enhancement and to discuss some of the constraints and opportunities facing the development of marine ranching as a tool for increased fishery production.

MAIN ISSUES

The critical difference between ranching and conventional aquaculture is that in ranching the animals must spend most of their lives in the wild as opposed to a culture facility. Thus, early feeding and conditioning and genetic resource management in the hatchery are necessary to produce a fish that can survive in nature. Furthermore, the stocking from the hatchery to nature means a loss of control over the harvest of the product, so access and ownership issues arise and cost effectiveness is more difficult to determine.

The use of hatcheries to enhance fishery production centers around five critical questions:

Can a hatchery produce a good product?
Can it be done cost effectively?
Will native aquatic biological diversity be endangered?
How is ownership/access to the hatchery-produced stock governed?
What alternatives to hatchery enhancement exist?

Each question will be briefly discussed in the following sections.

A Good Product
... from the Hatchery

A product from a hatchery enhancement programme that is considered "good" should meet the stated objectives of the enhancement programme (Allendorf and Ryman 1987). The production of healthy fish is the first basic objective. Proper animal husbandry, nutrition, and health management must be maintained in the hatchery to ensure that healthy and viable animals are released for ranching programmes. Much of this information has been determined, e.g. feeding practices, guidelines for disease prevention, culture practices, etc., is readily available, and has helped the aquaculture industry grow steadily over the last two decades (FAO 1995a). The number of species under culture has increased over the last 10 years (Fig 1) and it is now possible to culture large numbers of many species of marine fish and shellfish to their juvenile life history stages, at which point they may have better survival when released into the wild.

There is now the realization that genetic principles can play a major role in producing healthy fish from a hatchery. It will be necessary to insure that breeding and other hatchery procedures do not reduce genetic variability by inbreeding, reduced effective population size, by founder effect, or population bottle neck. Genetic variation and fitness can also be lost by outbreeding depression caused by mixing of genetically differentiated groups (Bailey 1987). Deliberate genetic modifications to hatchery organisms, e.g. hybridization, polyploidization, and gene transfer are discussed in following sections.

Outbreeding depression is another major difference between culture based fisheries and contained aquaculture where the mixing of different strains in the latter often produce beneficial results. The genetic characterization of brood fish has often been neglected, according to the ICES Working Group on Application of Genetic to Fisheries and Aquaculture (C.M. 1994/F:4). Also neglected has been the detailed genetic description of their progeny. Simple genetic techniques, such as isozyme analysis, can be used to describe both the brood stock and the allelic changes taking place in the progeny; more sophisticated molecular techniques are also being applied to fishery resource management (Wirgin and Waldman 1994). These data can provide information on inbreeding, brood fish contribution and effective population size (Sbordoni et al. 1987, Bartley et al. 1995).

A Good Product

... from the Wild (Enhanced Fishery)

Animals released from hatcheries must be able to adapt to the physical conditions and take advantage of natural resources in the area in which they are stocked. Thus, ecological and genetic interactions will be important and will depend on the objectives of the stocking programme, i.e. whether native or introduced species are to be stocked and whether stocked fish are meant to reproduce in nature.

Ecological concerns are critical. In mitigation stocking, the environment is often changed or manipulated so the species formerly living there may not be well adapted to the changed environment. Mitigation may also involve developing previoulsly unused habitat and there is an assumption that this newly utilized area will be nearly as productive as the original habitat that was lost. In augmentation stocking, it is assumed that the carrying capacity of the environment has not been reached and that increased numbers of the stocked species will not alter the community structure. When a new species is introduced, there is the assumption that, lin addition to the habitat being below carry capacity, the species performance in the new area will be similar to that in its native range.

In mitigation and augmentation enhancement programmes, the genetic structure of the hatchery population to be released must be compatible with the remnant natural population and the environment. When a new species is introduced into a community, its genetic structure must be compatible with the environment and the stocked population must have a good genetic resource base.

The hatchery product must adapt well to the natural environment and not cause outbreeding depression when mated with natural stocks. In an Atlantic salmon study a population composed by mixing adults from four different rivers had the lowest rates of return compared to the "pure" populations (Bailey 1987). Altukhov and Semelkova (1987) showed that by mixing genetically distinct stocks of chum salmon in Russia, the fitness of the native population was reduced. Hindar et al. (1991) provides a further review of decreased performance resulting from intraspecific hybridization for several species of salmon. Further discussion of the impact of stocking on native biodiversity is presented in a subsequent section.

Trophic interactions influence the success of stocking programmes, however there is often insufficient information on how the aquatic ecosystem operates and what contributes to a species natural mortality rate (Christensen 1994). The interactions among species will depend on the type of species present and also on the number of individuals in a population. Thus, pilot scale programmes that only release a limited number of individuals may not provide accurate information on the real impacts be they good or bad.

Another aspect of a good product is that it should be easily harvested by the group that produced it. This will entail more than just survival in the wild. Iceland marine ranching programmes of Atlantic salmon are selecting for fast growth and high return rates (Jonasson et al. 1994). Catfish stocked in reservoirs in the southern USA were selected and assessed for their "catchability" (Tave et al. 1981). For marine and many lacustrine species, migration patterns are at least partially genetically controlled, and must be considered in stocking programmes (Jonasson et al 1994). The failure of marine ranching of Pacific salmon in Chile was thought to be due, in part, to the failure of the salmon to navigate in the southern Pacific Ocean (J. Ruiz, Department of Fisheries Development (IFOP), Chile, pers. comm.). For some species of marine fish, stocks have been found with limited migration patterns that would make them easier to harvest after stocking, e.g. coastal stocks of cod, lobsters, and Pacific herring.

Because of the difficulty in improving in a hatchery traits that will help an animal in the wild, few attempts at genetic improvement of fish for marine ranching have been implemented, except for the cases mentioned above. None-the-less, genetic techniques are available to assist ranching programmes depending on the objectives of the programme (Table 2).

Modification of natural habitat may help increase efficacy of stocking. Japan has utilized tideland recovery, predator control, along with several countries that utilize artificial reefs, and stocking. South Pacific Islands are utilizing preserves where stocked clams (Tridacnae) are congregated on the reef to improve mating efficiency (clam circles) (Bell this volume).

Can it be done cost effectively?

For cost benefit analysis of ranching programmes there needs to be an assessment of the contribution that the ranching effort makes to the fishery. However, the real impact of many enhancement projects has not been determined because of poor monitoring and the inability to distinguish hatchery fish from native stocks (Coates 1995, Fernando and Holcik 1991).

However, even in instances where exotic species are used, therefore quite easy to distinguish, monitoring and assessment have often been lacking (Coates 1995).Enhancement projects have even been planned with no data on the status of the existing resource in the water body planned for stocking (Bartley 1993). Therefore, the first step in cost/benefit analysis is to know the current status of the resources and the factors that are affecting the fishery targeted for enhancement. Then estimates of production costs can be made and compared to the existing and potential value of the fishery. The next step is to devise a monitoring schedule that will provide data on the enhanced (ranched) fishery.

Monitoring schemes should provide input data to an economic model that evaluates cost-effectiveness. Included in such analyses should be cost of production including start up and hatchery running costs, opportunity costs, costs of other management strategies, depreciation and maintenance of hatchery, discount rates, roles of subsidies, and potential revenue from sale of hatchery fingerlings or from capture fishery. However, very few such studies have been performed on ranching programmes and there is no standard econimc model used. Moksness (this volumne) provides further insight into the economics of sea ranching.

Many stocking programmes are government supported or represent government-industry cooperatives, as in the cases of Japan and Alaska. Japanese fishery management involves cooperation among producers, harvesters, vendors, and the government. In such vertically integrated systems, cost/benefit analyses are complicated because losses in one sector can be made up by another. Thus, costs of hatcheries or habitat restoration can be recovered by other activities.

Genetic resources can also be utilized as inheritable tags to help monitor the impacts of an enhancement programme (Wirgin and Waldman 1994). Utter and Seeb (1990) presented tagging data that indicated that genetic tags are an effective means of tagging large numbers of fish and is the only means to identify contributions to subsequent generations. Genetic tags have been developed to aid in cod assessment programmes in Norway to evaluate reproductive success of hatchery vs wild steel head trout in the Pacific Northwest (Chilcote et al. 1986).

However, Smith and Francis (1991) stated that the breeding programme necessary to produce specific genetic tags may promote inbreeding or maladapted fish. Maximum likelihood mathematical procedures have been developed and utilized to determine the contribution of various salmonid hatchery and wild stocks to a mixed ocean fishery (Brodziak et al. 1991). Utter and Ryman (1993) demonstrated how genetic markers from a variety of species can, in theory, be used to assess the contribution of various stocks (including hatchery) to a mixed stock fishery. Thus, it may not be necessary to breed a specific marker into a hatchery stock, but merely to assess accurately its overall genetic structure and how it differs from the wild population.

Genetic markers can also be used to evaluate the performance of different strains used for stocking. Based on allozyme and mDNA character, Grewe et al. (1994) showed that when multiple strains of Lake trout, Salvelinus namaycush, were stocked in Lake Ontario, one strain had a significantly higher contribution to the next generation.

Conventional tagging by fin-clips, mechanical tags, injection of dyes, otolith marking, or the use of coded wire tags or PIT tags should not be excluded and can provide valuable information on movement and present contribution to a fishery.

Will native aquatic biological diversity be endangered?

The majority of production from the aquatic sector still comes from capture fisheries, although aquaculture and culture based fisheries figure prominently in production from inland waters (FAO 1995a). The natural diversity of aquatic organisms must be protected from adverse impacts, including aquaculture development. Thus, enhancement programmes must give due regard for all aquatic resources that form the basis for other fisheries, that provide forage for harvested species, and that may be ecologically important keystone species (FAO 1993).

Enhanced species populations or exotic species can directly affect local resources through ecological, genetic, and disease pathways. Codes of practice specific to the use of exotic species have been developed by ICES/EIFAC (Turner 1988) to reduce the threats to native resources. Such a code would also provide a measure of protection for any enhancement programme in that it forces a priori planning, assessment of resources, advice, approval, and outlines steps involved if the project is approved. Although these concerns were developed for exotic species, all enhancement programmes could be subjected to a similar process.

There is substantial interest in evaluating genetic impacts of stocking. Campton (1995) points out that although there is an impression held by some that hatchery enhancement is detrimental to native genetic resources, the reason for the decline in many native fisheries that are associated with stocking has not been due to direct genetic impacts of hatchery fish, but rather to associated fishery management actions that accompanied the stocking, for example, increased harvest rates on mixed fishery or habitat degradation and establishment of mitigation hatchery. (Campton does point out that ecological interactions (predation, competition and disease transfer) do directly affect native fish.). None-the-less the state of knowledge on this issue is not very complete and the possibility that adverse genetic interactions could arise should be addressed.

Mindful of the above paragraph and in response to criticism that it is harmful for hatcheries to release fertile fish closely related to, or conspecific with native species, a recommendation has been made that hatcheries should release sterile products or a mono-sex population (Turner 1988). Chromosome manipulation, sex reversal and subsequent mono-sex production, and interspecific hybridization (Shelton 1987, Seeb et al. 1993) have been promoted in this regard. Only triploid trout are allowed to be raised in Nova Scotia to minimize the threat of them breeding. A triploid hybrid between chinook and chum salmon may have both sterility and other favourable culture characters, such as reduced freshwater resident time and advantageous migration patterns. Sterile triploid grass carp are utilized in control of aquatic vegetation (Chilton and Muoneke 1992). Transgenic coho salmon may also be made triploid to reduce the chance of them breeding in nature (B. Devlin, pers. comm.).

Genetic principles have not been fully utilized in enhancement programmes and it is perhaps ironic that many of a species' characteristics that are favourable to culture can be detrimental if genetic concerns are not addressed (Table 3). In a brief review of over 50 marine and coastal hatchery enhancement projects (Bartley 1995b), less than 20 utilized some form of genetic applications and most of the applications were genetic stock identification involving salmonids. Only three projects utilized genetic resources to help increase production: a Canadian project considered selection for growth and conducted strain crossing to maximize returns, Iceland selects for early return and fast growth and in Lake Ontario stocked strains of Lake trout were evaluated for their contribution to subsequent generations.

The transmission of disease is also a main consideration in ranching programmes. The transfer from cultured to wild stocks is most serious in terms of biological diversity conservation. For example the fluke Gyrodactylus salaris has been spread to populations of Atlantic salmon in Norwegian rivers, most probably through the release or escape of fish from infected hatcheries (Egidius et al. 1991). However, there can also be transfer of pathogens from wild to cultured stocks which would reduce the efficacy of the ranching programme and then the disease could be spread even further through stocking (Johnsen and Jensen 1994). Wild stocks may act as a reservoir of disease that could adversely affect animals under culture conditions (Egidius et al. 1991).

The prevention of transmission of aquatic animal disease through trade and aquaculture is actively being undertaken by the international community. The fish Disease Commission of the Office International des Epizooties (OIE) International Animal Health Code and the Diagnostic Manual for Aquatic Animl Diseases to help in this regard. These codes and manual will also help evaluate the appropriateness of animal health in trade requirements for countries to ensure that they are not simply barriers to free trade (R. Subasinghe Fish Health Specialist, FAO, pers. comm.).

The OIE codes and manual and related codes, such as the ICES/EIFAC code on introductions which has a section on fish health, can be best applied in developed areas where trained personnel and resources for diagnosis and quarantine can be obtained; their application in developing and rural areas is more problematic and several organizations are working together to create regional guidelines to help implement the codes in these countries (Subasinghe 1996).

Technology for disease detection is increasing rapidly with ELISA (enzyme linked immunosorbent assay) for increased sensitivity and speed, better identification of pathogens, and the development of DNA probes that can detect minute quantities of certain pathogens based on their DNA structure, for example virus detection in marine shrimp (Mari et al. 1995). This technology coupled with the international attention to prevent the spread of diseases should help ensure healthy stocks for sea-ranching. However, the health of a fish is dependent on the interaction among the fish, the pathogen and the environment. A low level of infection may not cause any problem in a stock of fish that are raised with good animal husbandry practices.

How is ownership/access to the hatchery-produced stock governed?

Currently, many fisheries are managed on an open access basis with historic public fishing rights. The problem of how to ensure that the benefits of ranching programmes go to those supporting the programme must be added to the biological and technical aspects of fishery enhancement (Bannister and Pawson 1991). The rights of access and ownership need to be awarded to the investors in a ranching programme without causing conflicts over exclusion of public land, poaching, legal status of users, and proof of ownership of land or fish (Thompson 1989).

It may be necessary to modify fishing regulations to provide protection for a developing or recovering fishery, or to provide ownership rights to the hatchery that is engaged in enhancement. Iceland restricts offshore fishing for Atlantic salmon so that hatcheries can preferentially harvest their product as it returns to spawn. Japan's successful marine ranching programme relies, in part, on the extensive continental shelf area that lies within the countries EEZ and thus prevents foreign fishers from harvesting Japan's product. In some areas, such as Japan and Alaska, hatcheries are often joint ventures among government agencies, local communities and fishermen. In many Island States of the South Pacific, sections of the coastal sea floor are reserved for establishment of broodstock for the enhancement of molluscs and local communities with traditions of community management actively patrol and protect the broodstock from harvest and poaching (Dalzell and Adams 1995).

In ranching programmes that involve mitigation or stocking of an exotic species, the new or recovering fishery will need time to develop. There is the possibility that normal fishing activity may adversely affect the new fishery and fishing regulations may need to be temporarily modified (Campton 1994). Furthermore, if harvest quotas are based on hatchery output, or even on hatchery contribution to a fishery, native stocks which may be rare or diminished may be eliminated (Nelson and Soul 1987). In mitigation and augmentation enhancement, it should be recognized that there is a risk that the fishery will become dependent on stocking; stocking of exotic species may also be dependent on stocking at least initially. If this is not the desire, specific timelines and criteria for when a hatchery is to stop releasing fish should be established.

Genetic techniques are being applied to new areas, including those involved with ownership and access issues. Genetic stock analysis was used to manage trans-boundary Pacific salmon fisheries in the USA and Canada by identifying in which country stocks spawned, thus partitioning the catch to each country accordingly. In Chile, a fishery exists around the island of Chiloe that the salmon aquaculturist maintain is completely composed of escaped salmon from floating cages. The Fisheries Department (Chile) wishes to use genetic analysis to determine if the fish are the results of escapes and if so, the aquaculture industry wishes to impose fishing restrictions on the local fishermen. Although there are logistic problems with the use of genetic stock identification for all coho farms in Chile, the example shows that genetics may have broad application to fishery management.

The problem of access/ownership is not unique to ranching programmes. The philosophy of open access to the worlds aquatic resources has been blamed on the decline of many of the world's fisheries (FAO 1995b). The management of the world's capture fisheries is undergoing a change from open access to some form of property rights or rights of ownership. The first formal step in this process was the United Nations Law of the Sea (UNCLOS) that established 200 mile exclusive economic zones (EEZ) for coastal countries, although many societies in non-industrialized areas (see articles in Dalzell and Adams 1995) have traditionally awarded user rights to certain individuals or groups. New Zealand pioneered the idea of individual transferable quotas (ITQ) which is a form of property right to a portion of the allowable harvest from capture fisheries. Further restrictions on access to fisheries are being considered through licensing, limited enty, leasing plots of the ocean, and traditional community management plans.

Ranching programmes must be aware of these trends in fishery management and fit in where appropriate.

<u>What alternatives to ranching exist?</u>

The use of hatcheries to increase fishery production, especially in the marine environment continues to be controversial. Alternative approaches or scenarios need to be assessed and compared to ranching. Habitat improvement and better fishery management (see above) and legislation are basic alternatives that need to be evaluated. One unacceptable scenario is to allow wild stocks of fishes to disappear.

Loss or degradation of habitat is probably the biggest threat to most fisheries. Therefore, the feasibility and costs of habitat rehabilitation and reclamation should be assessed. Usually, habitat has been lost due to development projects that bring in substantial amounts of income, e.g. hydro-electric power generation, coastal industrial or housing projects. Fishing moratoria to allow a depleted stock to recover can also be very expensive as demonstrated by the subsidies (welfare) paid to approximately 40,000 fishers from the Canada's east-cost cod fishery. Government checks to these fishermen ranged from Can$225-460/wk and may cost the Canadian government over Can$2 billion over the planned 4 year moratorium. This is not to imply that cod ranching should be promoted in eastern Canada, simply that alternatives are not always cheap.

Alternatives may also be found outside of the fisheries sector. For example, increased animal protein and income may come from closed system aquaculture or agriculture rather than ranching. However, fishers would need to be trained for these activities and in certain areas such as small island states, land may not be available. It should be noted that many of the successful ranching programmes use hatcheries in conjunction with fisheries legislation, regulation and enforcement, and habitat restoration.

CONCLUSION

Ranching sits at the boundary between capture fisheries and aquaculture. This boundary is becoming more and blurred as natural habitats become physically modified to increase control over the harvest. Along with stocking, coastal lagoons are being enclosed and their fish protected by the removal of predators, inland lakes and reservoirs are being fertilized to increase fish production, artificial reefs and other structures are being added to the habitat, and access to many water bodies is being restricted to impart ownership on the fishery resources.

An accurate assessment of the role of stocking programmes in increasing fishery production is currently hampered by lack of data. How do we keep fishery statistics that will be meaningful and usefully differentiate among the different methods of producing fish? Monitoring studies to evaluate the impact of ranching programmes have not been implemented often because of the difficulty of identifying hatchery fish, and because many stocking programmes have been supported by governments that do not need to show cost/benefit analysis or centrally planned governments whose main goal was to generate foreign currency.

Models for marine ranching that include genetic, ecological and economic concerns exist for some developed areas and this technology is being applied to other areas of the world in support of fisheries development

(Bell this volume). FAO is trying to assess the role of hatcheries in fisheries enhancement and is involved in a number of upcoming international fora on the subject. To date, the data on stocking and hatchery enhancement from Member States are extremely incomplete. Therefore, FAO is requesting that Members contribute data on national stocking programmes, including number of fish stocked, life history stage stocked, and whether the animals were stocked into the wild or into contained facilities. Through these efforts we hope to learn from successful programmes and wisely advise Member States on the potential of marine ranching.

LITERATURE CITED

Allendorf, F.W. and Ryman, N. 1987. Genetic management of hatchery stocks. In: Ryman, N. and Utter F. (eds), Population Genetics and Fishery Management. University of Washington Press. Seattle, Washington, USA, pp.141-160.

Altukhov, Y.P. and E.A. Salmenkova. 1987. Stock transfer relative to the natural organization, management and conservation of fish populations. Pages 333-343 In: Ryman, N. and Utter F. (eds), Population Genetics and Fishery Management. University of Washington Press. Seattle, Washington, USA.

Bailey, J.K. 1987. Canadian sea ranching programme (east coast). Pages 443 - 448 in Tiews, K. (ed.), Selection, Hybridization, and Genetic Engineering in Aquaculture Vol II. Schriften der Bundesforschungsanstalt f symbol 252 \f "Times New Roman" r Fischerei, Hamburg, Germany

Baily, D. 1991. In Lockwood, S.J. (ed.), The Ecology and Management Aspects of Extensive Mariculture. ICES Marine Science Symposium, Vol 192. International Council for the Exploration of the Sea.

Bannister, R.C.A. and M.G. Pawson. 1991. A perspective on the management of enhanced fish and sellfish stocks in the territorial seas of England and Wales. Pages 242-246 in Lockwood, S.J. (ed.), The Ecology and Management Aspects of Extensive Mariculture. ICES Marine Science Symposium, Vol 192. International Council for the Exploration of the Sea.

Bartley, D.M. 1993. An application of international codes of practice on introductions of aquatic organisms: assessment of a project on the use of Chinese carps in Mozambique. FAO Fisheries Circular No. 863. Food and Agriculture Organization of the United Nations. Rome, Italy.

Bartley, D. M. 1995a. Conservation of biological diversity in hatchery enhancement programmes. - In: di Castri, F. and Youn symbol 232 \f "Times New Roman" s, T. (eds.), Biodiversity, Science and Development - Towards a new partnership. CAB International and International Union of Biological Sciences, Paris, France, pp. 424-438.

Bartley, D.M. 1995b. Marine and coastal area hatchery enhancement programmes: Food Security and Conservation of Biological Diversity. Paper prepared for Japanese/FAO Conference on Fisheries and Food Security. Kyoto, Japan, December, 1995.

Bartley, D.M., Kent, D.B. and Drawbridge, M.A. 1995. Conservation of genetic diversity in a white seabass (Atractoscion nobilis) hatchery enhancement programme in southern California. Uses and Effects of Cultured

Fish in Aquatic Systems, Symposium of the American Fisheries Society 15: 249-258.

Brodziak, J., B. Bentley, D. Bartley, G.A.E. Gall, R. Gomulkiewicz, and M. Mangel. 1992. Tests of genetic stock identification using coded wire tagged fish. Canadian Journal of Fisheries and Aquatic Sciences 49: 1507 - 1517.

Campton, D.E. 1995. Genetic effects of hatchery fish on wild populations of Pacific salmon and steelhead: what do we really know? Uses and Effects of Cultured Fish in Aquatic Systems, Symposium of the American Fisheries Society 15: 337-353..

CGIAR. 1995. From 'hunting' to farming fish. Press release, Consultative Group on International Agriculture Research. World Bank, Washington, DC.

Chilcote, M.W., S.A. Leider, and J.J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Transactions American Fisheries Society 115: 726-735.

Chilton, E.W. and M.I. Muoneke. 1992. Biology and management of grass carp (Ctenopharyngodon idella, Cyprinidae) for vegetation control: a North American perspective. Reviews in Fish Biology and Fisheries 2: 283-320.

Christensen, V. 1994. Assessing trophic impacts of fish stock assessment. ICES C.M. 1994/F:9. Report of the Workshop to Evaluate the Potential of Stock Enhancement as an Approach to Fisheries Management, Copenhagen, 1994.

Coates, D. 1995. Implementation of the EIFAC/ICES Code of Practice: Experiences with the evaluation of international fish transfers into the Sepik River Basin, Papua New Guinea. World Fisheries Congress 1992, Athens, Greece.

Cowx, I. G. 1994. Stocking strategies. - Fish. Man. Ecol. 1: 15-30.

Dalzell, P. and T.J.H. Adams. 1995. South Pacific Commission and Forum Fisheries Agency Workshop on the Mangement of south Pacific Inshore Fisheries. Vols I and II. South Pacific Commission, Noumea, New Caledonia.

Egidius, E., L.P. Hansen, B. Jonsson, and G. Naevdal. 1991. Mutual impact of wild and cultured Atlantic salmon in Norway. Cas Histories of Effects of Transfers and Introductions on Marine Resources. J. Cons. CIEM 47: 404-410.

Emerson, T. 1994. Fished out. Newsweek, April 25, 1994: 30-33.

FAO (Food and Agriculture Organization). 1993. Report of the Expert Consultation on Utilization and Conservation of Aquatic Genetic Resources. - FAO Fisheries Report No. 491. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (Food and Agriculture Organization). 1995a. Fishery Information, Data and Statistics Service. Aquaculture production statistics. FAO Fisheries Circular No. 815 (Rev 7).

FAO (Food and Agriculture Organization). 1995b. The state of the World Fisheries and Aquaculture. FAO Fisheries Department, Food and Agriculture Organization of the United Nations, Rome, Italy.

Garibaldi, L. 1996. List of animal species used in aquaculture. FAO Fisheries Circular No. 914. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fernando, C.H. and J. Holcik. 1991. Some impacts of fish introductions into tropical waters. Pages 103 - 129 in P.S. Ramakrishnan (editor), Ecology of Biological Invasion in the Tropics.

Grewe, P.M., C.C. Krueger, and J.E. Marsden. 1994. Hatchery origins of naturally produced Lake trout fry captured in Lake Ontario: temporal and spatial variability based on allozyme and mitochondrial DNA data. Trans. Amer. Fish. Soc. 123: 309-320.

Hindar, K., Ryman, N. and Utter, F. 1991. Genetic effects of cultured fish on natural fish populations. Can. J. Fish. Aquat. Sci. 48: 945-957.

Ikenoue, H. and Kafuku, T. 1992. Modern Methods of Aquaculture in Japan. - Elsevier, Tokyo.

Johnsen, B.O. and A.J. Jensen. 1994. The spread of furunculosis in salmonids in Norwegian rivers. J. Fish Biol. 45: 47-55.

Jonasson, J., T. Gjedrem, and H. Bentsen. 1994. Selection experiments in Atlantic salmon ranching: discussion of breeding plan, predicted and realized response to selection. Book of Abstracts, Fifth International Symposium on Genetics in Aquaculture, Halifax Nova Scotia.

Kent, D. B., Drawbridge, M. A. and Ford, R. F. 1995. Accomplishments and roadblocks of a marine stock enhancement program for white seabass in California. - In: Schramm, H. L. J. and Piper, R. G. (eds.), Uses and Effects of Cultured Fishes in Aquatic Systems. American Fisheries Society, Bethesda, MD, pp. 492-498.

Larkin, P. A. 1991. Mariculture and fisheries: future prospects and partnerships. - In: Lockwood, S. J. (ed.), The Ecology and Management Aspects of Extensive Mariculture, Vol. 192. International Council for the Exploration of the Sea,, pp. 6-14.

Leber, K.M., N.P. Brennan, S.M. Arce. 1995. Marine enhancement with striped mullet: are we repleneshing or displacing wild stocks? Uses and Effects of Cultured Fishes in Aquatic Ecosystems. American Fishery Society Symposium 15: 376-387.

Lorenzen, K. 1994. Dynamics and management of Asian culture-based reservoir fisheries. Aquaculture News 18: 20.

MacCall, A. D. (1989) Against marine fish hatcheries: ironies of fishery politics in the technological era. California Cooperative Oceanic Fisheries Investigations Report 30, 46-48.

Mari, J., D.V. Lightner, B.T. Poulos, and J.R. Bonomi. 1995. Partial cloning of the genome of an unusual shrimp parvovirus (HPV): Use of gene probes in disease diagnosis. Diseases of Aquatic Organisms 22: 129 - 134,

Nelson, K. And M. Soule 1987. Genetical conservation of exploited fishes. Pages 345-368 in N. Ryman and F. Utter (eds), Population Genetics and Fishery Management. University of Washington Press. Seattle, WA, USA.

New, M.B. 1991. Turn of the millennium aquaculture: navigating troubled waters or riding the crest of the wave? World Aquaculture 22: 28-49.

Petr, T. 1989. The use of common and Asian carps in the fisheries management of larger inland water bodies of the Indo-Pacific. Pages 1 - 5 in T. Petr (ed), Indo-Pacific Fishery Commission. FAO Fisheries Report No. 405 Supplement.

Rutledge, W.P. 1989. The Texas marine hatchery program - it works! California Cooperative Oceanic Fisheries Investigations Report 30, 49-52.

Sbordoni, V., La Rosa, G., Mattoccia, M., Cobolli Sbordoni, M., and De Matthaeis, E. 1987. Genetic changes in seven generations of hatchery stocks of the Kuruma prawn, Penaeus japonicus. In: Tiews, K. (ed.), Selection, hybridization, and genetic engineering in aquaculture. Vol I. Heenemann GmbH & Co., Berlin, Germany, 143-155.

Seeb, J.E., Thorgaard, G.H., and Tynan, T. (1993) Triploid hybrids between chum salmon female x chinook salmon male have early sea-water tolerance. Aquaculture 117, 37-45.

Shelton, W.L. 1987. Genetic manipulations - sex control of exotic fish for stocking. Pages 175 - 194, In: Tiews, K. (ed.), Selection, hybridization, and genetic engineering in aquaculture. Vol I. Heenemann GmbH & Co., Berlin, Germany.

Smith, P.J. and M.P. Francis. 1991. Snapper reseeding in the Hauraki Gulf: scientific considerations. MAF Fisheries Greta Point Internal Report No. 172. Wellington New Zealand.

Subasinghe, R.P. 1996. Health certification and quarantine of aquatic organisms: practical guidelines for Asia and the Pacific. FAO Aquaculture Newsletter No. 12: 10 - 13.

Svasand, T., K.E. Jorstad, G. Blom, and T.S. Kristiansen. 1991. Application of genetic markers fro early life history investigations on Atlantic cod. (Gadus morhua). ICES Marine Science Symposium 192: 193 - 199.

Tave, D., A.A. McGinty, J.A. Chappell, and R.O. Smitherman. 1981. Relative harvestability by sangling of blue catfish, channel catfish and their reciprocal hybrids. N. Amer. J. Fish. Management 1: 73-76.

Thompson, J.D. 1989. Administrative, legal, and sociological difficulties of scallop culture and enhancement. Pages 264-271 in Dredge, M.L.C., W.F. Zacharin, and L.M. Joll (eds), Proceedings of the Australasian Scallop Workshop.

Troadec, J.P. 1991. Extensive aquaculture: a future opportunity for increasing fish production and a new field for fishery investigations. In Lockwood, S.J. (ed.), The Ecology and Management Aspects of Extensive Mariculture. ICES Marine Science Symposium, Vol 192. International Council for the Exploration of the Sea pp.12-15

Turner, G. editor. 1988. Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms. - EIFAC Occasional Paper No. 23. European Inland Fisheries

Advisory Commission. Food and Agriculture Organization of the United Nations, Rome, Italy.

Utter, F. and J.E. Seeb. 1990. Genetic marking of fishes: Overview focusing on protein variation. Pages 426 - 438. In N.C. Parker and 5 co-editors Fish Marking Techniques. American Fisheries Society Symposium No. 7.

Utter, F. and Ryman, N. 1993. Genetic markers and mixed stock fisheries. Fisheries 18, 11-21.

Waples, R.S. 1991. Genetic interactions between hatchery and wild salmonids: lessons form the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 48, 124-133.

Wirgin, I.I. and J.R. Waldman. 1994. What can DNA do for you? Fisheries 19:16-27.sppp

Table 1. Types of hatchery enhancement programmes

	Species used	Genetic concerns	Ecological concerns	Examples
Mitigation	Native stock or a close relative	Duplicate natural variation to the extent that habitat will allow. In altered habitats wide genetic resource base or well adaped populations can be stocked	Alternate or altered habitat is suitable; fishery is recruit limited.	Common type of stocking for Pacific salmon; sturgeon and mahi sephid in Caspian Sea.
Augmentation	Native	Stocked animals must be compatible with native populations. Genetic concerns critical.	Fishery is recruit limited; - habitat use is below its carrying capacity; - additional animals won't alter community or depress production. Habitat improvement may also be involved.	Japanese examples of high value species, such Red Sea Bream, Kuruma prawn, halibut; Red drum in Gulf of Mexico; cod in Norway. Artificial reefs in Japan.
Community change	Exotic	Stocked animals must adapt to new environment, so good genetic resource base needed. Potential hybridization with related species.	Species performance in new environment will be similar to that in its old environment; habitat is below its carrying capacity.	Newly created water bodies (reservoirs) stocked with carp in Iran and Indo-Pacific; Nile perch and tilapia in Lake Victoria; Striped bass in western US; Pacific salmon in Great Lakes and failed attemps in Chile.

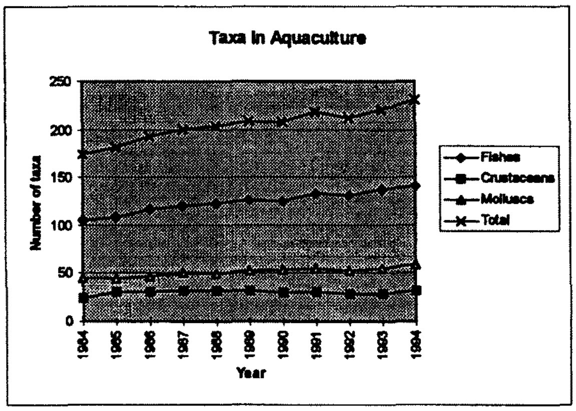
Table 2. Some genetic manipulations for hatchery enhancement programmes

Goal	Manipulation	Examples
Increased growh rate	Triplodization Selective breeding	Release of sterile Mahi sephid in Caspian Sea (FAO, 1992); High growth rate in Atlantic salmon in iceland (Jonasson et al. 1994).
Decreased reproduction in wild	Triploidization Hormonal treatment Hybridization Gamete manipulation	Atlantic salmon in Nova Scotia; sterile grass carp stocked in US (Chilton and Muoneke 1992); Androgen and estrogen treatments to reverse sex in several species reviewed by Shelton (1987); Female grass x male bighead carps produce sterile triploids; tilapia interspecific hybrids produce monosex progeny (Shelton 1987); Sperm and egg irradiation to produce androgens and gynogens (Shelton 1987).
Increased catchability	Selective breeding Stock selection	Channel, blue and their hybrid catfishes selected for ease of angling (Tave et al. 1981); Coastal stocks (e.g. Norwegian cod, lobsters and Pacific herring) used as broodstock potentially to reduce dispersal.
Changed migration patterns	Hybridization Selective breeding	Chum x chinook salmon triploids created for early seawater tolerance as well as sterility (Seeb et al. 1993); Early return selected for in Atalntic salmon in Iceland (Jonasson et al, 1994).
Facilitated indentification	Breeding of genetic markers	Genetic marker in released cod (Svasand et al. 1991) help determine movement and feeding; genetically marked steelhead used to assess performance difference between hatchery and wild steelhead (reviewed in Utter and Seeb 1990).
Conserved genetic resources	Hatchery management	Population genetic analyses to estimate effective population size, set conservation goals, and establish number of broodstock in white seabass hatchery (Bartley et al. 1995).

Table 3. Species characteristics that are favourable for culture, but that may promote adverse effects if genetic principles are not considered

Characteristic	Potential problem	Genetic application
" Hardy" eggs, larvae and fingerlings	May promote wide dispersal into areas, including hatcheries, where genes are maladapted or will mix with native gene pool	Genetic stock identification and minimize or plan stock transfers
Limited migration and good homing abilities	Locally adapted stocks that may be impacted by genes from other stocks; small effective population size and inbreeding depression.	Genetic stock identification, minimize or plan transfers, maximize effective population size
Fast recruitment to fishery or spawning stock	Rapid evolution in hatchery environment due to short generation time; early reproduction and stunting	Hatchery management of genetic resources including pedigree analysis of returning spawners. Selection for age at maturity
Good hybridization potential or ease of spawning	Uncontrolled spawning, or hybridization, mixing of strains and outbreeding depression or loss of desired type	Genetic stock identification, genetic manipulations to avoid unwanted reproduction
High fecundity	Can result in low effective population size, inbreeding depression and loss of diversity if only a few broodstock are used to contribute gametes.	Maximize effective population size and monitor genetic resources of hatchery product; infuse new genes when necessary
Domestication	A fish well adapted to a culture environment may not be well adapted to the wild	Avoid inadvertent and artificial selection in hatchery, maximize effective population size, infuse new genes when necessary

Figure 1. Number of species and other taxonomic levels[1] for which aquaculture production is reported (Garibaldi 1996, and FAO Aquastat PC 1996).



[1] Other taxonomic levels include data not reported at the species level, e.g. Molluscs, Osteichthyes, Crustacea, and Genus

ECONOMIC EVALUATION OF MARINE RANCHING

Erlend Moksness
Institute of Marine Research
Flodevigen Marines Research Station
N-4817 His, Norway

ABSTRACT

World wide, marine ranching includes more than 100 species in over 20 countries. In general, the various research programs for stock enhancement and sea ranching of marine organisms are focusing on local coastal stocks and not on abundant open sea stocks. While stock enhancement represents the effort to improve annual recruitment of depleted stocks or bring such stocks back to historical levels, ranching represents an attempt to increase the annual yield of a species. Economic evaluation (such as net present value and cost-benefit analysis) of ranching projects should take place during an early stage and before large scale release starts. At present, published results of economic analysis are available from very few marine ranching projects. The main reason for this may be lack of data on growth, survival and recapture rates of the released animals. Unfortunately, only a few of the selected species can today be produced in large enough numbers (> 1 million/year) to contribute to large scale releases. The published reports indicate that for species which have a low market price, the production costs of juveniles need to be reduced significantly to make the projects economically profitable in the future.

INTRODUCTION

Ranching of salmonids and marine fishes in modern times goes back more than 100 years (Isaksson, 1988; Solemdal et al., 1983), and has developed similarly for the two groups of fishes. Both started out by releasing young larvae. However, once juveniles could be reared artificially, the release strategy shifted to later stages.

In the past 30 years enhancement and ranching of salmonids and marine organisms have increased world-wide, today including more than 115 species, with activities in more then 20 countries (Bartley, 1995). In general, programs are focusing on local coastal stocks and not on abundant open sea stocks. In marine ranching, Japan is the leading country, with more then 80 marine species in their ranching program (Anon., 1995). In addition, Japan, in the initiative known as Marino-forum 21, has identified development of coastal areas for marine ranching as a high priority for the next 100 years.

Modified from Bannister (1991) the following definitions of enhancement and ranching are used:

a) Enhancement - Production of stock released for (i) Compensation for depletion of a natural resource (restocking), (ii) Compensation for loss of habitat, such as salmon breeding sites (augmentation), and (iii) Genuine addition of new stock (e.g. stocking artificial reefs) (addition).

b) Ranching (Sea ranching) - Production of identifiable stock with the intention of being harvested by the release agency and can separated into three categories (Isaksson, 1988): public, private and cooperative ranching. Implies a cost-benefit analysis based on comparing the harvested value with the cost of production, release, and harvesting.

Both enhancement and ranching involve artificial rearing of larvae, juveniles or adult organisms to be released in their natural environment. Ranching, however, differs from enhancement in several ways. For example, its aims to increase the annual recruitment to the fishery and thereby increase annual yield of valuable fish protein, either in commercial or recreational fishery, and to be economically profitable.

The objective of this paper is to evaluate published results on ranching of marine organisms and indicate any trends in the results, as well as possibilities and limitations.

Blankenship and Leber (1995) introduced the responsible-approach concept to ranching. One of its ten components is to "Identify economic and policy objectives". This implies that for each ranching project a cost-benefit analysis should be done at an early stage, before large scale releases starts. Bailly (1991) discussed the economic basis for marine ranching and indicated what kind of information we should be looking for: "cost of a reared and released juvenile.... the chances of this animal to survive and to be captured at a size of commercial interest...". He continued his argument saying: "If sea-ranching has been introduced to support and develop an existing fishery, the value we have to measure is the increase of catch per unit effort for a constant fishing effort" and "If the fishing effort is constant, the benefits appear when the increase in landing values is more than the hatchery/nursery/release cost". This approach may be correct, but for many studies to date, not enough information is available to accurately estimate catch per unit effort. Therefore, a better approach is to tag all juveniles released, and register all available data on the recaptured animals, such as date, size and location. According to Anon. (1994a), each project should then be able to address the following questions:

- Is there sufficient information to assess the financial viability of the project in terms of net present value over a realistic operational time scale, or to carry out a full scale cost-benefit analysis including quantification and allocation of the social benefits?
- Do these analysis indicate whether a stocking program is likely to be financially self-sustaining, or will require subsidy?
- How do the potential costs and benefits of restocking compare with the costs and benefits of stricter management of the wild fishery?

MARINE RANCHING

The marine species involved

Today Japan holds a unique position in ranching of marine organisms by releasing (in 1994) a total of 70.7 million juveniles of 33 different marine fish species (Anon, 1995), including more than 20 million red sea bream (*Pagrus major*), 19 million Japanese flounder (*Paralichtyhs olivaceus*), 7 million black sea bream (*Acanthopagrus schlegeli*) and 1.8 million tiger puffer (*Takifugu rubripes*) (Table 1)(see also Matsuoka this volume for additional information). In addition to 357.5 million crustaceans, 17827.6 million shellfish and 72.9 million others, such as sea-urchin (*Echinoidea*). Only the red drum (*Sciaenops ocellatus*) program in the USA (Denson et al., 1994; Roberts et al., 1994; Rutledge, 1989) releases a larger number of fish annually, with more then 30 million red drum juveniles in 1994 (Moksness and Støle, 1996). For most ranching programs in the world, the number of organisms released annually is below 500.000. In the USA three other marine fish species are included in enhancement projects; white seabass (*Atractoscion nobilis*) (Kent et al., 1994), striped mullet (*Mugil cephalus*) and Pacific threadfin (*Polydactylus sexfilis*) (Anon., 1994b). In Scandinavia the target fish species are cod (*Gadus morhua*) and turbot (*Scophthalmus maximus*). In addition, Denmark has released a limited number of flounder (*Platichthys flesus*) for recreational purposes (Svåsand, 1994; Støttrup et al., 1994a; Støttrup et al., 1994b). Ranching with lobster (*Homarus gammarus* and *H. americanus*) has taken place in Europe and North America respectively for many years (Anon, 1994a) and today this activity are still taken place in the UK, Ireland, France, Norway and the USA.

In Australia several species have been identified for ranching, both for commercial and recreational purposes (P. Rothlisberg, CSIRO, Australia, pers. comm., 1996), such as penaeid prawn (*Penaeus esculentus*) and several fin fish species respectively. In China studies are taking place on ranching of Chinese prawn (*Panaeus orientalis*) and false halibut (*Paralichthys olivaceus*) (Bartley, 1995)

Lessons from salmon ranching

The salmonids differ from the marine fish species by the fact that they spend part of their lives in the marine environment. Ranching with salmon therefore is not directly comparable with the marine species. However, with all the effort put into the ranching of salmon, common important issues have been addressed and discussed, such as legal right over ranched organisms (Howarth, 1989), possibilities and problems regarding public and private ranching (Royce, 1988), the case where the fish might be released in one area but move to other areas for feeding, possibly involving more than one country (Shelton and Koenings, 1995), fishing pattern and its impact on the costs, benefits and economics in ranching in general (Isaksson, 1988; Stokes, 1982; Rockland, 1988; Carter and Radtke, 1988). Since most cases ranching with marine organisms normally takes place in local coastal areas, two aspects that have a significant impact on the economy have been addressed in the salmon story: the carrying capacity and the institutional structure.

Carrying capacity can be defined as (Anon, 1996a): ".... a measure of the biomass of a population that can be supported by the ecosystem. The carrying capacity changes over time with the abundance of predators and supply of food. The food supply is a function of the productivity of the prey populations and competition for that food from other predators. Changes in the biotic environment affect the distributions and productivity of all populations involved". Effects on salmon have been discussed by Kaeriyama (1996) who concluded that Pacific salmon have a density-dependent growth rate and that returning fish did get smaller, most likely due to the high number of releases. Similar effects might be expected in cases with large scale releases of marine organisms.

With regard to institutional structures, the choice of public, private and cooperative ranching is of great importance; each has different positive and negative effects (Isaksson, 1988) on the economic results of a ranching operation and the structure chosen will be of great importance. With salmon, private ranching experienced little or no economic success, indicating that public ranching might be a better approach. In Norway this probably will demand that both commercial and recreational fishermen pay a fee for fishing. Introduction of such a fee in Norway might create problems, due to the fact that most Norwegians think that its their right to fish in the marine environment anywhere and anytime, without paying.

Economy in marine ranching

Ranching projects might be successful from a biological point of view -- that is, one may be able to produce juveniles, release them and have a significant proportion of the juveniles grow, survive and be recaptured -- while from an economic point of view the same project might be an economic disaster. A classical example of a successful project both biologically and economically is the introduction of King crab (*Paralithodes camtschatica*) from the Pacific to the north-east Atlantic during the period 1961-69 and in 1978 (Kuzmin and Olsen, 1994; Orlov and Ivanov, 1978). In 1995 the Northeast Atlantic stock was estimated to consist of more than 600.000 animals, and investigations indicates an near doubling of the abundance every year (Anon., 1996b). The stock continues to spread along the Norwegian coast and into the Barents Sea, thereby forming a basis for an important commercial fishery in the future.

The strategy today is not to introduce new species into a ecosystem, but to increase the abundance of high-value organisms in the ecosystem and let them feed on the available prey in the sea. To examine the economics of ranching program is complicated, requiring exact numbers for production cost, fishery cost, catches and market prices. The net present value (NPV) of a project will depend on return rate of the released animals, the duration of the project and the interest rate. The NPV, however, is a useful tool to see how the above-mentioned parameters affect the project's economic results. Additionally, cost-benefit analysis are important since they include the political, social, recreational or tourism benefits of projects and how the benefits are allocated among different user groups.

Unfortunately, as reflected in Table 2, few published reports are available regarding the economic feasibility of ranching of marine organisms. Most likely, a significant number of reports exists as "grey literature"; however, these are not easy available. Japan includes many species in their ranching program, but only for red sea bream and Japanese flounder have reports been published regarding the economic feasibility of these operation. A study on red sea bream in the Kagoshima prefecture (Ungson et al., 1993) presents how the operation is organised and funded and the economic feasibility of the project. They concluded that the project was an economic success, mainly due to the high return rate (~ 15 %) and market price (35 - 115 US$/Kg). The authors state, however, that this is not necessarily the case for other red sea bream projects, because return rates are normally much lower. Kitada et al. (1992) examined the fish market for Japanese flounder (Hirame), a high priced and high quality product in Japan, with a value between 10 and 60 US$/Kg on the fish market. They distinguished the released and wild fishes by abnormal pigmentation on the artificially produced fishes. They estimated an recapture rate of approximately 15% and concluded from their analysis that ranching of Japanese flounder was economically profitable. The results are based upon estimated juvenile cost and recapture rate, and total value of the fish market. Still, both the red sea bream and the Japanese flounder reports lack high quality data on recapture rates.

The number of red drum released annually is the highest for any single marine fish species in the world (Table 1), with more then 30 million fishes released every year. Red drum provide an important recreational fishery, according to McEachron et al. (1995) including 1.6 million fishermen with a value up to US$ 2.3 billion. As for the Japanese projects, the red drum projects lack information on recapture rates of the released fishes. The cost-benefit analysis on red drum (Matlock, 1986; Rutledge, 1989; R. Vega, Texas Parks and Wildlife Department, USA, Pers. comm., 1996) do indicate that ranching with red drum is economically profitable, due to the fact that return rates as low as 0.02 % are acceptable. The lack of data on recapture rates, however, has been identified as a weak part of the projects; such data are now included (McEachron et al., 1995).

The Norwegian ranching program for cod has included recapture data for the last 20 years. However, none of the available reports discussing the economics (Sandberg and Oen, 1993; Moksness and Støle, 1996) indicate that the operation is economically feasible. The two main reason for their conclusion is the high production cost (~ 1 US$/juvenile) and low market value (~ 2.5 US$/Kg gutted fish). The possibilities for ranching of lobster in Europe and North America have not been fully explored and no reports are available. However, Anon (1994a) indicates that the operation will only be economically feasible if juvenile production cost is reduced significantly. Preliminary economic analysed indicate a US$20 million profit on ranching of Chinese prawn in China (Bartley, 1995) but absence of cost effectiveness for Tiger prawn in Australia (P. Rothlisberg, CSIRO, Australia, Pers. comm., 1996). Japan have large scale ranching of marine organisms other than fishes, such as scallop (*Patinopecten yessoensis*) and Kuruma prawn (*Penaeus japonicus*) with releases of more than 3.1 billion and 304 million respectively in 1994 (Anon., 1995). For Kuruma prawn it has been reported (Bhat, 1989) that it is difficult to measure any effect on the annual yield due to problems of obtaining realistic recapture rates from tagging studies.

Bottlenecks in marine ranching

Overall, the largest single problem in connection with marine ranching is to obtain a high and stable production of high-quality juveniles ready to be released in the sea. Sandberg and Oen (1993) and Moksness and Støle (1996) concluded that sea ranching of cod only could be economically profitable only if juvenile cost and mortality post-release was reduced significantly. They recommend an optimisation of the release strategy and better fitness of the cod juveniles. Similar recommendations are given for red sea bream (Ungson et al., 1993) indicating a need of a significant drop in production cost and a stable production of high-quality red sea bream juveniles, to ensure high survival and growth in the natural environment. Sproul and Tominaga (1992) reported that in juvenile Japanese flounder, survival in the first year after release is the single most important parameter for improving the economy in the project.

CONCLUSION

Ranching of marine organisms has experienced increasing world-wide interest in the past 20 years and today includes more then 100 species. Published results from economic evaluation of ranching projects are rare, and the main reason for this might be lack of survival and recapture data in most of the projects. The published reports indicate that for species which have a low price in the market, the juvenile production cost needs to be reduced significantly to make the projects economically profitable in the future.

Table 1. The approximate number of juveniles of some marine organisms released in 1994 for sea ranching purposes, grouped by species and countries.

Species	Country	Release in 1994 (million)	Reference
red sea bream	Japan	20.6	Anon, 1995
Japanese flounder	Japan	19.4	Anon, 1995
black sea bream	Japan	7.1	Anon, 1995
tiger puffer	Japan	1.8	Anon, 1995
yellowtail	Japan	0.8	Anon, 1995
striped jack	Japan	0.6	Anon, 1995
red drum	USA	> 30	*
cod	Norway	0.12	**
cod	Denmark	< 0.1	Støttrup et al. (1994b)
lobster	Norway	0.03	**
turbot	Denmark	0.35	Støttrup et al. (1994b)

*) C. Grimes, SEFSC-Panama City Laboratory; J. Holt, The University of Texas at Austin; Pers. comm., 1995

**) T. Svåsand, Institute of Marine Research, Bergen, Pers. comm., 1995.

Table 2. Overview of paper published on stock enhancement and sea ranching and economics. NPV = net present value.

Species	Country	Comments	Reference
Cod	Denmark	Break-even estimates	Paulsen, 1994
	Norway	Juvenile cost Break-even estimates	Sandberg and Oen, 1993
	Norway	NPV Juvenile cost Break-even estimates	Moksness and Støle, 1996
Japanese flounder	Japan	Hokkaido Prefecture Positive NPV	Sproul and Tominaga, 1992
Japanese flounder	Japan	Fukushima Prefecture Fish market surveys Economically feasible	Kitada et al., 1992
Red drum	USA	Cost benefits Estimates of minimum recapture rates	Matlock, 1986 Rutledge, 1989 R.R. Vega, USA, Pers. comm., 1996
Red sea bream	Japan	Kagoshima Prefecture Total production and harvesting cost Positive net income	Ungson et al., 1993
Penaeid prawn	Australia	Not cost effective	P. Rothlisberg, CSIRO, Australia, Pers. comm., 1996

BIBLIOGRAPHY

Anonymous 1994a. Report of the workshop to evaluate the potential of stock enhancement as an approach to fisheries management. CM 1994/F:9, 1-139.

Anonymous 1994b. The Oceanic Institute annual report 1993, 28 pp.

Anonymous 1995. Saibai Gyogyo Syubyo Seisan, Nyusyu - Horyu Jisseki (Zenkoku) Heisei 5 Nendo: 1-109 (In Japanese; temporary English title: Annual technical report of Japan Sea Farming Association 1994)

Anonymous 1996a. Report on climate change and carrying capacity of the north Pacific ecosystem. U.S. Globec, 15: 1-95.

Anonymous 1996b. Ressursoversikt 1996. Fisken og havet, særnummer 1: 90-92. (In Norwegian).

Bailly, D., 1991. Economic and social issues in sea ranching. In: T.N. Pedersen and E. Kjørsvik (Editors), Sea Ranching - Scientific Experiences and Challenges. Proceedings from the symposium and workshop 21-23 October 1990, Bergen, Norway, pp. 57-64.

Bannister, R.C.A. 1991. Stock enhancement (Workshop report). ICES Mar. Sci. Symp., 192: 191-192.

Bartley, D.M. 1995. Marine and coastal area hatchery enhancement programmes: Food security and conservation of biological diversity. International conference on sustainable contribution of fisheries to food security, Kyoto, japan, 4-9 December 1995. 26 pp.

Bhat, B.V. 1989. Shrimp mariculture: Sea ranching technology in Japan. Seafood Export Journal, Sept-Oct 1989: 29-34.

Blankenship, H. Lee and K.M. Leber 1995. A responsible approach to marine stock enhancement. American Fisheries Society Symposium, 15: 000-000.

Carter, C.N. and H.D. Radtke 1988. Coastal community impacts of the recreational/commercial allocation of salmon in the ocean fisheries. p 139 - 159 In: W.J. McNeil (Ed.) Salmon production, management, and allocation; Biological, Economic, and policy issues. Oregon State University Press.

Denson, M.R., T.I.J. Smith and W.E. Jenkins 1994. Overview of a pilot-scale stock enhancement project for red drum, *Sciaenops ocellatus*, in South Carolina. World Aquaculture Society Meeting, New Orleans, 1994. Abstract

Howarth, W. 1989. Aquacultural Possibilities and Legal Obstructions: Salmon Ranching in the United Kingdom. International Journal of Estuarine and Coastal Law, 4: 1-25.

Isaksson, A. 1988. Salmon Ranching: A World Review. Aquaculture, 75: 1-33.

Kaeriyama, M. 1996. Population dynamics and stock management of hatchery-reared salmons in Japan. Bull. Natl. Res. Inst. Aquacult., Suppl. 2: 11-15.

Kent, D., M. Drawbridge and R. Ford 1994. A comprehensive assessment program for hatchery-reared white seabass (*Atractsocion nobilis*) released into the wild. World Aquaculture Society Meeting, New Orleans, 1994. Abstract.

Kitada, S., Y. Taga, and H. Kishino 1992. Effectiveness of a stock enhancement program evaluated by a two-stage sampling survey of commercial landings. Can. J. Fish. Aquatic. Sci., 49: 1573-1582.

Kuzmin, S. and S. Olsen 1994. Barents Sea King Crab (*Paralithodes camtschatica*) The transplantation experiments were successful. ICES CM 1994/K:12, 12 pp.

Matlock, G.C. 1986. Estimating the direct market economic impact of sport angling for red drum in Texas. North American Journal for Fisheries Management, 6: 490-493.

McEachron, L.W., C.E. McCarty and R.R. Vega 1995. Successful enhancement of the Texas red drum (*Sciaenops ocellatus*) population. Page: 53-56 in: M.R. Collie and J.P. McVey (Eds.) Interactions between cultured species and naturally occurring species in the environment. Proceedings of the twenty-second U.S. - Japan Aquaculture Panel Symposium, 21-22 August 1993.

Technical Report/U.S. - Japan Cooperative Program in Natural Resources No. 22. Alaska Sea Grant Report: AK-SG-95-03. Homer, Alaska.

Moksness, E. and R. Støle 1996. Larviculture of marine fish for sea ranching purposes: is it profitable? Aquaculture (In press).

Orlov, Yu. I. and B.G. Ivanov 1978. On the introduction of the Kamchatka King Crab *Paralithodes camtschatica* (Decapoda Anomura: Lithodidae) into the Barents Sea. Marine Biology, 48: 373-375.

Roberts, D.E.Jr., W. Falls, H. Grier, W. Halstead, J. Landsberg and S. Willis 1994. Coastal marine fish stock enhancement research in Florida: A systematic approach. World Aquaculture Society Meeting, New Orleans, 1994. Abstract.

Rockland, D.B. 1988. Sport fishing economics today and tomorrow. p 165 - 169 In: W.J. McNeil (Ed.) Salmon production, management, and allocation; Biological, Economic, and policy issues. Oregon State University Press.

Royce, W.F. 1988. Our outdated policies. p 1 - 5 In: W.J. McNeil (Ed.) Salmon production, management, and allocation; Biological, Economic, and policy issues. Oregon State University Press.

Rutledge, W.P. 1989. The Texas marine hatchery program - it works. CalCofi Rep., 30: 49-52.

Sandberg, P. and R. S. Oen 1993. Economic consequences of large-scale sea ranching of cod in Norway. ICES Statutory Meeting. 1993. 15 pp.

Shelton, J. and J.P. Koenings 1995. Marine factors in the production of salmon: Their significance to the Pacific salmon treaty. Alaska Fishery Research Bulletin, 2: 156-163.

Solemdal, P., E. Dahl, D.S. Danielssen and E. Moksness 1984. The cod hatchery in Flødevigen - background and realities. In: E. Dahl, D.S.

Danielssen, E. Moksness and P. Solemdal (Editors), The Propagation of Cod *Gadus morhua* L. Flødevigen rapportser., 1, 1984: 17-45.

Sproul, J.T. and O. Tominaga 1992. An economic review of the Japanese flounder stock enhancement project in Ishikari Bay, Hokkaido. Bulletin of Marine Science, 50: 75-88.

Stokes, R.L. 1982. The Economics of Salmon Ranching. Land Economics, 58: 464 - 477.

Støttrup, J.G., J.R. Nielsen, C. Krog and K. Rasmussen 1994a. Results on the extensive production of North Sea cod, *Gadus morhua* L., and their growth and distribution subsequent to release in the Limfjord, Denmark. Aquaculture and Fisheries Management, 25, Supplement 1: 143-159.

Støttrup, J., H. Nicolajsen, H. Paulsen, K. Nitchke og C. Pedersen 1994b. Marin fiskepleje. DFH rapport, 487: 1-17. (In Danish).

Svåsand, T. 1994. Cod enhancement studies - A review. In: Report of the workshop to evaluate the potential of stock enhancement as an approach to fisheries management. ICES CM 1994/F:9, 105-106.

Paulsen, H. 1994. Opdræt og udsætning af torsk; Status 1994. DFH rapport, 483: 1-40. (In Danish).

Ungson, R. R., Y. Matsuda, H. Hirata and H. Shiihara 1993. An economic assessment of the production and release of marine fish fingerlings for sea ranching. Aquaculture, 118: 169-181.

TRANSFER OF TECHNOLOGY ON MARINE RANCHING TO SMALL ISLAND STATES

Johann D. Bell
International Center for Living Aquatic Resources Management
Coastal Aquaculture Centre, P.O. Box 438
Honiara, Solomon Islands

ICLARM Contribution no: 1335

INTRODUCTION

Fish and invertebrates associated with inshore habitats are one of the few resources that can be harvested for protein, or as a source of income, by residents of small island states in the Indo-Pacific. Inshore marine resources also provide food and generate funds for coastal communities in the more remote areas of larger developing countries in the region, e.g., Philippines, Indonesia and the Melanesian nations. The top shell (*Trochus niloticus*), green snail (*Turbo marmoratus*), pearl oysters (*Pinctada margaritifera* and *P. maxima*) and sea cucumbers (Holothuroidea) are particularly important sources of revenue because products derived from them can be stored easily until sold (Wright and Hill 1993).

In some tropical developing countries, destruction of habitat through poor land-management practices and fishing methods, over-harvesting and increased use of the resource for subsistence have reduced catch rates of inshore species drastically (McManus 1996). Re-establishment of spawning stocks, repair of habitats and sustainable harvesting practices are needed to restore fisheries in these places. The release of cultured juveniles is one way to expedite the re-establishment of spawning stocks (Blankenship and Leber 1995, Bartley 1996, Munro and Bell 1996). This process is widely known as "stock enhancement" or "marine ranching", although Moksness (this volume) makes the distinction that marine ranching usually implies that a cost-benefit analysis is involved, i.e., a comparison of the increased value of the harvest due to released juveniles with the costs of production and release. For the purposes of this paper, however, I have regarded the terms as synonymous and have used "marine ranching" throughout the text.

It is now apparent that marine ranching should be able to improve fisheries production even where there is limited exploitation of inshore species (Munro and Bell 1996). The release of juveniles reared in hatcheries, or caught from the wild and grown-out to a more robust size, can improve productivity in such situations because recruitment of most tropical marine species is limited by the supply of larvae (Doherty and Williams 1988, Doherty and Fowler 1994). In other words, the carrying capacity of tropical inshore habitats for fisheries species is seldom reached because the larvae fail to arrive in sufficient numbers. If juveniles could be released into nursery habitats to augment recruits from the wild to the limit of the carrying capacity, then fisheries production from the system would be maximised.

Clearly, marine ranching is an attractive fisheries management tool for Indo-Pacific countries that depend heavily on inshore marine resources - it promises to restore and maximize production. The dilemma for developing countries is that they do not usually have the financial and human resources to research methods for marine ranching, or to implement large-scale release programs. Fortunately for developing countries, they are not the only ones that stand to benefit from the use of the marine ranching: most marine products originating from the tropical Indo-Pacific are consumed in the more prosperous nations. For example, the majority of beche-de-mer (processed sea cucumbers) from the region is exported to Hong Kong and Singapore (Conand and Byrne 1993). Increased continuity of supply to markets demanding the products, and sustainable incomes for the producers, will only be possible if the more prosperous countries assist the developing ones to implement stock enhancement programs for their inshore fisheries.

Another factor that should encourage the use of marine ranching in the Indo-Pacific is the geography of the smaller nations themselves - there are many small islands isolated from one another by deep water. These circumscribed habitats are well suited to marine ranching because individuals released into them cannot migrate from the system and should be relatively easy to harvest.

In this paper, I summarise the major steps involved in implementing marine ranching programs, suggest criteria for transferring the technology to developing countries, outline the facilities and methods needed to meet these criteria and list several marine ranching programs currently underway in the Indo-Pacific. I conclude by identifying opportunities for the transfer of Japanese technology in marine ranching to small island states and developing countries in the region.

Important Steps in the Development and Implementation of Marine Ranching Programs

Marine ranching is not simply a matter of learning how to produce juveniles, and then releasing them into inshore habitats. Successful implementation of stock enhancement involves several steps. Only once all steps have been completed successfully can the technology be regarded as profitable and sustainable, and only then should it be implemented in small island states and developing nations. The basic steps involved in evaluating and implementing a marine ranching program are reviewed by Munro and Bell (1996) and summarized below.

MARINE RANCHING

Production of Juveniles

Methods need to be developed to mass-produce juveniles cost-effectively. Technically, this can be done by collecting larvae from the wild, as practiced commonly for many species of bivalves in Japan (Honma 1993, Matsuoka, this volume), or by rearing larvae in hatcheries (see Sorgeloos and Sweetman 1993 for a summary of progress in this field). The critical point, however, is that unless the cost of the juveniles can be kept low, marine ranching is unlikely to be profitable.

Ensuring that juveniles are fit for the wild

We must also learn how to rear juveniles so that they overcome behavioural deficits that result from being kept in captivity. Unless juveniles are conditioned to respond appropriately to threats from predators, or unless juveniles know how to forage effectively shortly after release, they will not be fit for life in the wild (Howell 1994, Olla et al. 1994). This is less of a problem when wild larvae are reared to a more robust size and then returned to the sea.

Optimising Release Strategies

We must determine how to optimize the survival of released juveniles. A variety of research programs have shown that unless comprehensive field experiments are conducted to improve release strategies, survival of hatchery-reared juveniles is often very poor (e.g., Stoner 1994, Leber et al. 1996). At least four factors need to be considered.
i) *Size at release:* survival is usually a function of size and so the best trade-off between liberating juveniles at a size that reduces the cost of producing them, and one that results in high survival, needs to be identified.
ii) *Release habitat*: juveniles often have different habitat requirements to adults (Bell and Worthington 1993) and will not survive unless placed into habitats where food can be obtained reliably, and where they can avoid predators (Stoner 1994).
iii) *Release season*: abundances of preferred foods, and predators, vary seasonally (Choat 1982) and so survival will be greater at certain times of the year (Leber et al. 1996); these times need to be identified.
iv) *Stocking density*: if too few juveniles are released, the carrying capacity of the habitat will not be reached and production will not be maximized. When the carrying capacity is exceeded, there are likely to be unwanted intra- and inter-specific interactions (Kearney and Andrew 1995). However, where additional nursery habitat is provided, stocking densities can be increased (Honma 1993, Yanagisawa 1996, Morikawa, this volume).

Testing the impact of large-scale releases

Once juveniles which survive well in the wild can be produced at low cost, we need to test whether large-scale releases into a fishery actually result in significant increases in catches and profits. This entails liberating tens to hundreds of thousands of juveniles in a way that optimizes their survival, and then measuring their contribution to commercial catches. Methods for analysing whether such large-scale releases significantly increase catches are summarized by Munro and Bell (1996). Recent examples of such studies in Japan are given by Kitada (this volume).

The information for steps 3 and 4 can only be gained through well-designed field experiments. Such experiments will usually rely on distinguishing cultured juveniles from wild ones by "marking" or "tagging" them (see Buckley and Blankenship 1990, Rothlisberg and Preston 1992, Munro and Bell 1996 for overviews of several different methods and important criteria). For large-scale enhancement trials aimed at measuring the economic viability of marine ranching, it is important to choose the most conspicuous of the suitable "marks" available. Otherwise, failure to detect released animals may be misinterpreted as failure to survive.

TRANSFERRING TECHNOLOGY FOR MARINE RANCHING TO DEVELOPING COUNTRIES

The type of support required

There are two major considerations here. First, the transfer of technology should not be done until the development of methods for marine ranching of a species has passed through all the steps outlined above - small island states and developing countries do not have the resources to complete studies. In circumstances where the technology has not been developed or tested completely, and there are pressing reasons to complete the process in a developing country, the latter stages should be funded " in situ" by appropriate donors or external agencies.

Second, support for the transfer of technology should be continued until increased profits from the fishery are able to pay for the cost of producing and releasing juveniles. Otherwise, the developing country will not be able to maintain the program when support is withdrawn. A related issue is the potential size of the fishery to be enhanced: it should be large enough to yield the revenue needed to finance sustained marine ranching operations.

Integrating marine ranching with other forms of management

It is vital that methods for marine ranching are transferred together with responsible advice on how to harvest the resource in a sustainable way. Marine ranching should be just one part of an overall plan to manage a fishery (Preston and Tanaka 1990, Blankenship and Leber 1995, Bartley 1996, Munro and Bell 1996). Harvests from enhanced fisheries should be managed to allow the biomass of released juveniles to accumulate, and to provide sufficient numbers of eggs and larvae to sustain the yield at a level that minimizes the need for augmentation of natural recruitment with hatchery releases. In some situations, e.g., where larvae are retained consistently near fishing grounds, it may eventually be possible to cease releasing juveniles and to rely on recruitment from the restored biomass of spawners. These types of benefits are now occurring for the scallop fishery in Hokkaido, Japan. There, stock enhancement dramatically improved the average annual catch, however the current high levels of harvest are now due largely to the reproductive output of released scallops (Honma 1993, Kitada, this volume).

For stock enhancement programs to be successful in small island states, they will need the support of local communities. They will also need to be dovetailed to local harvesting practices. The situation in much of the Pacific serves as an example. Customary marine tenure (CMT) (Ruddle et al. 1992), a system whereby local communities own the reefs and their resources, is widespread in the Pacific. The successful transfer of marine ranching to these places would involve educating the leaders of the communities about the merits of the process, and negotiating permission to make releases, and setting up closures to fishing until the released animals were ready for harvest. Customary marine tenure should actually facilitate marine ranching because CMT simplifies the issues of ownership and access to the enhanced resource. Policies to resolve such issues have yet to be formed in developed countries (Munro and Bell 1996).

Use of appropriate methods and species

For technology on marine ranching to be adopted successfully and sustainably by developing nations, it should match the capabilities of the recipient country. The use of simple, low-cost methods for collecting larvae (" spat") from the wild are particularly likely to succeed - the materials required are usually inexpensive to purchase or deploy and, as mentioned previously, wild juveniles are generally fitter than those reared in hatcheries. The range of tropical species that can now be caught from the wild as larvae or post-larvae include a variety of reef fish (Dufour et al. 1995), blacklip pearl oysters (Coeroli et al. 1984, Friedman and Bell 1996), and spiny lobsters (Phillips and Brown 1989, Ito 1996). Post-larval sea cucumbers have also been collected in temperate Japan (Arakawa 1990, Yanagisawa 1996).

Production of juveniles in hatcheries will also be suitable for implementing marine ranching for some species in the developing world. Tropical species that are relatively simple and inexpensive to rear in hatcheries include *Turbo marmoratus* (Murakoshi et al. 1993), *Trochus niloticus* (Heslinga and Hillmann 1981, C. Lee, pers. comm.) and Tridacnidae (Braley 1992, Calumpong 1992). The scope for producing tropical sea cucumbers in hatcheries for stock enhancement projects is currently under investigation by ICLARM in Solomon Islands, and in the Maldives (D. James, pers. comm.) and Sri Lanka (Siriwardena, pers.comm.).

Possible negative impacts and how to reduce them

Where it is necessary to produce juveniles in hatcheries, the temptation may be to transfer the equipment, personnel and broodstock required to initiate a marine ranching program. However, broodstock introduced from elsewhere within the range of a species can differ genetically from local populations (Benzie 1993) and can carry diseases and parasites (Langdon 1989, Humphrey 1995). Release of cultured juveniles that differ in gene frequency from local populations can alter the genepool once interbreeding occurs, with the risk that the overall fitness of stock declines (see Bartley 1996, this volume, Munro and Bell 1996 for details). This risk is increased in situations where the local stock has been fished down and cultured juveniles compose the majority of the stock.

The genetic problems associated with releasing hatchery-reared juveniles can be reduced substantially by ensuring that: i) broodstock are collected from the same population into which cultured juveniles are to be released, ii) large numbers of broodstock (50-100 individuals of each sex) are involved in producing batches of juveniles, and iii) broodstock are replaced regularly. In situations where it is not possible to meet the second criteria, several cohorts, each derived from different parents, are needed to ensure that gene frequencies of released juveniles eventually approximate those of the wild stock (Bartley and Kent 1990, Newkirk 1993). Bartley (1996, this volume) describes several other measures that also help to minimize the loss of biodiversity during the implementation of stock enhancement programs.

The process of culturing juveniles often results in conditions suitable for the proliferation of pathogens. Unless cultured juveniles are quarantined prior to release, diseases can be introduced from hatcheries and nurseries to wild stocks. Munro (1993) and Humphrey (1995) list the basic precautions that should be taken before releasing cultured animals to the wild. The transfer of diseases and parasites not only poses a risk to the productivity of the target species, other species are also vulnerable (Langdon 1989).

The onus is on the country responsible for transferring technology on stock enhancement to ensure that it is done in a responsible way. Otherwise, mismanagement of the gene-pool and introduction of diseases could negate the purpose of marine ranching by decreasing production due to reduced fitness of the population.

A related issue is the introduction of exotic (non-indigenous) species to create new fisheries. Although there are some situations where introductions of species have established important marine fisheries in developing countries, apparently without adverse effects, e.g., the introduction of *Trochus niloticus* to numerous islands in the Pacific

(Eldredge 1994), there is much scope for reducing biodiversity through competitive or predatory interactions, and through the transfer of diseases (Bartley 1996). Pullin (1996) advocates that introductions of exotic species should not be considered for marine ranching until the potential of indigenous species has been investigated fully. He also stresses that the benefits and risks of introducing an exotic species need to be evaluated rigorously and, if recommended, the introduction must be endorsed by the government of the recipient country. Pullin (1994) and Bartley (1996) outline codes of practice for assessing these risks and benefits.

Marine Ranching Programs in Developing Countries of the Indo-Pacific

Several agencies have established, or are setting up, programs in developing countries of the Indo-Pacific to transfer technology on marine ranching of inshore species associated with coral reef habitats. To date, projects to restore and enhance wild stocks of inshore fisheries species in these countries have focused mainly on invertebrates (Table 1). Programs to re-establish giant clams (Tridacnidae) and *Trochus niloticus* are the most advanced; broodstock have been accumulated and juveniles are being grown-out for release in several countries (Table 1). In Solomon Islands, for example, methods have been developed to optimize the survival of juvenile giant clams until they are large enough to escape predation (Bell et al. 1996). Projects on *Turbo marmoratus* and Holothuroidea (sea cucumbers) are at relatively early stages.

In the past, there have been at least six cases where stock enhancement programs have introduced exotic species to locations within the Pacific, and five cases where animals have been transferred from other countries to augment indigenous populations of the same species. The transfer of giant clams to the Philippines (Mingoa-Licuanan 1993, Calumpong 1993) and Fiji (Ledua 1993) (see Table 1) was necessary to provide broodstock to replenish extinguished stocks. For the reasons outlined by Pullin (1994, 1996), future marine ranching in the Indo-Pacific should use indigenous populations if at all possible.

Opportunities for Transferring Japanese Technology on Marine Ranching

Japan is in a strong position to assist the developing nations of the Indo-Pacific with the transfer of technology on marine ranching. During the past 30 years, more than 90 marine species have been managed by stock enhancement in Japan (Matsuoka 1989, this volume, Honma 1993, Kitada, this volume). Moreover, in several cases, the marine ranching of the species has been profitable (e.g., Kitada et al. 1992, Sproul and Tominaga 1992, Ungson et al. 1993). Some of the species used for marine ranching in Japan are also widespread in the Indo-Pacific, e.g., *Turbo marmoratus*, *Trochus niloticus* and *Tridacna crocea*. The opportunities available for transferring technology for these three species include; i) designing, constructing and commissioning hatcheries, ii) developing and testing appropriate release strategies for habitats in the Pacific, iii) undertaking large-scale releases to enhance existing fisheries, and iv) conducting economic appraisals of these releases.

Japanese scientists are also well placed to transfer skills on the culture and enhancement of coral reef fish, spiny lobsters (Palinuridae) and tropical abalone (Haliotidae). All three groups of species have potential for aquaculture and marine ranching in the region (Bell and Gervis 1996, Ito 1996). Coral reef fish, such as *Chelinus undulatus* (Labridae) and several species of Serranidae (particularly *Leopardus* spp.), are in high demand in the live seafood markets of Hong Kong and China (Johannes and Riepen 1995, Erdmann and Pet-Soede 1996). Live spiny lobsters command high prices in Japan and Asia and tropical abalone are in high demand in Taiwan. Modification of Japanese hatchery technology for closely related species could provide the opportunity to sustain or increase production of these three groups of species by small island states and developing countries for the lucrative markets in Asia. Japanese scientists could also assist in devising inexpensive methods for collecting the post-larvae of spiny lobsters and coral reef fish of high value.

CONCLUSIONS

There are numerous opportunities to transfer the technology on marine ranching from Japan to the Indo-Pacific. Successful large-scale releases of cultured juveniles will enable small island states and other developing countries to sustain or increase production of inshore fisheries, and increase continuity of supply of valued marine commodities to the importing countries. The technology for marine ranching of a species should be proven to be viable within the recipient country prior to transfer or, alternatively, development and testing of the methods should be completed in small island states and developing countries with support from external agencies. Support should then also be provided to implement the technology until the fishery is able to meet the cost of producing and releasing juveniles in its own right.

Marine ranching programs need to be conducted responsibly to minimize risk to the maintenance of biodiversity and production through: i) changes to the genepool, ii) introduction of pathogens, and iii) the increased occurrence of intra- and inter-specific interactions. Similarly, exotic species should not be used for marine ranching programs unless indigenous species have been demonstrated to be unsuitable, and unless there is compelling evidence that the introduced species will not have adverse impacts on other biota. Although the measures summarized in this paper will limit the range of species for marine ranching in the Indo-Pacific, and prolong the time taken to replenish and enhance wild fisheries, they will increase the likelihood of success.

Table 1. Summary of programs on marine ranching of coral reef species in developing nations of the Indo-Pacific. Only species cultured for release in the wild are listed. A = introduced species, B = indigenous species introduced from another country for purposes of stock enhancement. OFCF = Overseas Fishery Co-operation Foundation of Japan, ICLARM = International Center for Living Aquatic Resources Management.

Country	Species	Status	Reference
Indonesia	*Tridacna derasa*	Broodstock accumulated, juveniles produced.	Braley (1995)
	Trochus niloticus	Broodstock accumulated.	C. Lee, pers. comm.
Maldives	Holothuroidea	Research on production of juveniles initiated 1995.	D. James, pers. comm.
Philippines	*Tridacna derasa*[B] *Tridacna gigas*[B]	Broodstock transferred, juveniles produced, some releases into marine protected areas.	Calumpong (1993) Mingoa-Licuanan (1993)
Korea	*Trochus niloticus*[A]	Juveniles produced from introduced stock, experimental releases conducted.	Sigrah (1996)
Marshall Islands	*Tridacna derasa*[A]	Juveniles introduced and released into wild, 2nd generation individuals reputed to have established.	S. Lindsay, pers. comm.
Cook Islands	*Tridacna derasa* [A]	Broodstock accumulated, juveniles produced.	J. Dashwood, pers. comm.
	Tridacna gigas[A]	Juveniles introduced.	Eldredge (1994)
Fiji	*Tridacna derasa* *Tridacna squamosa*	Broodstock accumulated, juveniles produced for stocking.	Ledua (1993), Saqata (1994)
	Tridacna gigas[B]	Broodstock transferred.	Ledua (1993)
	Hippopus hippopus[B]	Juveniles transferred.	Ledua (1993)
Kiribati	Holothuroidea	Project initiated by OFCF in 1995.	
Solomon Islands	*Tridacna derasa* *Tridacna gigas* *Tridacna maxima* *Hippopus hippopus*	Broodstock accumulated, juveniles produced, survival & growth of juveniles estimated during grow-out.	Bell et al. (1996)
	Holothuroidea	Project initiated by ICLARM in 1995, broodstock accumulated, juveniles produced	
	Turbo marmoratus	Project initiated by OFCF in 1996.	
Tonga	*Tridacna derasa*	Broodstock accumulated, juveniles produced, survival and growth of juveniles estimated during grow-out.	Loto'ahea & Sone (1996)
	Tridacna gigas[A]	Juveniles introduced.	Eldredge (1994)
	Turbo marmoratus[A]	Broodstock introduced, juveniles produced.	Manu et al. (1996)
	Mugil cephalus[B]	Juveniles transferred, growth monitored in wild.	Kimura & Fa'anunu (1996)
Vanuatu	*Trochus niloticus*	Juveniles produced, experimental releases to optimize release strategies.	R. Jimmy, L. Castell, pers. comm., Nguyen (1996)

REFERENCES

Arakawa, K.Y. 1990. A handbook on the Japanese sea cucumber. Its biology, propagation and utilization. Tokyo, Midori-Shobo Publishers. Summary of chapters 1, 2 and 4 translated by M. Izumi In: SPC Beche-de-mer Information Bulletin, 3: 8-15.

Bartley, D.M. 1996. Conservation of biological diversity in hatchery enhancement programs. In: di Castri, F. and Younes, T. (eds.), Biodiversity, science and development: towards a new partnership. CAB. International, U.K., pp. 424-438.

Bartley, D.M. (this volume) Marine ranching: current issues, constraints and opportunities.

Bartley, D.M. and Kent, D.B. 1990. Genetic structure of white seabass populations from the southern California Bight region: applications to hatchery enhancement. Calif. Co-op. Fish. Invest. Rep. 31: 97-105.

Bell, J.D. and Gervis, M. 1996. New species for aquaculture in the Pacific - constraints, prospects and considerations. In: Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga, pp. 311-318.

Bell, J.D., Hart, A.M., Foyle, T.P., Gervis, M. and Lane, I. 1996. Can aquaculture help restore and sustain production of giant clams? Proc. 2nd World Fish. Congress (in press).

Bell, J.D. and Worthington, D. 1993. Links between estuaries and coastal rocky reefs in the lives of fishes from south-eastern Australia. In: Batterschill, C.N., Schiel, D.R., Jones, G.P., Creese, R.G. and McDiarmid, A.B., (eds.), Proc. Second Int. Temperate Reef Symp., Wellington, New Zealand, NIWA Marine, pp. 85-92.

Benzie, J.A.H. 1993. Review of population genetics of giant clams. In: Munro, P.E., (ed.), Genetic aspects of conservation and cultivation of giant clams, ICLARM Conf. Proc. No. 39, Manila, International Center for Living Aquatic Resources Management, pp. 1-6.

Blankenship, H.L. and Leber, K.M. 1995. A responsible approach to marine stock enhancement. Am. Fish. Soc. Symp. 15: 165-175.

Braley, R.D. 1992. The giant clam hatchery and nursery culture manual. ACIAR Monograph 15, Australian Centre for International Agricultural Research, Canberra, Australia.

Braley, R. 1995. New giant clam hatchery for Indonesia. Clamlines (ICLARM) 14: 8.

Buckley, R.M. and Blankenship, H.L. 1990. Internal extrinsic identification systems: overview of implanted wire tags, otolith marks, and parasites. Am. Fish. Soc. Symp. 7: 173-182.

Calumpong, H.P. (ed.) 1992. Giant clam: an ocean culture manual. ACIAR Monograph 16, 64 p.

Calumpong, H. 1993. Philippines, 2. In: Munro, P.E., (ed.), Genetic aspects of conservation and cultivation of giant clams, ICLARM Conf. Proc. No. 39, Manila, International Center for Living Aquatic Resources Management, pp. 1-6.

Choat, J.H. 1982. Fish feeding and the structure of benthic communities in temperate waters. Ann. Rev. Ecol. Syst. 55: 313-332.

Coeroli, M., De Gaillande, D., Landret, J.P. and AQUACORP (D. Coatanea) 1984. Recent innovations in cultivation of molluscs in French Polynesia. Aquaculture 39: 45-67.

Conand, C. and Byrne, M. 1993. A review of recent developments in the world sea cucumber fisheries. Mar. Fish. Rev. 55: 1-13.

Doherty, P. J. and Fowler, T. 1994. An empirical test of recruitment limitation in a coral reef fish. Science 263: 935-939.

Doherty, P.J. and Williams, D.M. 1988. The replenishment of coral reef fishes populations. Oceanogr. Mar. Biol. Ann. Rev. 26: 487-551.

Dufour, V., Riclet, E. and Loyat, A. 1995. Colonisation of reef fishes at Moorea Island, French Polynesia. Proc. Int. Larval Fish Conf. (in press).

Eldredge, L.G. 1994. Perspectives in aquatic exotic species management in the Pacific Islands. Vol. I. Introductions of commercially significant aquatic organisms to the Pacific Islands. South Pacific Commission, Inshore Fisheries Research Project, Technical Document No. 7, 127p.

Erdmann, M.V. and Pet-Soede, L. 1996. The live reef food fish trade in eastern Indonesia. NAGA 19(1): 4-8.

Friedman, K.J. and Bell, J.D. 1996. Effects of different substrata and protective mesh bags on settlement of spat of the pearl oysters *Pinctada margaritifera* and *Pinctada maculata* (in press).

Heslinga, G.A. and Hillmann, A. 1981. Hatchery culture of the commercial top snail *Trochus niloticus* in Palau, Caroline Islands. Aquaculture 22:35-43.

Honma, A. 1993. Aquaculture in Japan. Tokyo, Japan FAO Association.

Howell, B.R. 1994. Fitness of hatchery-reared fish for survival in the sea. Aquacult. Fish. Manage. 25: Supplement 1, 3-17.

Humphrey, J.D. 1995. Perspectives in aquatic exotic species management in the Pacific Islands. Vol.II Introductions of aquatic animals to the Pacific Islands: disease threats and guidelines for quarantine. South Pacific Commission, Inshore Fisheries Research Project, Technical Document No. 8, 53p.

Ito, M. 1996. An overview of palinurid lobster culture and prospect of aquaculture development in the South Pacific region. In: Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga, pp. 323-337.

Johannes, R.E and Riepen, M. 1995. Environmental, economic and social implications of the live reef fish trade in Asia and the western Pacific. Unpublished report prepared for The Nature Conservancy and the South Pacific Forum Fisheries Agency, 82p.

Kearney, R. and Andrew, N. 1995. Enhancement of Australian fish stocks: issues confronting researchers and managers. In: Bellwood, O., Choat, J.H. and Saxena, N.K, (eds.), Recent advances in marine science and technology '94. James Cook University, Townsville, pp. 591-598.

Kimura, T. and Fa'anunu, U. 1996. Mullet resource and aquaculture in Tonga. In: Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga, pp. 139-143.

Kitada, S., Y. Taga and H. Kishino. 1992. Effectiveness of a stock enhancement program evaluated by a two-stage sampling survey of commercial landings. Can. J. Fish. Aquat. Sci. 49: 1573-1582.

Kitada, S. (this volume). Contribution of hatchery enhancement and comprehensive fishery resource management: the Japanese experience.

Langdon, J.S. 1989. Disease risks in fish introduction and translocations. In: Pollard, D.A., (ed.), Introduced and translocated fishes and their ecological effects, Australian Society for Fish Biology Workshop, 24-25 August 1989. Bureau of Rural Resources Proceedings, Canberra, Australian Government Printing Service. No. 8, pp. 98-107.

Leber, K.M., Arce, S.M., Blankenship, H.L. and Brennan, N.P. 1996. Influence of release season on size-dependent survival of cultured striped mullet, *Mugil cephalus*, in a Hawaiian fishery. Fish. Bull. (US) (in press).

Ledua, E. 1993. Fiji. In: Munro, P.E., (ed.), Genetic aspects of conservation and cultivation of giant clams, ICLARM Conf. Proc. No. 39, Manila, International Center for Living Aquatic Resources Management, pp. 1-6.

Loto'ahea, T. and S. Sone. 1996. Present status of giant clam culture in Tonga. In: Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga, pp. 209-214.

McManus, J. 1996. Tropical marine fisheries and the future of coral reefs. Proc. 8th Int. Coral Reef Symp. (in press).

Manu, N. Fa'anunu, U. Niumeitolu, S. and Kikutani, K. 1996. A preliminary seed production of green snail (*Turbo marmoratus*) in Tonga. In: Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga, pp. 81-87.

Matsuoka, T. 1989. Japan sea-farming association (JASFA). Int. J. Aq. Fish. Technol. 1: 90-95.

Matsuoka, T. (this volume). Present state and prospects of Japan's sea farming.

Mingoa-Licuanan, S. 1993. Philippines, 1. In: Munro, P.E., (ed.), Genetic aspects of conservation and cultivation of giant clams, ICLARM Conf. Proc. No. 39, Manila, International Center for Living Aquatic Resources Management, pp. 1-6.

Moksness, E. (this volume). Economic evaluation of marine ranching.

Morikawa, T. (this volume). Status and prospects on the development and improvement of coastal fishing ground.

Munro, J.L. and Bell, J.D. 1996. Enhancement of marine fisheries resources. Rev. Fish. Sci. (in press).

Munro, P.E. 1993. Genetic aspects of conservation and cultivation of giant clams. ICLARM Conf. Proc. No. 39, Manila, International Center for Living Aquatic Resources Management.

Murakoshi, M., Komatsu, T. and Nakamura, R. 1993. Development of mass seed production techniques for green snail, *Turbo marmoratus*, in Okinawan water. Suisanzoshoku 41: 299-309.

Newkirk, G. 1993. A discussion of genetic aspects of broodstock establishment and management. In: Munro, P.E., (ed.), Genetic aspects of conservation and cultivation of giant clams. ICLARM Conf. Proc. No. 39. Manila, International Center for Living Aquatic Resources Management, pp. 6-12.

Nguyen, F. 1996. Report on trochus aquaculture in Vanuatu. In: Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga, pp. 73-79

Olla, B.L., Davis, M.W. and Ryer, C.H. 1994. Behavioural deficits in hatchery-reared fish: potential effects on survival following release. Aquacult. Fish. Manage. 25: Supplement 1, 19-34.

Phillips, B.F. and Brown, R.S. 1989. The West Australian rock-lobster fishery: research for management. In: Caddy, J.F. (ed.), Marine invertebrate fisheries: their assessment and management. J Wiley & Sons, New York, pp. 159-181.

Preston, G.L. and Tanaka, H. 1990. A review of the potential of aquaculture as a tool for inshore marine invertebrate resource enhancement and management in the Pacific islands. Report to the 22nd South Pacific Commission Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 6-10 August 1990.

Pullin, R.S.V. 1994. Exotic species and genetically modified organisms in aquaculture and enhanced fisheries: ICLARM's position. NAGA 17(4): 19-24.

Pullin, R.S.V. 1996. Conservation of genetic resources for aquaculture. Proc. 2nd World Fish. Congress (in press).

Rothlisberg, P.C. and Preston, N.P. 1992. Technical aspects of stocking: batch marking and stock assessment. In: Hancock, D.A., (ed.), Recruitment processes, Australian Society for Fish Biology Workshop, August 21, 1991. Bureau of Rural Resources Proceedings, Canberra, Australian Government Printing Service. No. 16: pp. 187-191.

Ruddle, K., Hviding, E. and Johannes, R.E. 1992. Marine resources management in the context of customary tenure. Mar. Res. Ecol. 7: 249-273.

Saqata, B. 1994. Giant clam mariculture research program, Fiji. Clamlines (ICLARM) 13: 13-14.

Sigrah, R. 1996. Trochus fishery in Kosrae. In: Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga, pp. 61-71.

Sorgeloos, P. and Sweetman, J. 1993. Aquaculture success stories. World Aquaculture 24(1): 4-14.

Sproul, J.T. and Tominaga, O. 1992. An economic review of the Japanese flounder stock enhancement project in Ishikari Bay, Hokkaido. Bull. Mar. Sci. 50: 75-88.

Stoner, A. W. 1994. Significance of habitat and stock pre-testing for enhancement of natural fisheries: experimental analyses with queen conch *Strombus gigas*. J. World Aquacult. Soc. 25: 155-165.

Ungson, J.R., Matsuda, Y., Hirata, H. and Shiihara, H. 1993. An economic assessment of the production and release of marine fish fingerlings for sea ranching. Aquaculture 18: 169-181.

Wright, A. and Hill, L. 1993. Nearshore marine resources of the South Pacific. Forum Fisheries Agency, Honiara, Institute of Pacific Studies, Suva.

Yanagisawa, T. 1996. Sea cucumber ranching in Japan and some suggestions for the South Pacific. In: Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga, pp. 387-411.

DEVELOPING A MARINE RANCHING PROGRAMME : A MULTI-DISCIPLINARY APPROACH

Donald B. Kent* and Mark A. Drawbridge
Hubbs-Sea World Research Institute
2595 Ingraham Street
San Diego, CA 92109 USA

ABSTRACT

The significant decline in worldwide fishery yields has prompted an expanded interest in aquaculture. Besides the development of advanced technologies for the culture of commercially important species for direct market consumption, research on the enhancement of marine populations is now being conducted for many species other than the established programs for anadromous species. The use of stock enhancement as a fisheries management tool has been debated for over a century. Arguments favoring the need for stocking have been countered with concerns ranging from the potential loss of biological diversity to the political inappropriateness of providing technological solutions to complex conservation problems. Although much discussion has been focused on the biological and resource management questions regarding stocking, this paper describes some of the operational and political aspects associated with developing a marine stock enhancement program. Based on our experiences, we identify some of the potential pitfalls associated with initiating stocking programs and provide recommendations on how they might be avoided or overcome.

Since 1984 the California Department of Fish and Game has supported the Ocean Resources Enhancement and Hatchery Program (OREHP) that has been dedicated to evaluating the economic and technical constraints to the enhancement through the culture and release of juvenile marine fish into wild habitats along the Southern California coastline. Early program research included developing the culture technology (i.e. spawning induction, larval rearing, nutrition, disease prevention) for the program's target species, the white seabass (*Atractoscion nobilis*).

Substantial work on evaluating the life histories of white seabass has concentrated on identifying juvenile habitats where releases would occur. Estimates of annual mortality and growth have been reviewed from the literature and refined by observation of both wild and cultured fish. The genetic structure of the wild population has been evaluated relative to the delineation of sub-population structure, and to proposed methods by which loss of genotypic variability could be minimized.

Post-release mortality is evaluated through the mark and recapture experiments employing coded wire tags. The program's feasibility is evaluated using a bioeconomic computer model that compares costs of culturing fish to a given release size, weighted by post-release survival to recruitment, to the value of the fish recruited into the commercial fishery. The resulting "benefit to cost" ratio is also used in sensitivity analyses to evaluate the priorities for future research work.

Based on the experiences of OREHP, we recommend that each species under consideration for enhancement be evaluated individually before the efficacy of stocking it can be promoted or denounced. The evaluation should consider the biological characteristics and management history surrounding

each species. If possible, operational funds should be secured through a dedicated account so the program can be evaluated over several years, at least until the stocked fish are recruited into the fishery, and to prevent having the funds diverted into other unrelated programs. Both scientific and user group advisors should be involved when establishing the goals and oversight responsibilities for the program, and lines of authority for the program should be established early in its development. A high profile review process should be maintained, and post-release and genetic assessments should be incorporated into the program as early as possible.

INTRODUCTION

The harvest of many fishery resources at or above maximum sustainable levels worldwide (NMFS 1992) has increased the need for research and development on stock enhancement. The Food and Agriculture Organization (FAO) has reported that approximately 33% of the 200 fisheries it monitors are depleted or overexploited (FAO 1995). The United States' National Marine Fisheries Service (NMFS) has similarly reported that 26% and 28% of fisheries resources of the United States were fully utilized or over utilized, respectively, while the status of 34% of the stocks is unknown (NMFS 1992). By comparing worldwide population growth to the reported diminishing yields from harvest fisheries, New (1991) concluded that there will be a 50 million ton annual aquaculture production deficit by the year 2025. Since he reports current production at around 11 million tons, this more than four-fold expanded production in just over three decades will require that the aquaculture industry try to meet this goal through development of the following three, as yet, under exploited production methods: 1) the expanded use of inland farms that integrate aquaculture and agriculture, 2) the increased use of off-shore sites where the development of protected embayments for a myriad of other uses is not in conflict with aquaculture, and 3) the further development of culture based fisheries (i.e., stock enhancement) that will augment the natural production capabilities of wild populations. If this expanded food production capability is to be met, it is clear that future fisheries management plans will have to evaluate stock enhancement as a means of helping to maintain or increase food resources and overall resource diversity.

In addition to the commercial harvest, the Pacific coastline and its many embayments afford a significant recreational opportunity and provide for many ocean related industries. Marine coastal fisheries represent a significant economic value through both commercial and recreational harvests. A 1985 study estimates that marine sport fishing contributes anywhere from $250 to $450 million annually to the San Diego economy alone, with the state-wide contribution exceeding $2 billion annually (Venrick, 1985).

Because of its social and economic contribution to southern California, many recreational fishing groups have expressed concern over the decline in take from many fisheries. In 1982 several sport fishing organizations along with the California Sportfishing Association, an affiliation of commercial passenger vessel owners, suggested the evaluation of the potential for marine fish hatcheries designed to augment depleted populations.

WHITE SEABASS RANCHING PROGRAMME

In 1983, the California legislature established the Ocean Resources Enhancement and Hatchery Program (OREHP) under the direction of the California Department of Fish and Game (CDF&G) to conduct "basic and applied research on the artificial propagation and distribution of adversely affected marine fish species..." (Assembly Bill No. 1414, 1983). The legislation established $1 sportfishing and $10 commercial marine fishing stamps to fund this program. It also mandated the formation of an Advisory Panel to oversee the program with members representing the commercial and sportfishing industries (Sportfishing Association of California, California Gillnetters Association), a conservationist group (National Coalition for Marine Conservation), the aquaculture industry (California Aquaculture Association), the scientific community (University of California, California State University) and the Department of Fish and Game.

The OREHP Advisory Panel identified the white seabass Atractoscion nobilis as the most appropriate species for use in an experimental stocking program. It is an important sport and commercial species, and catches have declined to low levels. Figure 1 shows the dramatic decline in both the commercial catch by weight and the number of individual fish in the sport catch from passenger vessels landed in California waters since 1945. Regulations to manage the white seabass fishery have been in place since 1931 and continue to the present day with some modifications. The regulations include a minimum size limit (711 mm TL), closed seasons, bag limits, and gear restrictions. Despite the regulations, commercial and recreational fisheries catches have continued to decline (Vojkovich and Reed 1983; Vojkovich, CDF&G, pers. comm.).

The feasibility and desirability of a marine hatchery was, and continues to be, questioned. The major arguments against hatchery induced restoration of marine species are that: 1) not enough information is known about the culture of marine species native to Californian waters, and therefore, large scale culture would not be feasible; 2) little is know about the natural history of the species under consideration for culture, so that their contribution to the fishery could not be adequately assessed; 3) a successful culture, release and enhancement program would disrupt the genetic composition of wild stocks and therefore further diminish the viability of the affected fisheries, and 4) artificial propagation represents a politically attractive "techno-fix" solution to a natural resource problem, and invites further exploitation of the resource rather than promoting proper management.

In order to obtain definitive answers to questions regarding the efficacy of stocking marine fish, the Advisory Panel established specific goals for the program that were used to solicit and evaluate research proposals. These goals were directed toward 1) developing culture techniques, 2) assessing natural population characteristics and post-release survivorship, 3) evaluating genetic characteristics of wild and hatchery stocks, and 4) determining the economic feasibility of marine stock enhancement. More recently, Blankenship and Leber (1995) have characterized the strategy mandated by the goals as the " responsible approach to marine stock enhancement" .

Because the funding source for the operation of OREHP is derived from fishermen north of the Mexican border and south of Point Arguello, the culture, release and assessment work has also been confined to this region.

Program Development (1983-1993) Culture

Culture and stocking research was conducted from the marine laboratory on Mission Bay, CA jointly maintained by Hubbs-Sea World Research Institute and San Diego State University. White seabass brood fish were obtained from several sources, primarily commercial sportfishing vessels. At this writing the hatchery maintains a breeding population of 33 wild-caught white seabass (18 kg average weight). Effort is being dedicated to increase the total available brood fish spawning population to 200 animals - well over the number (i.e., 150) recommended by Bartley and Kent (1990) to minimize genetic impact on the wild population.

Brood fish are divided into separate recirculating pools where they are maintained under controlled temperature and photoperiod regimes to induce spawning throughout the calendar year. For example, Figure 2 shows the out-of-phase induction of spawning in two separate brood groups. Eggs are collected and reared through the larval, post-larval, and juvenile stages in culture pools until reaching a size of approximately 65 mm TL (60 days). During this culture sequence, juveniles are weaned from a diet of live and frozen crustacean food to a commercially available pellet. After weaning the juvenile seabass are transported to cages where they are held for an additional 6-7 months prior to release.

Pre and Post-Release Assessment

Initial ecological surveys and subsequent attempts to recapture hatchery-reared white seabass employed different gear types, including beach seines, beam and otter trawls, experimental gill nets, and hook and line. Experimental gill nets have been the most effective because they catch a wide size range (200-850 mm TL), can be used in a diversity of habitats (kelps beds, embayments, rock reefs, etc.), and have relatively high catch rates. Since the gill net sampling program was initiated in 1988, the majority of effort has been focused within Mission Bay, the primary release site, and along the adjacent open coast in kelp beds. A hook and line sampling program was initiated in 1992 utilizing the efforts of fishermen aboard commercial sportfishing vessels. This program is relatively inexpensive and samples a wide area. Due to the current size limit of 711 mm TL, this method only provides data for larger white seabass.

Prior to release, all hatchery reared fish are marked for future identification. Oxytetracycline was initially used to mark hatchery-produced fish. This mark was found ineffective for our purposes because it did not last for more than four years. Coded wire tags (CWTs) have been used since 1990 to mark hatchery fish prior to release. This tagging system has enabled precise identification of the release group to which recaptured fish belong and more accurate estimates of growth and patterns of migration.

Genetic Assessment

The genetic diversity of white seabass in southern California has been measured (Bartley and Kent 1990), and continues to be evaluated at this time. From genetic analysis of wild and cultured white seabass the program concluded: 1) there are no measurable temporal, clinal or geographic components to the genetic diversity of the white seabass population studied, 2) the genetic diversity of cultured fish from a single spawn is less than that of the wild population, 3) the genetic diversity observed between multiple spawns approaches that of the wild population, and 4) a spawning group of at least 150 brood fish is necessary to provide the rarest alleles (approximately 2%) observed in the wild population (Bartley et al., 1995). The resulting brood stock protocol for the hatchery program uses 200 brood fish maintained in four separate environmentally controlled pools with a sub-sample (20%) of males rotated between pools every year as well as an annual introduction of 5% of new fish (Figure 3).

Bioeconomic Assessment

A computer model was developed by Botsford and Hobbs (1988) that provides a standard method for evaluating new culture techniques, and for estimating the costs to produce fish of different ages prior to release. These culture cost estimates are then used in combination with estimates of post-release survival to predict the cost benefits of the program. A calculated, theoretical curve defining the relationship between the size-at-release and post-release survivorship predicts that the optimal size (TL) at release when evaluated with the cost to culture is 210 mm (Figure 4). As new growth and survival data are gathered, the bioeconomic model is updated to track the performance of the program.

Planning for Expansion (1991-1994)

Beginning in 1991, OREHP initiated an expansion of the stock enhancement program. A review of the work performed from 1983 to 1991 allowed the Advisory Panel to recommend to the Department of Fish and Game an increase in the size of the experimental rear and release program. To expand the program in a cost effective manner, a logistical decision was made to centralize the hatchery operation, and to decentralize the grow-out culture by using cage systems operated throughout the southern California range of the experiment (i.e., San Diego to Santa Barbara counties, see Figure 5). The planning process involved developing funding sources for operational and capital expenses, evaluating cage-rearing sites and operators, and obtaining pre-release baseline data on the abundance of white seabass toward identifying other potential release areas. A location for a full-scale hatchery was identified and a preliminary design for it developed.

Funding

Operational funds to support the hatchery and assessment work had to be secured to expand OREHP. Support from the local fishing community and legislators resulted in reauthorization of the original legislation and extended the life of the fishing stamp for an additional ten years to 2003 (California State Assembly Bill 960 1993).

In the summer of 1991 OREHP representatives approached the California Coastal Commission about the value of including a marine hatchery as part of a mitigation plan for the San Onofre Nuclear Generating Station immediately south of San Clemente, CA. Following a two year review of the viability of stock enhancement programs by Coastal Commission staff and scientific advisors, the Coastal Commission agreed to release $1.2 million to support the capital cost of hatchery construction. The capital cost estimate was based on a preliminary hatchery design, which in turn was based on production capabilities that could be supported by the available operational funds.

Site Selection for Central Hatchery and Cages

During the time funding sources were being sought, potential sites for the main hatchery and cages were being reviewed It soon became evident that availability of sites within embayments for small-scale cage systems was not as limiting as was the availability of undeveloped land adjacent to a clean seawater supply along the southern California coast.

A suitable site for the hatchery was selected in Carlsbad, CA (Figure 5) on property owned by the local utility company, San Diego Gas & Electric Co. (SDG&E), also part owner of the San Onofre Nuclear Generating Station. Through a license agreement with SDG&E, the property has been made available virtually free of cost. It is situated adjacent to the outer basin of Agua Hedionda Lagoon, which receives tidal flushing from a coastal inlet, located approximately 300 m away. The site was specifically designated for aquaculture use by a local Coastal Plan.

Efforts to incorporate cage culture in the overall program for white seabass were initiated in 1991. The cage systems are located in various southern California embayments and are owned and operated by volunteer groups of sport fishermen that have incorporated as non-profit entities. These systems allow not only an expansion of the culture program by providing more fish of a larger size, but also an expansion of the release program from just San Diego to the entire southern California Bight (Figure 5).

Gill net surveys

In preparation for large scale releases of white seabass, the gill net survey was expanded to include embayments where white seabass were being cultured in cages, as well as other potential sites in southern California (Figure 5). The primary objective of the expanded gill net survey is to collect pre-release baseline data on the relative abundances of white seabass and other sympatric fish species in these areas. Areas inhabited by wild white seabass of the same age class as released fish should represent the most suitable areas for release. This information will also be used to help determine if wild white seabass or other species are being displaced or consumed by stocked fish.

Implementing the Expansion (1993)

Securing the Capital Funds

Due to the comprehensive nature of the expanded program, the involvement of "coastal resources" and the need to assess the mitigation value of the program, several organizational tasks and a series of assurances were required by the Coastal Commission before mitigation moneys could be released. These tasks are as follows.

1) A Joint Panel comprised of representatives from the CDF&G, the California Coastal Commission, the OREHP Advisory Panel, the Southern California Edison Company, the National Marine Fisheries Service, and the University of California must be formed. The responsibilities of this joint panel are stated in detail in the Memorandum of Agreement (MOA) described below.

2) An MOA was developed between the two state agencies (CDF&G and California Coastal Commission) that outlines the regulatory authority of

the agencies in management of the joint research and mitigation missions of the hatchery program;

3) A Comprehensive Hatchery Plan was prepared that details the operational methods by which the goals of the MOA will be accomplished, and

4) A Coastal Development Permit was issued by the California Coastal Commission, permitting the construction of the hatchery facility.

The MOA identified all of the parties involved and the purpose of the agreement. It provided a description of the project and responsibilities for planning and oversight, including the composition of the Joint Panel. Assurances to be made regarding the maintenance of environmental quality were described as they relate to hatchery and cage system operations. Requirements for a post-release evaluation program and a genetic quality assurance program were described in detail, including the minimum annual funding requirements to be dedicated to each. Finally, procedures manuals were required for both the hatchery and cage system operations.

The Comprehensive Hatchery Plan addresses the initial objectives for culture, stocking and assessment of white seabass, and included the following:

1) Defined enhancement objective or endpoint in units of biomass or catch contributed;
2) Culture protocols for producing white seabass with a minimum impact to the wild population's genetic variability;
3) Methods for tagging fish and managing the resulting database;
4) Procedures for juvenile culture and release;
5) Methods for transporting the fish from the hatchery to cage systems, and from cage systems to release sites;
6) Standards for measuring the success of the hatchery;
7) Budget and schedule for hatchery construction;
8) Procedures manual for cage systems, and
9) Provisions for revising the Hatchery Plan after the first year and biennially thereafter.

The Hatchery Plan is important for several reasons. First, it acknowledges that stock enhancement programs, especially those in their infancy, are part of a dynamic process. Secondly, it provides a common framework from which to direct research effort. This is especially critical when many organizations and agencies have a vested interest in helping to establish the objectives and assess the results.

Permits and Approvals for Hatchery Construction

The permitting requirements for development in California's coastal zone (even "ecologically friendly" development) is a very involved process and often requires expert consultation with outside resources. Also, this process is site and project-specific.

At the federal level, applications for permits were required by the Regional Water Quality Control Board and the Army Corps of Engineers. A discharge permit, formally referred to as a National Pollutant Discharge Eliminations System Permit (NPDES), is required by the owner or operator of any facility that discharges waste into any surface waters of the state (California Permit Handbook 1992). Because our anticipated annual production level falls well below the federal requirements (9,090 kg) for a concentrated animal holding facility, we were given a waiver from this permit but were conditioned to conduct periodic monitoring of both hatchery discharge and storm water runoff. Because the Army Corps of engineers maintains jurisdiction over all navigable waters, a permit was required to install the seawater intake structure for the hatchery.

At the State level, a Coastal Development Permit was required from the California Coastal Commission. The Coastal Commission retains permit authority over tidelands, submerged lands, and certain lands held in the public trust. Because OREHP is administered by the California Department of Fish and Game, no formal permit was required by this state agency to culture or release fish.

On a local level, permits were required that reviewed and approved the use of the site as well as construction permits (i.e., grading, construction and tenant improvements). Because the site was previously undeveloped, a Conditional Use Permit was required which allows the local government to apply special requirements that are tailored to fit the proposed project, and thus avoid problems that may be associated with the particular type of use (California Permit Handbook 1992). As part of the Conditional Use Permit, an environmental impact report may be required, if a mitigated negative declaration is not found to be sufficient.

DISCUSSION

Because many questions still need to be addressed, the decision to increase the scale of the OREHP experiment has gone through significant critical review. The mission early in the program to address not only the culture problems inherent to hatchery enhancement, but also the economic and ecological impacts, has allowed the program to carefully scale-up to its current level. However, even with acceptance of the experimental concept and a clear mandate to proceed, OREHP's expansion has been dramatically slowed by the inertia inherent in the development project in the California coastal zone. In fact, the debate over the value of the proposed OREHP hatchery pales in comparison to the effort needed to obtain all of the permits required for construction and operation of the proposed facility.

The procedural hurdles associated with obtaining the necessary permits and approvals to construct and operate the enhancement hatchery are a major deterrent. There are multiple agencies at the federal, state, and local levels with overlapping jurisdictions and different permitting and reporting requirements. Without the help of a professional development consultant, it would be nearly impossible for organization operated by scientists to identify the numerous agencies from which permits must be obtained The requirements imposed by different agencies on the hatchery project are duplicative and sometimes contradictory. The permitting and reporting requirements of many individual agencies are burdensome and time consuming, and agency staff have little or no apparent incentive to process permit applications on a timely basis.

The experience of OREHP in its effort to develop this relatively modest culture facility has been that even with an overall consensus to construct the hatchery, there exists a bureaucratic log-jam. Agency regulations and requirements are designed to allow managed growth, but in their application, they became a discouragement to the execution of the program. The permits acquired have involved two public hearings, an appeal to city council, which required an additional public hearing, and a lawsuit that was final dismissed for procedural improprieties. In an effort to provide fair public review of development projects, California law has, in effect, allowed single individuals to cause significant expenditures in time and funding to delay, and in some cases by attrition, halt projects that have an overwhelming majority of public support.

In addition to this permitting impasse, pressure continues to be exerted from both sides of the stock enhancement question. Some feel that the maintenance of fishing yields should only be accomplished through the informed management of the existing stock. Many in this group also hold that stock enhancement simply represents a seemingly attractive technical solution to very complicated environmental resource problems, and that its appeal to user groups in the short-term cannot really balance the need to correct the underlying causes of the diminished harvest. In addition, because of the significant number of salmon hatcheries built in the Pacific Northwest in response to logging and hydroelectric projects, a fear exists that the acceptance of marine stock enhancement as a viable resource management tool might result in its common use for mitigation, allowing further degradation of the coastal environment.

On the other side of the argument, user groups of both recreational and commercial fishermen have stated the opinion that the concerns raised by resource managers and the scientific community have little practical merit, and that costs associated with scientific investigations can be eliminated in lieu of supporting increased hatchery production. It can be extremely difficult to convince the lay person that concerns as seemingly esoteric as the genetic variability of the progeny produced in the hatchery may in some way diminish the viability of the wild population, even though this concept is readily accepted as a primary component of the scientific community's enhancement debate and should, therefore, be given significant consideration in any proposed enhancement effort.

These on-going arguments often only serve to further polarize the debate on the usefulness of enhancement hatchery programs, ultimately toward limiting the ability to actually test their efficacy. It is incumbent upon the fisheries management community to resist these pressures and apply the best scientific procedures in testing the real potential for fisheries enhancement. If this does not occur, then user groups that control or strongly influence the economic and political resources supporting enhancement programs will cause projects to be performed that lack the scientific structure required to allow adequate assessment of positive or negative impacts.

Based on the experiences of OREHP, we recommend that each species under consideration for enhancement should be evaluated individually before the efficacy of stocking it can be promoted or denounced. The evaluation should consider the biological characteristics and management history surrounding each species. If possible, operational funds should be secured through a dedicated account so the program can be evaluated over several years, at least until the stocked fish are recruited into the fishery, and to prevent having the funds diverted into other unrelated programs. Both scientists and user groups should be involved when establishing the goals and oversight responsibilities for the program, and lines of authority for the program should be established early in its development. A high profile review process should be maintained, and post-release and genetic assessments should be incorporated into the program as early as possible.

In the case of California's OREHP, we feel that an excellent working relationship has been developed between the scientists conducting the research, the management agencies responsible for the resource and the user groups providing the funding. With continued scientific review the OREHP hopes to further the goal of adequately testing marine fisheries enhancement as a responsible resource management tool.

LITERATURE CITED

Assembly Bill No. 1414, 1983. (Authored by California Assemblyman Larry Stirling).

Assembly Bill No. 960, 1993. (Authored by California Assemblywoman Dede Alpert).

Bartley, D.M. and D.B. Kent. 1990. Genetic structure of white seabass population from the southern California Bight region: applications to hatchery enhancement. California Cooperative Oceanic Fisheries Investigations Report 31:97-105.

Bartley, D.M., D.B. Kent and M.A. Drawbridge. 1995. Conservation of Genetic Diversity in a White Seabass (Atractoscion nobilis) Hatchery Enhancement Programme in Southern California. Proceedings of the American Fisheries Society Special Symposium on Uses and Effects of Cultured Fishes in Aquatic Ecosystems, Albuquerque, New Mexico. 15:249-258.

Blankenship, H.L and K. M. Leber. 1995. A Responsible Approach to Marine Stock Enhancement. Proceedings of the American Fisheries Society Special Symposium on Uses and Effects of Cultured Fishes in Aquatic Ecosystems, Albuquerque, New Mexico. 15:167-175.

Botsford, L.W. and R.C. Hobbs. 1988. Economic evaluation of the culture of white seabass (Atractoscion nobilis) and California halibut (Paralichthys californicus) for fishery enhancement. Paper presented at the World Aquaculture Society 19th Annual Meeting, Honolulu, Hawaii.

California Permit Handbook 1992. Governor's office of planning and research, office of permit assistance. 1400 Tenth Street. Sacramento, CA 95814.

FAO (Food and Agriculture Organization). 1995. The State of World Fisheries and Aquaculture, Food and Aquaculture Organization of the United Nations, Rome, Italy.

New, M.B. 1991. Turn of the millennium aquaculture: navigating troubled waters or riding the crest of the wave? World Aquaculture 22(3): 28-49.

NMFS (National Marine Fisheries Service). 1992. Our living oceans: report on the status of U.S. living marine resources, 1992. NOAA Tech. Mem., NMFS-F/SPO-2, Silver Spring, MD.

Venrick, E.L. 1985. Marine Recreational Fishing in The Oceans and Economy of San Diego. Scripps Institution of Oceanography. 38-42

Vojkovich, M., and R.J. Reed. 1983. White seabass, Atractoscion nobilis, in California-Mexico waters: status of the fishery. Reports of the California Cooperative Oceanic Fisheries Investigations XXIV: 79-83.

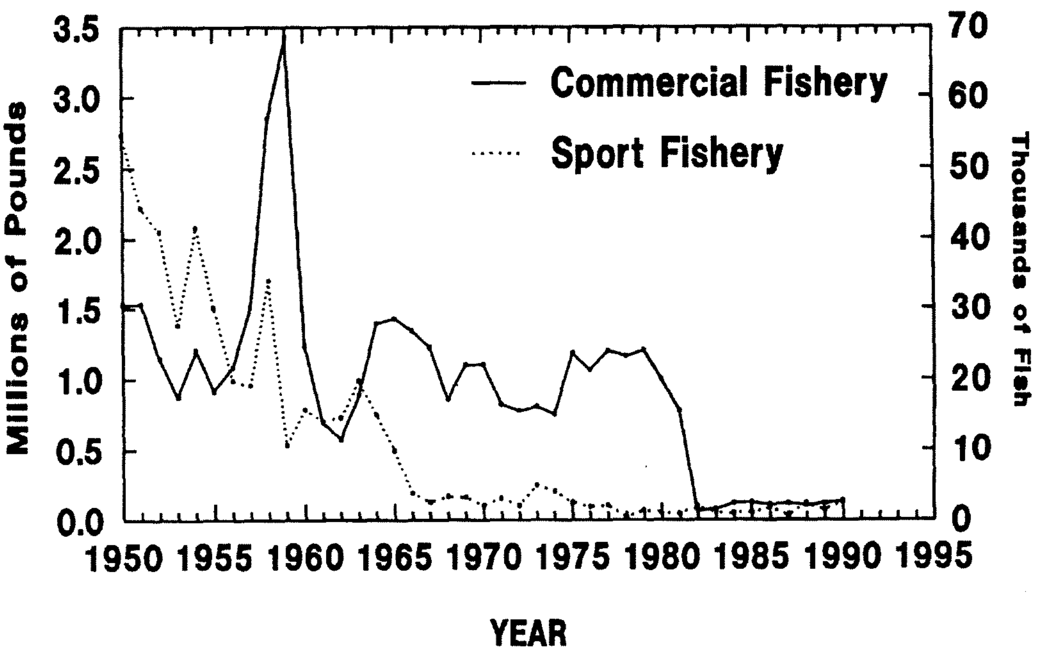


Figure 1. Sport landings (thousands of fish) and commercial take (millions of pounds) of white seabass in California.

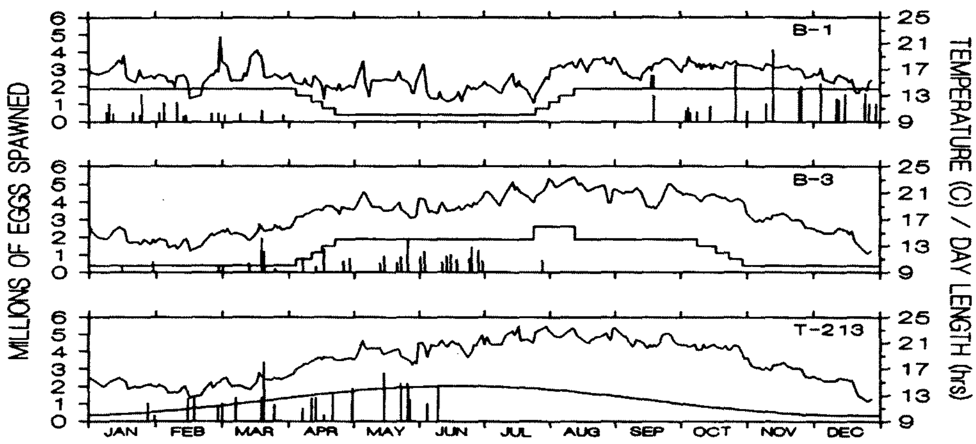


Figure 2. Spawning regime (water temperature and photoperiod) for three different groups of white seabass. Spikes indicate spawning events. Groups B-1 and B-3 were held under artificial, controlled conditions while T-213 was held under ambient conditions.

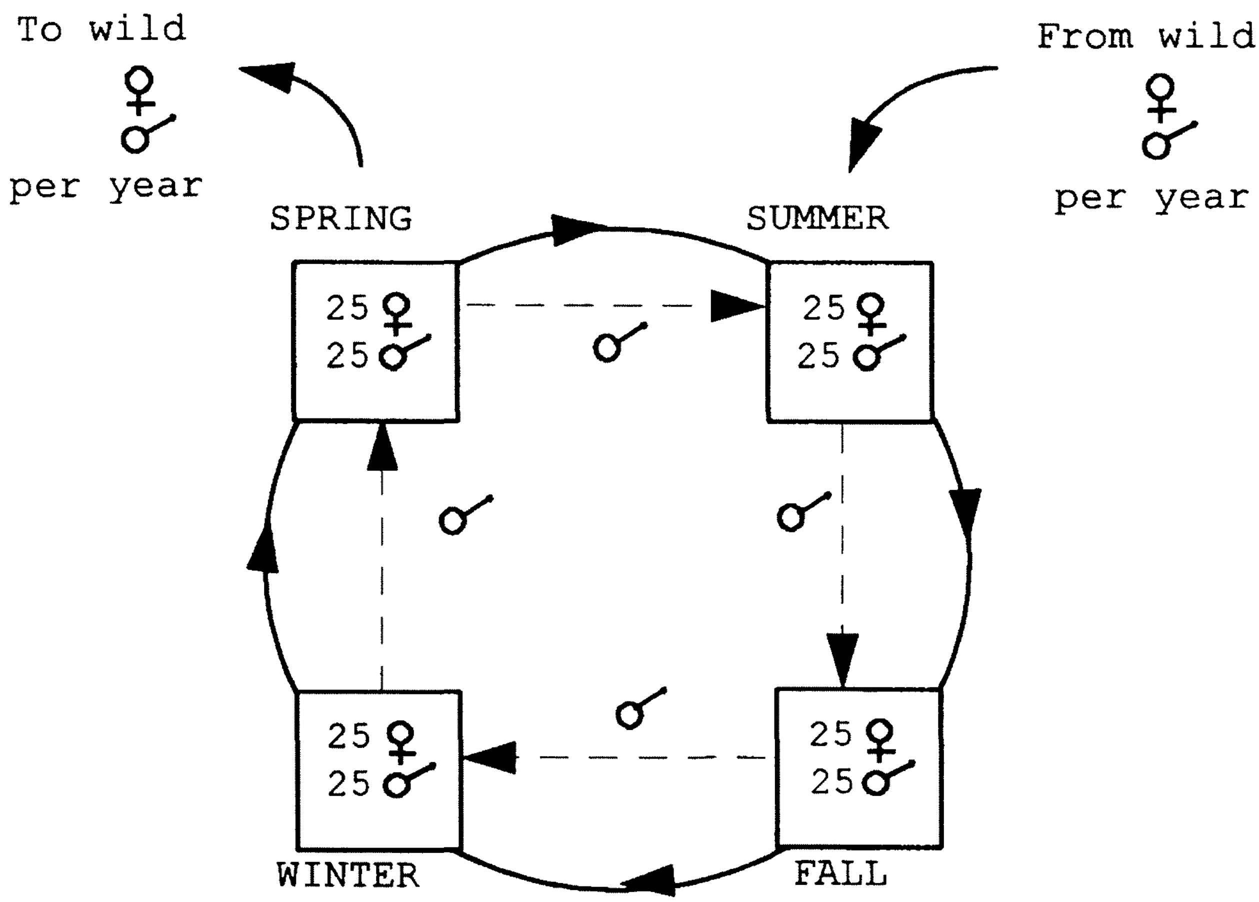


Figure 3. Schedule of broodstock rotation and replacement as part of overall broodstock management plan. Squares represent mass spawning tanks with 25 males and 25 females

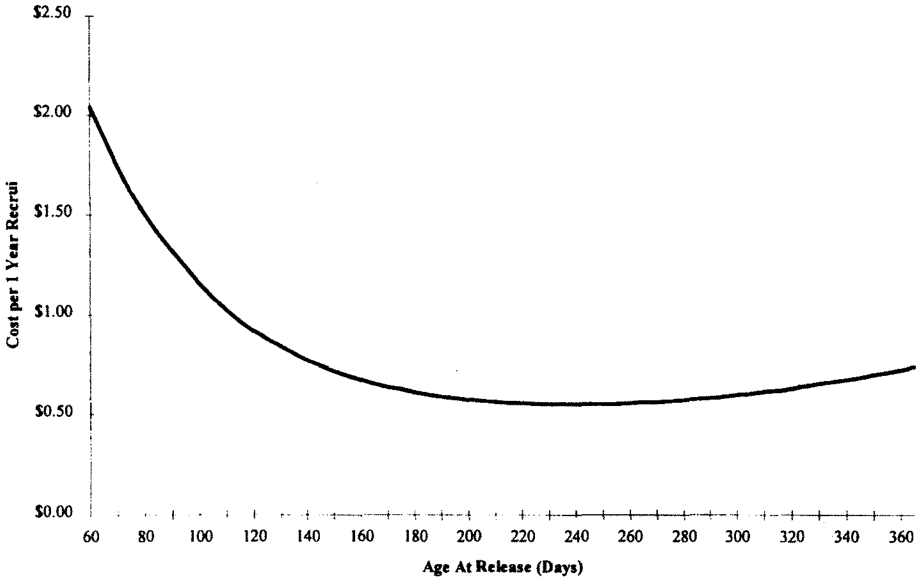


Figure 4. Estimated cost of one year old fish relative to age at release

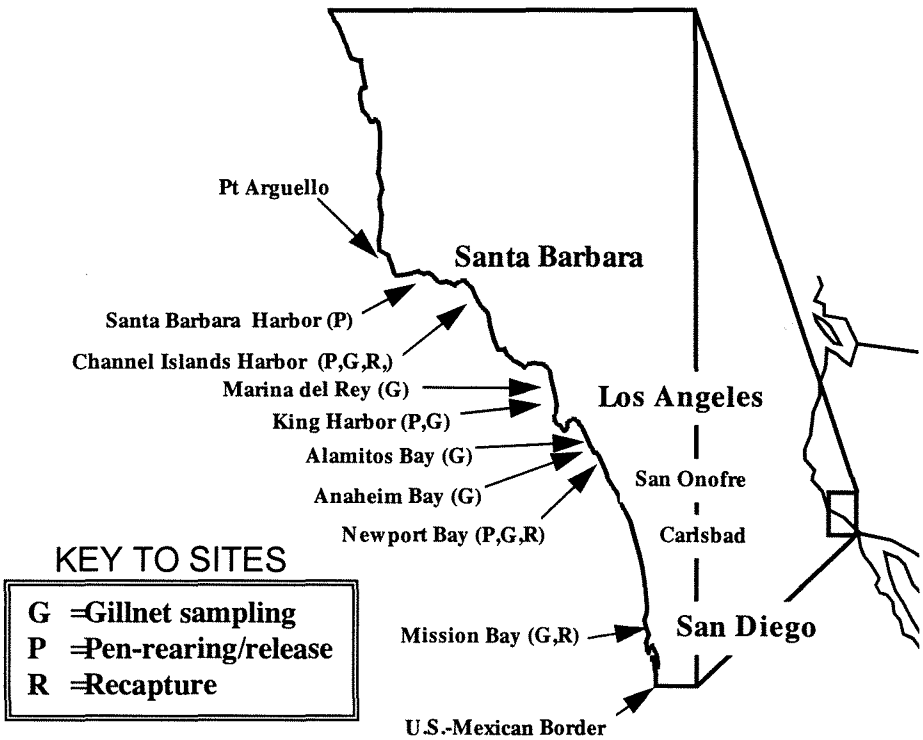


Figure 5. Site map of southern California showing culture, release and assessment areas

PRESENT STATE AND PROSPECTS OF JAPAN'S SEA FARMING

Taira Matsuoka
Japan Sea-farming Association

INTRODUCTION

Warm and cold currents flow in the sea off Japan. There exist abundant fishery resources that originate in northern and southern seas. Fish found in Japanese waters exceed 3,000 species. The two ocean currents meet and nurture the world's most productive fishing grounds.

Japanese have thus been fish-eating people since ancient times. Bones and shells of more than 330 different seafoods were unearthed in the shell mounds of the Jomon period (ca. 8,000 BC-300BC). Recent studies revealed that marine products were traded in inland areas. This suggests that some people were already professionally engaged in fishing in that period. Many globefish bones were discovered in the ruins of the Jomon period. This fish is poisonous but is a high-quality and expensive seafood loved by contemporary Japanese. It is intriguing that people in those days must already have known how to counteract the fish' s poison.

Many East Asians use chopsticks. In Japan people generally use chopsticks with sharp points, unlike those preferred by Chinese and Southeast Asians. Probably Japanese chopsticks were developed to cat fish dexterously.

The fact that about 800 proverbs relating to fishing and seafood are found in the Japanese language indicates how deeply fishery products penetrated Japanese culture as well as eating habits.

Inasmuch as eating habits and housing conditions have been Westernized in this country, people particularly the younger generation are now consuming less rice and fish. Seafood consumption has consequently declined in recent years. Each Japanese, however, still ingests 190 grams of marine products per day on average. This intake comprises the highest volume among the animal proteins absorbed by our people. We are the world's leading piscivorous nation.

Although Japan has fishery traditions, its fishing industry now faces a critical time in respect to the newly established international order of the sea. This new order is represented by the UN Convention on the Law of the Sea (1994), and by the UN Treaty on Straddling Stock and Highly Migratory Fish (provisional title). In preparation for ratification of the UN Convention, Japan must urgently take necessary measures effectively to preserve, control, and utilize fishery resources in its ambient waters.

Japan has long implemented a variety of measures to preserve and expand aquatic resources. In this paper I will introduce sea farming and discuss its present state and prospects. Sea farming is designed to expand useful resources by releasing seeds. It is one of the methods for preserving and propagating aquatic resources.

JAPAN'S FISH CATCH AND PRESENT STATE OF FISHERY, AQUACULTURE, AND MARINE-PRODUCT TRADE

Present production

I will comment on Japan's present fisheries and aquaculture to provide a background for this discussion of sea farming.

Table 1 shows the latest production status of fishery and aquaculture. Output in 1994 totaled 8. 10 million tons, down 63% from the all-time high of 12.78 million tons of 1988. The decline was mainly because of the recent sardine-resource reduction. This country continues nevertheless to rank among the world's leading fishing countries that include China, Peru, and Chile.

Rice is our staple food. Its annual production is somewhere between 8 million and 10 million tons. Fishery production almost equals the annual rice harvest.

The total fishery production in Table 1 includes 6.59 million tons from sea fisheries. Offshore fishery stood at 3.72 million tons, comprising the predominant part of total production. Coastal and far-seas fisheries follow sequentially. Marine culture produced 1.34 million tons, surpassing the once-prosperous far-seas fishery.

The total production value was \2.37 trillion. This amount accounts for 0.5% of Japan's gross domestic product. (For comparison, gross agricultural production was about \8 trillion, comprising 1.7% of GDP) Coastal fishery produced \685 billion and topped the first of sea fisheries. Marine culture ranked second at \627 billion.

Sea fishing operators have been diminishing in number in recent years. The number was 167,367 in 1994, accounting for 0.4% of all Japanese households, or only one-seventeenth of the farming families of this country. Fishery personnel numbered 312,890 and fishing vessels 256,829. Of these figures, coastal-fishery operators were 158,948, constituting 95% of Japan's overall fishery operators. Personnel in coastal fisheries totaled 263,040, comprising 84% of all fishery workers. The enormously high ratio of coastal fishery operators and workers is one of the reasons why coastal-fishery-promotional measures are essential in Japan.

Present marine-product trade

Table 2 shows the latest imports and exports of marine products. Japan is a large marine-product importer because it annually imports seafood worth \1.7 trillion. In the past this country was an exporter but the situation was reversed in 1971. Now marine products rank second on Japan's import list, following crude oil. Japan's imports account for 33% of the world's overall marine product imports by value.

A greater part of the imported marine products were macrurans that comprised 10% or more of the global catch. Tuna, marlin, salmon and trout followed prawn and prawn. The rapid increase in marine-product imports caused fish prices to decline and strained fishing-operational management.

Marine-product exports include pearls, tuna and marlin, and canned marine foods. Total exports, however, are but a fraction of import totals. The situation is undesirable for Japanese fishermen, but ironically has contributed to reducing Japan's trade imbalance.

SEA FARMING

A general attribute of aquatic organisms is that they spawn abundantly at a single occasion. Only a small portion of the spawn, however, survives to parenthood. Headfish spawn hundreds of million eggs, tuna tens of millions, and salmon and trout several thousand. The greater portion of the spawn will perish when they are eggs and fry because of food shortfalls immediately posthatching, inadequate water temperature, or being consumed by natural enemies. If eggs seldom perish, however, and favorable conditions exist for the survival of eggs and fry, resource expansion would result (See Fig. 1).

Eggs and fry are protected artificially from large diminution in the early period. They will be released into the sea after they are reared and grown sufficiently to survive in their natural habitat. These activities to increase fishery resources are known as sea farming. Propagation of aquatic organisms began in ancient times (several thousand years ago according to some literature). Table 3 fists methods of propagating fishery resources, implemented by governmental or fishermen's initiatives.

The preservation and propagation of aquatic organisms is classified into three categories as shown in Table 3.

The first category is resource management. This concerns regulations and prohibitions concerning fishing tackle and methods, areal and seasonal closings, fish-size restrictions, and other regulations. These controls are implemented under the Fishery Law and local-government ordinances. In some cases fishermen voluntarily impose restrictions.

The second category is farming that is likened to soil cultivation in conventional agriculture. This operation is to prepare and improve habitable conditions by creating fish reefs in the water and by cultivating submarine forests and spawning grounds. Many of these activities are subsidized by the national government.

The third category is species production. Sea farming is part of this category. Basically we artificially produce seeds and then release them to develop useful resources. Transplants and releases have a long history. The release of the artificially produced seed of salmon and trout has been conducted for more than 100 years. It was only in the sixties, however, that Japan began to release the seed of fish such as red sea bream, Japanese flounder, macruran, and crab, which are presently cultivated insea-farming operations.

I would like to restress the concept of our sea-farming project. We took notice of the characteristics of aquatic organisms, especially that they are prolific but that an astonishingly great number perish as juveniles. We therefore embarked upon a project to preserve and expand fishery resources by spawning a great quantity of eggs and by rearing juvenile fish to a size large enough to escape being eaten by predators. The fish are then released into the sea where growth conditions are favorable.

Sea-Farming History

Japan sustained great damage in World War 11 but the country's economy began to recover in the fifties after rehabilitation from the devastation. National income also began gradually to increase in tandem with economic recovery. The country entered a period of high economic growth in the sixties. People wanted to enjoy tasty marine products. Such demand led to increased pressure for catching expensive fish, and resulted in continuous exhaustion of useful aquatic resources.

Another factor that depleted fishery resources was the country's economic development and industrial policies. Many coastal shallows were reclaimed to create industrial property, causing filthy water to flow into inland waters. Industrial development thus destroyed breeding areas and continued to diminish fishery resources.

Concurrent research progressed in many areas of fishing operations. As a result, the early-life history of a variety of aquatic organisms became clear. Artificial seed-production technologies were further developed for some species of fish.

Under these circumstances, the Fisheries Agency in 1963 proposed a project for sea farming that was initiated in the Inland Sea where extinction of fishing grounds and water contamination became evident. The project was not for maintaining the status quo by resource protection and control. Rather, it was for positive resource expansion to produce and release seed.

Many fishery experts questioned the possible result of the new project because they doubted whether seed production and release would surpass nature's productive power. Despite this skepticism, the national government constructed two sea-farming centers in the Inland Sea, and subsidized prefectural test and research activities in seed production. Subsidizing the construction of prefectural sea-farming centers triggered the nationwide promotion of similar fishery projects.

One thing we must remember in sea-fanning development is discovery of the effects of rotifer as feed during the initial rearing period. Before its discovery, the feed used in sea farming was oyster, sea urchin, barnacle larvae, and Artemia (Brine prawn) larvae imported from the United States. Seed production in those days was on a small scale. A university researcher in the sixties discovered rotifer cultivation and its effective utilization for feed in early seed production. Mass production of different seeds became feasible as a consequence.

Sea Farming and Cultivation

I should clarify the difference between sea farming and cultivation because even some experts are unable to distinguish between the two.

By cultivation we mean stocking fry in the crawl or fish reservoir to rear the hatched fish until they grow sufficiently large to be marketed. In this regard it does not matter whether fry become available by hatching spawn or by catching natural fry.

In sea farming, however, we hatch spawn, rear fry, and release them into the sea when they grow sufficiently large to be able to survive. The released fish do not belong to any specific persons, but to the fishermen - who happen to catch the fish.

SEA-FARMING TECHNICALITIES

Selection of sea-farming species

The following factors should be taken into account when species are selected for sea farming.

(a) Species do not migrate or travel far away from the point where they are released.

(b) Species are in great demand among fishermen because such fish are comparatively expensive, and yield greater income for fishermen.

(c) Species grow rapidly and in two or three years become large enough to be caught.

The government selects sea-farming species in consultation with the Fisheries Agency and the Fisheries Research Laboratory with due consideration to requests from prefectures that border water areas. Today the government decides its basic policies every five years. Sea-flaming research and development programs have been implemented according to announcement of the government's decision.

On the prefectural level, a sea-farming-promotion council deliberates and adopts necessary species to be farmed by each prefecture. The council formed within the prefectural government is comprised of government officials, research and development institutes, sea-farming centers, fishing communities, and men of learning and experience. Prefectural governments draw up the basic plans every five years according to the central government's decision. Detailed plans such as sea-farming species, production quantity, and release quantity are announced to citizens and fishermen.

Each prefecture selects its specialties in addition to abalone, sea bream, and Japanese flounder that are released by many prefectures. Northern prefectures choose scallop and sea urchin developed in the northern sea, while southern prefectures select grouper and snapper as their specialties.

Cultivation of parent fish, maturation acceleration, and egg collection

Figure 2 shows methods of securing eggs and fry of sea-farming species as presently practised in Japan.

The methods are roughly divided into (a) natural-seed collection, and (b) artificial-egg collection. Two different processes are employed in artificial-egg collection. One is to catch and rear natural fish and to obtain eggs when the fish become parents. The other is to rear artificially produced fish to use them as parents.

Artificial-egg collection is possible from bivalves such as scallops and Japanese short neck clams. Nevertheless, the artificial method is seldom employed because natural-seed collection is easier and more effective for securing a large quantity of seed. We lower seed-collecting devices into the water when floating larvae are abundant, in the same way as collecting seed for oyster cultivation.

Some types of fish such as parent Kuruma prawn can be reared, but eggs are collected mostly from natural parent prawn that are caught. This is because a large quantity of eggs must be collected at a time. We now re-examine the method of rearing parents that have originated from artificially produced seed. As many parents as possible should be used. Using one and the same parent for a long time should be avoided to preserve genetic diversity.

To accelerate parent maturation, a maturation-accelerating hormone is injected into yellowtails. For sea bream and Japanese flounder, however, good eggs are collected by giving good feed to the fish in the cultivation pond.

We prepare fish tanks of several tens of cubic meters'capacity to rear parent fish of ordinary size. For large fish such as yellowtails, fish tanks of several hundreds of cubic meters or net crawls floating in the sea are employed.

Sea urchin and shellfish including abalone are reared mostly in a small glass-fiber tank of several cubic meters into which raw or filtered seawater is pumped. For shellfish such as abalone, seawater irradiated with ultraviolet rays is employed, or the water temperature is caused to fluctuate to encourage spawning. We control sunshine hours and water temperature to adjust spawning periods for some types of fish.

Eggs were formerly collected by artificial insemination from natural fish in the same manner as for salmon and trout. Inasmuch as rearing techniques have rapidly advanced recently, the major rearing process is now to cultivate good parents and to encourage natural spawning, and to secure fertilized eggs in the pond. The process of breeding good parents has predominated to encourage natural spawning and to secure fertilized eggs in the pond.

Feed in the early breeding period

To produce seed using fry, feeds are (a) rotifer (Rotatoria; Branchionus plicatilis), (b) nauplius larvae of Arternia (Branchiopoda; Artemia), and (c) assorted feed or minced fish. These seeds are provided in the above order of utilization. For some fish such as red sea bream, Japanese flounder, and Kuruma prawn, artificial assorted feed in ultrafine particles is being developed for use in the early production stage.

Nannochloropsis (Eustigma; Tophyceae) is supplied as feed for the cultivation of rotifer. A large water tank is necessary to cultivate Nannochloropsis. Many sea-farming centers use yeast to cultivate rotifer. Some centers began to feed freshwater Chlorella that is manufactured by industrial plants.

Rotifer is classified into large, small, and very small types. The different types of rotifer are employed according to the type of fish and growth stages. We have recently imported rotifer from Thailand and Fiji. Regarding Artermia, both nauphus larvae and adult form are supplied according to growth stages. The adult form is also used according to growth stage.

Bacillariophyceae including Nitzchia and Navicula are provided for abalone. For Kuruma prawn, microalgae such as Tetraselmis (Pransinophyceac) are used. Floating Bacillariophycae and Nannochloropsis are given to sea urchin and sea cucumber in the initial cultivation stage.

If we assume a capacity of one for a pond required for the seed production of ordinary fish, we will need a pond of the same capacity to cultivate microalgae such as Nannochloropsis that are the feed for rotifer, and also to cultivate rotifer.

For rearing abalone and sea urchin after they are deposited, we place in the tank corrugated plastic boards on which beforehand.,

Seed production (fry, and strong-seed poodruction)

Feeding, as described in the preceding section, begins when fry take in yolk and open their mouths and cloacae.

In the early feeding period when rotifer is supplied, feed must be highly densified, for example ten individuals/cc or more. Otherwise growth and the survival rate will deteriorate. Excessive feeding will reduce the dissolved oxygen and deteriorate water quality. Accordingly, feeding conditions and the feed remaining until the following morning should be carefully monitored.

Well-balanced, nourishing feed is essential for producing healthy seed. Highly unsaturated fatty acids (HUFA) and vitamins (vitamin A as the main factor) are added to feed.

Generally fry will not take feed at night. Accordingly, feed is supplied profusely in the evening and in the early morning. Some prefectural sea-farming centers began artificially illuminated - cultivation to save labor and to normalize employee working hours. Cultivation tanks are left dark during off-duty hours, and are lighted while workers are on duty.

Automatic feeders are used when fry grow large and can take assorted feed. With technical advancement, automatic feeding has rapidly become widespread.

When water temperature is low in winter or when temperature control is necessary, water is heated. In summer, when water generally rises, we cool water for fish that inhabit the deep sea or cold water.

Stagnant water is used at the beginning of cultivation, but we should change seawater frequently as fry grow.

Aeration is provided to the cultivation tanks to inprove oxygen supply and water circulation. Fine dust such as pollen or oily film may sometimes cover the surface of a cultivation pond and hinder air-bladder formation. A necessary step is to provide a shelter and appropriate drainage for the pond.

Intermediate rearing

Fish are reared in the densely populated water tank on land until they grow to a size of from one to two centimeters. To rear a great number of juvenile fish, fry must be moved to a larger pond or to a net-crawl that is floating in the sea. Intermediate rearing is a process in which fry become accustomed to marine conditions and grow too large to be eaten by natural enemies. Fishermen's cooperatives often take the lead in the operation of intermediate rearing. Fishermen rear and release juveniles, and coincidentally become more aware of fishery-resource protection. The fishermen are also willing to participate in resource management, including restrictions on fish size and fishing seasons, because they must voluntarily protect released fish.

Release

After intermediate rearing, seeds are released. As a rule, all seeds under technical-development study must be marked when they are released. Before releasing, careful attention should be given to water temperature, ocean currents, seabed properties, and the existence of natural enemies. Optimal areas and seasons should also be selected for successful releasing. Whether the seed have ever before been released or whether the seed now live in a given area will guide future releases.

PRESENT SEA FARMING

Table 4 shows seed production and releases for major fish in recent years. According to the statistics for fiscal 1995, Japan produced and released 90 seeds in total, divided into 38 pisces, 17 crustaceans, 27 shellfish, and eight invertebrates.

The sea-fam-fing operational system is outlined in Fig. 3. The national government develops basic and applied technologies for the sea farming of pisces, including migratory species as the main category. Prefectural governments are in charge of the technological development and commercialization of migratory and seashore species. Public corporations and fishery cooperatives commercially cultivate seashore species and operate fishery businesses.

Despite the above operational system, the national government takes responsibility for the technological development of such seashore species as lobsters because risks are beyond prefectural governments'capabilities.

Fig. 4 gives the locations of national sea-farming centers. Sixteen centers are located over a wide area ranging from Akkeshi Station, Hokkaido, in the subarctic zone close to 43* north latitude, to Yacyama Station on Ishigaki-jima Island, Okinawa, in the subtropical zone close to 24* north latitude. Each sea-farming center continues the technical development of species that are adaptable to each regional environment.

Prefectural sea farming centers total 53. Thirty-nine prefectures that face the sea have one or more centers. Each center makes full use of national or prefecture developed technologies in the production and release of seeds that are associated with the center.

The prefectural centers are operated directly by local governments or are subcontracted to corporations established jointly with the private sector. The operations of such joint corporations are increasing these days.

In addition to the national and prefectural centers, municipalities, villages, and fishery cooperatives have founded their own sea-farming centers. They produce and release seashore species as major seed.

Table 5 shows the seed production and release volume by operating organizations and species. The national and prefectural centers operate most of the seed production of pisces, accounting for 95% of national production. These centers also release 52% or more than a half of the total pisces seed. Administrative agencies and public research institutes lead in the seed productian and release of this category.

Regarding crustacea, the state and prefectures share 80% of total seed production, but municipalities, villages, and fishery cooperatives, commissioned by the state and prefectures, release 72% of the seed produced.

Shellfish are seashore species. State-operated centers do not produce or release shellfish seeds. Prefectural and other local centers produce only 3% of the total seeds. Fishery cooperatives produce and release almost all types of seed.

Most prefectural sea-farming centers in northern Japan cultivate abalone and sea urchin as major seed-production items. The cultivation ponds are therefore rather small and shallow and are mostly made of glass fiber. The centers operate all yearround inasmuch as these creatures grow slowly.

In southern Japan, however, the majority of sea-farming centers produce fish seed, using concrete cultivation ponds. The centers generally produce two types of seed a year: fish in spring; and abalone, sweetfish, and other seeds in autumn. This is because fish and shellfish grow rapidly in the southern regions.

Sea-Farming Problems

Japan has been engaged in sea farming for more than thirty years since the technology was inaugurated in the sixties. Although the cultivation technology has tremendously advanced over these years, many problems have remained to be solved. Here 1 will give you a rundown of the main issues.

Technological problems in seed production

Initial-stage feed: The feed currently used for rearing hatched fish are, as stated in Section 5 (3), combinations of rotifer, Artemia, assorted feeds, and minced fish. Rotifer and Artemia are live feed and as such are costly. To produce the five feed you would need a large space, including a water tank for Nannochloropsis cultivation. Using assorted feed instead of five feed would without doubt reducc farming costs and lead to sea-farming automation.

Diseases: The gravest problem in seed production under high-density conditions is diseases. The diseases are caused by factors such as bacteria and viruses. Viral diseases have recently sprung up among many types of fish including striped jack, Kuruma prawn, and Japanese flounder. This has caused great concern among fishery communities. Preventive measures have been taken, such as the disinfection of water tanks, prohibition of unauthorized entry into production sites, and intensified viral examination of parent fish. Despite these efforts, no complete countermeasure has been developed. Fortunately, however, a viral-examination technique has been devised and has contributed to improved seed production. This critical problem must be urgently resolved to disseminate nationwide sea-farming activity.

Abnormal form (including abnormal color): At the seed-production stage, color and skeletal anomalies are often found among many types of fish. Countermeasures have been experimented with, such as enriching initial-stage feed with vitamins, but no absolute solution has been discovered. For example, black pigment often appears on the white side body of Japanese flounder, which is the side on which the fish has no eye. Such abnormal fish appear inferior and may not be sold at standard fish prices although there is no difference in taste.

Seed quality: Whether or not seed is suitable for production and release constitutes the quality. A crucial matter is whether seed can survive after being released. Artificially produced seed must be habituated to catch feed and must protect themselves from predators after being released. Such discipline is now an important factor in seed production. Experiments on red sea bream revealed that seed quality substantially improved when feeding frequency was reduced during intermediate cultivation.

Technical problems in seed releasing

Successful sea farmning depends on the collection of fish of a size suitable for marketing after fish are released following seed production. The releasing, which is the last stage of sea farming, counts most in the overall operation.

Effective markings: Markings should be easily affixed but not come off, and should be readily identified. Such markings are indispensable in seed releasing. Particularly for crustacea that cast off their skins, markings different from those for fish must be devised.

Releasing grounds and seasons: You must survey releasing grounds to discover whether seabeds are sandy or rocky, and whether there exist submarine forests. As a rule you should select regions where exist the same fish as the ones to be released. Grounds and seasons for seed releasing should be apropos to the habits of the fish.

Evaluation of release results: You need to evaluate the collection of released seed scientifically and accurately to determine sea-farming results. For this purpose, a survey system should be organized to gather basic data through market research and other investigations.

Consideration for genetic diversity (ecological-system preservation): Standards must be formulated to protect seed production and release against genetic and ecological aggravation. Forthe formulation of standards, comments and recommendations should be invited from experts including scientists at research institutes and universities, and FAO specialists.

Business-management problems

Future sea-farming projects should be managed by fishermen who will benefit from the projects. In the sea farming of Japanese flounder in Aomori Prefecture, the fishermen acknowledge the results of seed releasing and collect as sea-farming costs a portion of the sum for Japanese flounder harvest. Before establishing a cost-bearing practice by beneficiaries throughout the country, the following problems must be solved.

Reduction of seed-production costs: Efforts should be exerted to reduce seed-production eda through energy conservation and labor saving so that more fishermen will join sea-farming activities.

Transparency of release results: Clarification of seed-release results will encourage fishermen to agree to Cost sharing and to participate in sea-farming projects.

Necessity of legislative improvement: Released fish are legally regarded as ownerless. All fishermen are thus authorized to catch the fish. If, however, fishermen manage sea farming on their own, anyone who catches released fish will be requested to pay for what he catches. If the principle of cost bearing by beneficiaries is strictly observed, laws will be necessary to protect the rights of the beneficiaries who bear the sea-farming costs.

Closing Comment Including Prospects for Sea Farming Sea farming is an extensive aquaculture that is a positive, not passive, technique. This extensive aquaculture faces many problems, but people involved in the marine products industry are obliged to address their wisdom to solution of the problems and to overcome difficulties.

Furthermore, scientific and technological cooperation should be organized by experts, not only from the fishery industry, but also from basic biology, biochemistry, medicine, pharmaceuticals, electronics, electricity, thermodynamics, hydraulics, mechanical engineering, civil engineering, building engineering, chemistry, mathematics, statistics, and other sciences. Such a cooperative system must include the bureaucracy, the private sector, fisheries, and sport fishing people. The understanding and cooperation of the entire nation is indispensable.

If released fish are caught before they grow to marketable size, sea-farming operators will gain absolutely nothing from their efforts. Sea farming must operate in tandem with resource management and the creation of fishing grounds.

Unlike mineral resources such as petroleum and coal, aquatic organisms have reproductive capability if they are controlled properly. This is their great strong point. Conservation and the expansion of valuable fishery resources are important undertakings that must be passed on to posterity.

The direct beneficiaries of Japan's sea-farming projects are fishermen and people who enjoy fishing as a pastime. If sea farming constantly succeeds in supplying good fish, it will at length benefit all Japanese.

I am confident that when our sea-farming expertise is acknowledged and disseminated worldwide, it will render great service to humans everywhere who catch and consume fishery resources.

Table 1. Fishery and aquaculture Production in Japan, 1994

	Production volume (1,000 tons)	Production value (1 billion)
Sea fishery	6, 590	1, 582
Far-seas fishery	1, 063	347
Offshore fishery	3, 720	550
Coastal fishery	1,807	685
Marine culture	1,344	627
Subtotal	7,934	2,209
Inland-waters fishery and aquaculture	169	164
Inland-waters fishery	92	72
Inland-waters aquaculture	77	92
TOTAL	8,103	2,374

Table 2. Japan's major Fishery Export and Imports, 1994

Imports		
Category	Import volume (1,000 tons)	Import value (1 billion)
Prawn, shrimp,etc	320	375
Tuna, marlin,etc.	298	186
Salmon,trout,etc.	243	131
Crab, etc.	124	123
Total marine products	3,295	1,709
Exports		
Category	Export volume	Export volume (1 billion)
Pearls	71	42
Tuna, marlin,etc.	41 (1,000 tons)	10
Canned marine foods	21 (1,000 tons)	6
Total marine products	296	123

Table 3. Methods of Propagating Fishery Resources

I. Resource Management

1. Regulations and prohibitions for fishing tackle and methods
2. Regulations on fishing seasons (closed seasons)
3. Regulations on fishing areas (closed areas)
4. Regulations on species, volume, size, operational days, etc.
5. Transplantation of harmful organisms; regulations and prohibitions on seed release
6. Prevention of poaching

II. Propagation-Grounds Creation

(Environmental Improvement)

1. Creation and conservation of spawning and rearing grounds for fry and spore, including submarine-forest and tideland development
2. Expansion and preparation of colonies, periphyte surfaces fishint-grounds creation)
3. Submarine-forest and weed-jungle development
4. Preparation of fishways
5. Prevention of water contamination

III. Seed Production

(Expansion of Resource Supply-Reproduction Volume)

1. Direct method
a. Seed production and transplantation
b. Seeding and mother-algae transplantation
2. Indirect method
a. Conservation and expansion of spawning grounds (devices to settle eggs and spore)
b. Creation of slow and eddy currents (to ensure fry deposition)

Table 4.

Number of seeds produced and released in 1995 (1995.Apr-1996.Mar)

×1000 individuals

	Specific name			Number	Number
	Japanese name	English name	Scientific name	produced	released
Pisces	NISHIN	Pacific herring	*Clupea pallasi*	2.178	2.270
	MADARA	Pacific cod	*Gadus macrocephalus*	143	84
	AKAAMADAI	Japanese tilefish	*Branchiostegus japonicus*	4	
	SHIMAAJI	Striped jack	*Pseudocaranx dentex*	333	250
	HIRAMASA	Amberjack	*Seriola aureovittata*	64	37
	KANPACHI	Amberjack	*Seriola dumerili*	0	
	BURI	Yellow tail	*Seriola quinqueradiata*	743	359
	MAAJI	Horse mackerel	*Trachurus japonicus*		186
	KYUSEN	Wrasse	*Halichoeres poecilepterus*		1.963
	HAMAFUEFŪKI	Bluestreak emperor	*Lethrinus choerorhynchus*	153	109
	ISHIDAI	Japanese striped knifejaw	*Oplegnathus fasciatus*	17	19
	ISHIGAKIDAI	Spotted parrot fish	*Oplegnathus punctatus*	11	15
	SUZUKI	Sea bass	*Lateolabrax japonicus*	664	404
	ISAKI	Three-lane grunt	*Parapristipoma trilineatum*	644	606
	OONIBE	Japanese croaker	*Nibea japonica*	228	228
	KIJIHATA	Grouper	*Epinephelus akaara*	58	14
	SUJIARA	Blue spotted grouper	*Plectropomus leopardus*	9	2
	KURODAI	Black sea bream	*Acanthopagrus schlegeli*	10.144	6.521
	MINAMIKURODAI	Black sea bream	*Acanthopagrus sivicolus*	360	177
	MADAI	Red sea bream	*Pagrus major*	26.650	21.309
	HATAHATA	Sandfish	*Arctoscopus japonicus*	5.208	5.052
	KUROMAGURO	Bluefin tuna	*Thunnus thynnus*	0	
	MUTSUGORO	Bluespotted mud-hopper	*Boleophthalmus pectinirostris*		1
	AINAME	Greenling	*Hexagrammos otakii*		773
	KOCHI	Flathead	*Platycephalus indicus*	143	66
	MEBARU	Japanese stingfish	*Sebastes inermis*		536
	KUROSOI	Jacopever	*Sebastes schlegeli*	2.734	1.969
	KASAGO	Scorpion fish	*Sebastiscus marmoratus*	455	310
	ONIOKOZE	Devil stinger	*Inimicus japonicus*	237	174
	HIRAME	Japanese flounder	*Paralichthys olivaceus*	27.713	21.574
	MUSHIGAREI	Roundnose flounder	*Eopsetta grigorjewi*	30	11
	MAGAREI	Flatfish	*Limanda herzensteini*	573	176
	MAKOGAREI	Mud dab	*Limanda yokohamae*	4.319	2.098
	BABAGAREI	Dover flounder	*Microstomus achne*	3	1
	YANAGIMUSHIGAREI	Willowy flounder	*Tanakius kitaharai*	0	
	MATSUKAWA	Barfin flounder	*Verasper moseri*	9	13
	HOSHIGAREI	Spotted halibut	*Verasper variegatus*	56	23
	TORAFUGU	Ocellate puffer	*Takifugu rubripes*	2.344	1.722
Pisces total	38			86.227	69.052
Crustacea	KURUMAEBI	Kuruma prawn	*Penaeus japonicus*	480.782	277.866
	KUMAEBI	Kuma prawn	*Penaeus semisulcatus*	11.133	2.989
	KOURAIEBI	Chinese prawn	*Penaeus chinensis*	3.217	3.204
	YOSHIEBI	Speckled shrimp	*Metapenaeus monoceros*	43.908	24.383
	HOKKAIEBI	Northern prawn	*Pandalus kessleri*	36	140
	TOYAMAEBI	Coonstripe shrimp	*Pandalus hypsinotus*	542	301
	ISEEBI	Japanese spiny lobster	*Panulirus japonicus*	0	10
	UCHIWAEBI	Shovel-nosed lobster	*Ibacus ciliatus*	0	

Table 4. Continued

×1000 individuals

	Specific name			Number	Number
	Japanese name	English name	Scientific name	produced	released
Crustacea	HANASAKIGANI	King crab	*Paralithodes brevipes*	127	20
	ASAHIGANI	Frog crab	*Ranina ranina*	0	
	ZUWAIGANI	Tanner crab	*Chionoecetes opilio*	0	
	KEGANI	Horsehair crab	*Erimacrus isenbeckii*	279	60
	NOKOGIRIGAZAMI	Manglobe crab	*Scylla serrata*	1.186	688
	AMIMENOKOGIRIGAZAMI	Mangrove crab	*Scylla oceanica*	2	
	GAZAMI	Swimming crab	*Portunus trituberculatus*	61.447	30.985
	TAIWANGAZAMI	Blue crab	*Portunus pelagicus*	3.356	1.752
	MOKUZUGANI	Freshwater crab	*Eriocheir japonicus*	381	
Crustacea Total	17			606.396	342.398
Shellfish	TOKOBUSHI	Japanese abalone	*Sulculus diversicolor squatilis*	627	662
	FUKUTOKOBUSHI	Japanese abalone	*Sulculus diversicolor*	2.369	1.966
	KUROAWABI	Disk abalone	*Nordotis discus*	7.525	4.640
	EZOAWABI	Yezo abalone	*Nordotis discus hannai*	20.273	17.163
	MADAKAAWABI	Giant abalone	*Nordotis madaka*	15	35
	MEGAIAWABI	Giant abalone	*Nordotis gigantea*	3.342	1.888
	SARASABATEI	Trochus shell	*Tectus niloticus maximus*	133	
	SAZAE	Spiny top shell	*Batillus cornutus*	2.488	1.971
	YAKOUGAI	Green snail	*Turbo marmoratus*	139	10
	BAI	Ivory shell	*Babylonia japonica*	133	177
	AKAGAI	Ark shell	*Scapharca broughtonii*	4.374	1.871
	IGAI	Sea mussel	*Mytilus coruscum*	35	
	HIOUGI	Scallop	*Chlamys nobilis*	50	50
	HOTATEGAI	Scallop	*Patinopecten yessoensis*	2.896.561	2.960.325
	YAMATOSHIJIMI	Freshwater clam	*Corbicula japonica*		21.309 *
	TORIGAI	Cockle	*Fulvia mutica*	1.039	159
	HIMEJAKO	Smooth giant clam	*Tridacna crosea*		42
	HAMAGURI	Hard clam	*Meretrix lusoria*	4.200	8.710 *
	CHOSENHAMAGURI	Hard clam	*Meretrix lamarckii*	3.475	3.660
	KOTAMAGAI	Rock cockle	*Gomphina melanaegis*		190 *
	ASARI	Short-neck clam	*Tapes philippinarum*	42.569	10.930.117 *
	BAKAGAI	Hen clam	*Mactra chinensis*	887	600
	EZOBAKAGAI	Hen clam	*Mactra carneopicta*	27	698
	UBAGAI	Surf clam	*Spisula sachalinensis*	8.957	9.364
	MIRUKUI	Gaper	*Tresus keenae*	395	170
	SARAGAI	Great northern tellin	*Peronidia venulosa*		192
	MATEGAI	Jack knife clam	*Solen strictus*	40	40
Shellfish Total	27			2.999.653	13.966.009 *
Others	MADAKO	Common octopus	*Octopus vulgaris*	25	41 *
	SHIRAHIGEUNI	Sea urchin	*Tripneustes gratilla*	145	85
	AKAUNI	Red sea urchin	*Pseudocentrotus depressus*	2.807	2.948
	BAFUNUNI	Sea urchin	*Hemicentrotus pulcherrimus*	922	862
	EZOBAFUNUNI	Sea urchin	*Strongylocentrotus intermedius*	56.244	54.636
	KITAMURASAKIUNI	Sea urchin	*Strongylocentrotus nudus*	11.553	15.120
	MURASAKIUNI	Purple sea urchin	*Anthocidaris crassispina*		82 *
	MANAMAKO	Sea cucumber	*Stichopus japonicus*	2.557	1.692
The others Total	8			74.253	75.466

Remarks : * Moslty natural seeds release.
0 refers to the number of seeds less than 500 individuals.

Table 5. Seed Production and Release by Operating organizations and Categories

		National	Prefectural	Municipalities and villages	Fishery cooperatives	Private business	others 1)	Total
Pisces	Production	11,665	69,032	2,689	582	2,250	9	86,227
	Release	1,257	34,944	5,303	11,873	760	14,915	69,052
Crustacea	Production	111,946	378,963	33,167	41,637	24,080	16,603	606,396
	Release	1	60,960	42,933	129,027	3,082	106,395	342,398
Shellfish	Production	0	86,719	2,576	2,908,388	631	1,339	2,999,653
	Release	0	36,350	72,832	9,001,173	7	4,855,647	13,966,009
Others	Production	25	25,429	25,543	21,760	30	1,466	74,253
	Release	0	631	352	73,752	0	731	75,466

Note: 1) others include the Fisheries Development Council and other bodies

Survival rate (%)

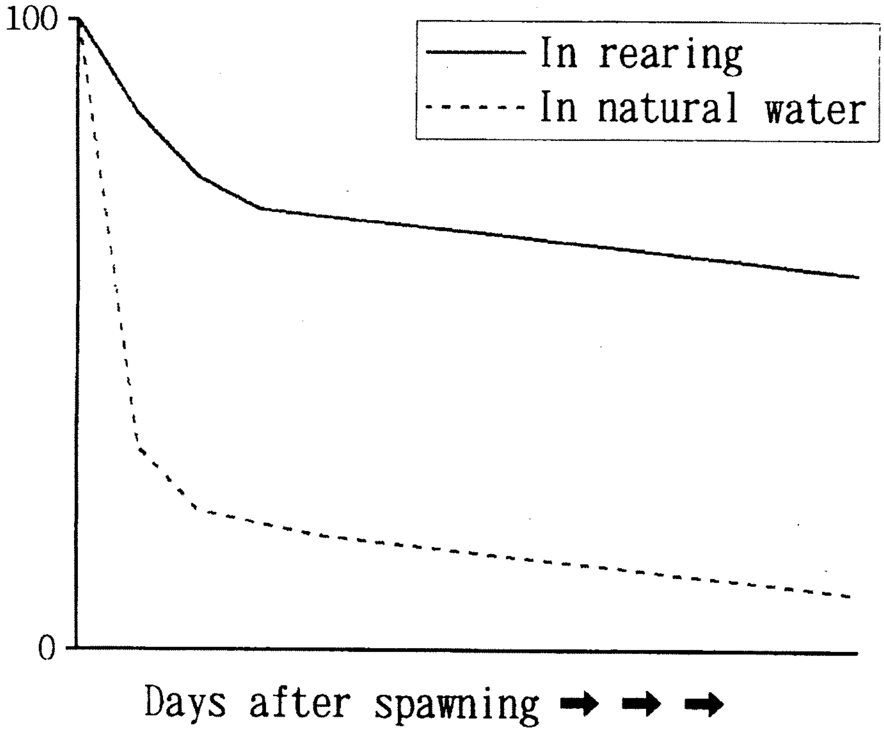


Figure 1. Survival-Rate difference between rearing water and natural Water

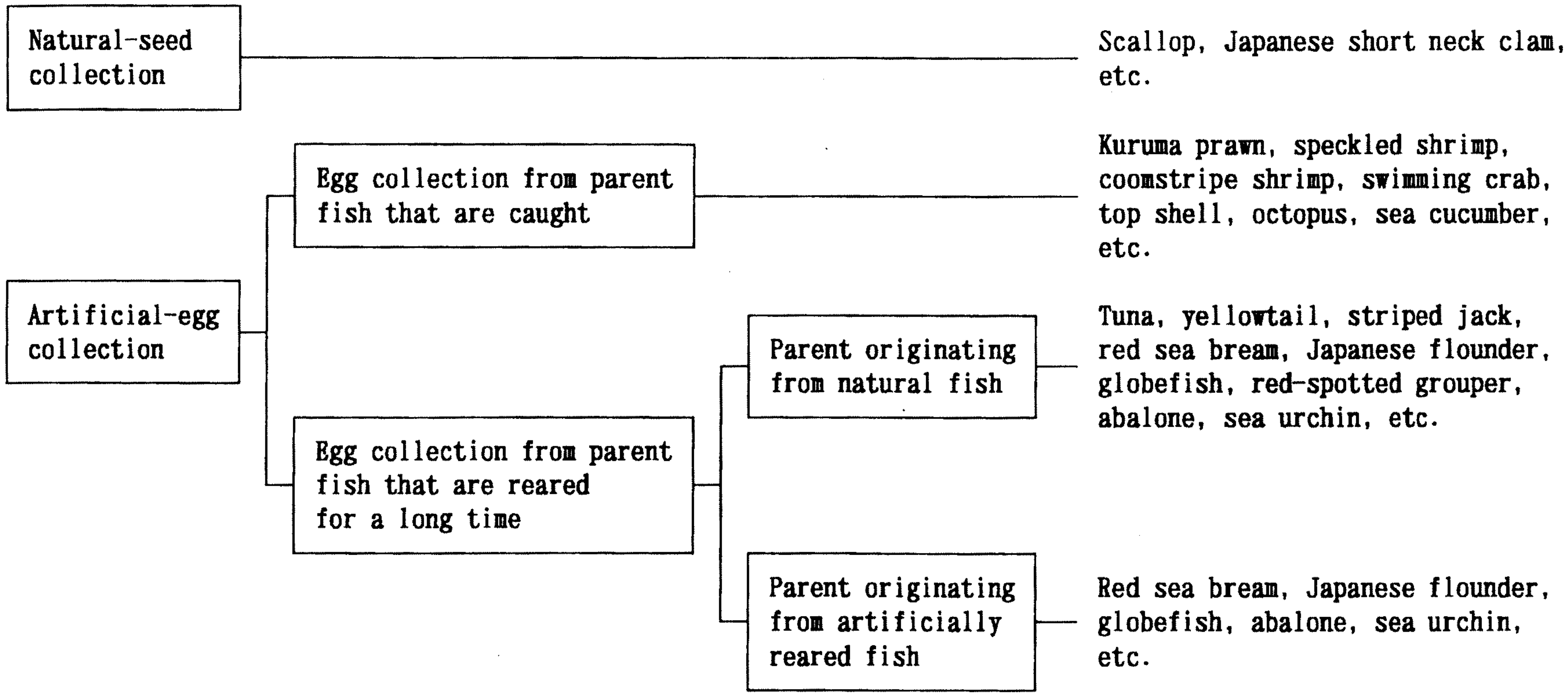
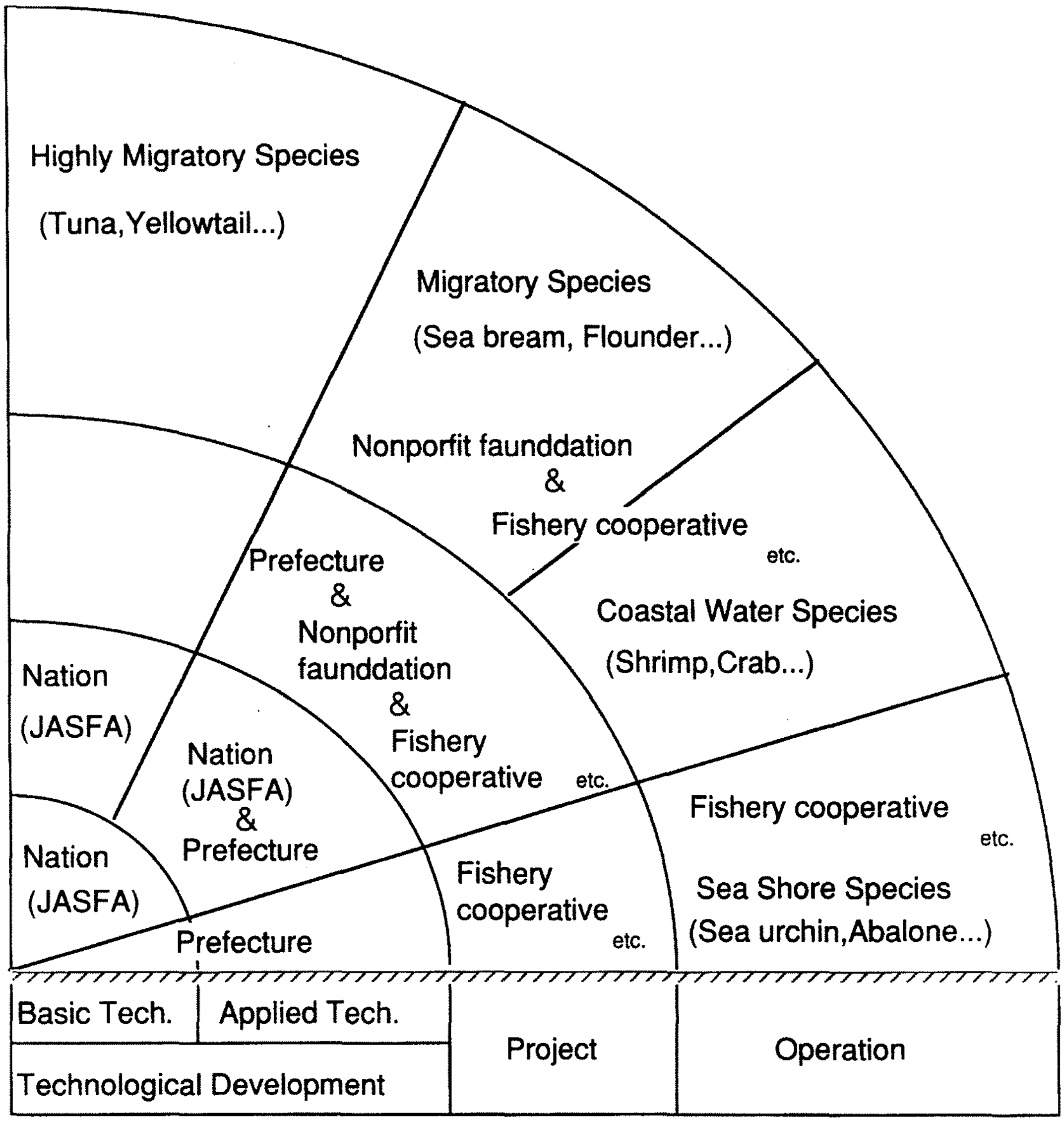


Figure 2. Difference between Egg Collection and Natural-Seed Collection



JASFA=Japan Sea-Farming Association

Figure 3. Share of roles in sea-farming

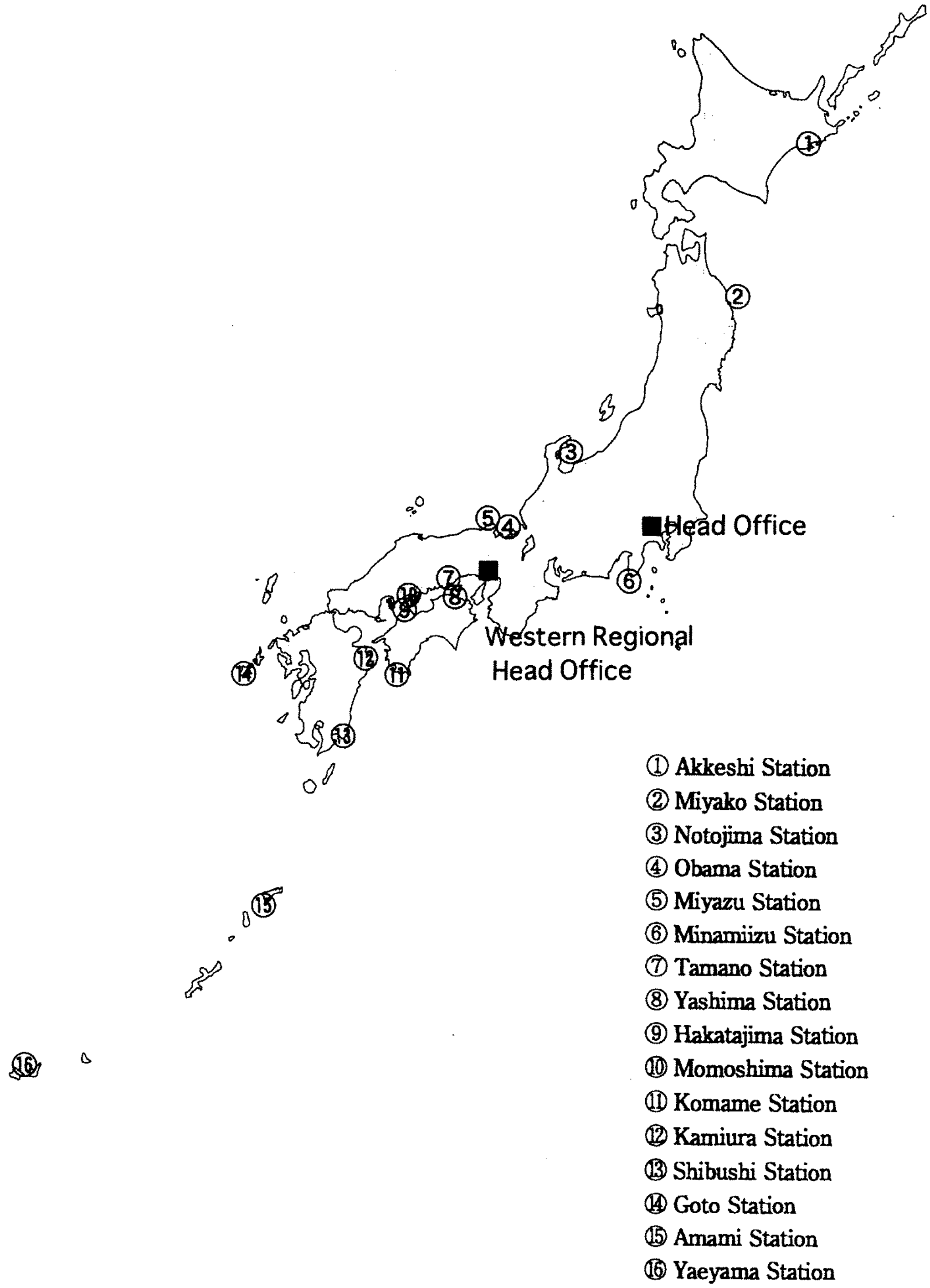


Figure 4. National (Japan Sea-Farming Association) Center

Contribution of Hatchery Enhancement and Comprehensive Fishery Resource Management: from Japanese Experience

Shuichi Kitada
Department of Aquatic Biosciences
Tokyo University of Fisheries
Konan, Minato-ku, 108 Japan

Presented to
The International Symposium on Marine Ranching
Kanazawa, Ishikawa Prefecture, Japan
13-16 September 1996

The history of hatchery enhancement began in the latter half of the 1870s. The main targets of hatchery enhancement were salmon and cod. The hatchery release of cod, which had been conducted principally in the United States and Norway, gives us important lessons concerning hatchery enhancement.

In the United States the hatchery release of cod had been conducted for about 70 years from 1885. It was officially decided, however, that the stocking effectiveness was inconclusive. As a result the hatcheries were closed and releases ended in 1952 (Solemdal *et al.* 1984). In Norway the hatchery release of cod was conducted for about 90 years from 1884 to 1971. The stocking effectiveness of this period, however, has not been established (Solemdal *et al.* 1984). The causes of such failures are (a) the size at release was inappropriate (hatched larvae were released), and (b) because of the releases without any tags and marks, stocking effectiveness could not be verified. Several papers (e.g., Bartley 1995, Blankenship and Leber 1995) pointed out these reasons for failure. The causes have thus been commonly recognized.

For the last ten to twenty years, seed-production techniques have been remarkably developed. It has become possible to release large seeds of salmon and other species. The marking techniques have enabled quantitative surveys. In the United States, a responsible approach to marine stock enhancement has been made to avoid repeating past failures (Blankenship and Leber 1996).

Japan's history of hatchery-enhancement began in 1876 when Akekiyo Sekizawa after studying hatchery technique in the United States induced the spawning of chum salmon in Ibaraki Prefecture's Nakagawa River. The hatchery-enhancement of chum salmon has been promoted by the Japanese government, as will be seen below. The hatchery-enhancement of scallops has also been conducted in Hokkaido from the latter half of the 1950s. Apart from these projects, hatchery-enhancement programs called "Saibai-Gyogyo" have been conducted since 1963 by the Japanese government targeting species other than those that travel up rivers. The development of seed-production techniques has been promoted. Stocking effectiveness has already been verified for some of the species that can be released in large quantities. In accordance with the recognition of stocking effectiveness, the concept of comprehensive resource management including hatchery enhancement has been gradually formulated.

It is expected that hatchery enhancement will further contribute to the stabilization of resources as well as to the increase of fishery production. In addition, hatchery enhancement raises the consciousness of commercial fishermen toward resource management. A new direction is provided for resource management, which will be to manage the wild stock and the hatchery stock in a comprehensive manner.

For recent years, recreational fishermen's total catches sometimes surpassed those of commercial fishermen. It is therefore difficult for commercial fishermen by themselves to preserve resources. It is desired that commercial and recreational fishermen will take common responsibilities for resource preservation by bearing the expenses of seed growth in proportion to the benefits they will receive. It is therefore important to estimate how many released seeds will be recovered as harvest, as well as to evaluate the profitability of hatchery enhancement against seed-cultivation costs.

In the promotion of hatchery enhancement, it is essential to know the recovered amount of the seeds released. Many recovery surveys have been conducted. There is, however, no comprehensive review focusing on the effectiveness of Japan's hatchery- enhancement programs. This paper therefore aims at (a) analyzing the present situations of Japan's hatchery-enhancement programs in terms of stocking effectiveness, and (b) considering the future direction of hatchery enhancement. This paper consists of nine sections.

Section 1 outlines the present situation of hatchery enhancement programs. Section 2 examines the chum salmon and scallops that are released in vast quantities, and considers the results of large-scale release. Section 3 evaluates the release scales of the main species in comparison with the number of landings, and ranks each species according to the magnitude of the stocking effectiveness. Section 4 gives examples of highly migratory red sea bream and flounder, and examines the actual degrees of stocking effectiveness. Section 5 reviews the evaluating methods for stocking effectiveness.

Section 6 describes the relationship between recreational fishing and hatchery enhancement. Section 7 reveals the actual situations concerning the resource management promoted in conjunction with hatchery enhancement, introduces hatchery-enhancement programs conducted at fishermen's expense, and considers hatchery enhancement and fishermen's consciousness towards resource management. Section 8 clarifies challenges in hatchery-enhancement programs. Finally, as the conclusion to this paper, Section 9 describes the future direction of hatchery enhancement.

1 Present Seed-Release Situation

Seed production is mainly conducted in 16 National Sea Farming Centers as well as in 57 Prefectural Sea Farming Centers. Seeds are also produced in municipal facilities as well as in those of the Federation of Fishermen's Cooperative Associations and the facilities of each fishermen's association. For the statistics on seed production and release, the Japan Sea-Farming Association (JASFA) tabulates and publishes the results every year.

According to the statistics, the seeds of 74 species were released in 1995 (34 fish species, 12 crustacean species, 25 shellfish species, and three sea-urchin and sea-cucumber species). Many of these species are at the technical development stage but some can already be produced en masse and are released in large quantities. For the annual scale of release, that of scallops is the largest (3 billion); followed by kuruma prawns (300 million); sea urchins (70 million); and by swimming crabs, abalones, red sea bream, and flounder (about 20 to 30 million in total). In recent years the number of seeds released has been stabilized for scallops, kuruma prawns, swimming crabs, abalones, and red sea bream; while the number has been remarkably increased for flounder and sea urchins (Fig. 1).

The release of salmon has been conducted as a separate project from Saibai-Gyogyo. The salmon seen in Japan are chum salmon, pink salmon, and masu salmon. Besides these native species, sockeye salmon are also released. The release scale has been stabilized in recent years and about 2 billion chum salmon are annually released. For other kinds of salmon, about 100 million pink salmon, about 20 million masu salmon, and about 800,000 sockeye salmon were released in 1994. Compared with other species, the release scales of scallops and chum salmon are overwhelmingly large. Let us first look at the results of the large-scale release of chum salmon and scallops.

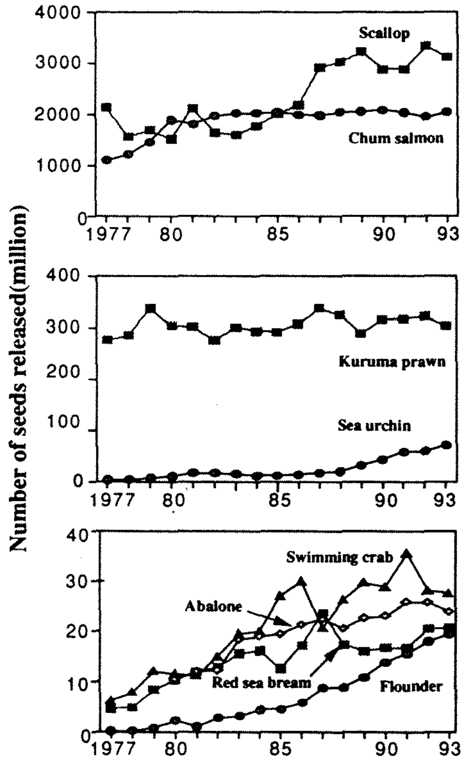


Fig. 1: Changes in the number of seeds released for representative species

2 Stocking Effectiveness of Chum Salmon and Scallops

2.1 Chum salmon

In Japan, chum salmon that have returned for reproduction are partly caught by coastal trap nets. The remainder go upriver. In principle, chum salmon entering the river are all caught and reproduction is by artificial hatching. According to the data on long-term shifts in the number of adults returned and the released juveniles of chum salmon in Hokkaido (Kaeriyama 1989, Fig. 2), the number of returned adults alternated between 2 million and 10 million until the first half of the nineties, when the released quantities were rather small. Despite hatchery enhancement, the number of returned adults had shifted at a low level of between 3 million and 5 million until the beginning of the seventies. Because it was in 1952 that the national hatchery was opened for salmon and trout, it can be surmised that the hatchery-enhancement programs for chum salmon came into stride in about 1952. Even after this period, however, juveniles continued to be released soon after the absorption of the yolk sacs, and no remarkable stocking effectiveness was observed for a long time.

A turning point occurred in the sixties. Researchers began to pay attention to the reproduction process of wild chum salmon. It was noted that an upwelling stream ran through the spawning location and that the seaward migration took place during the snow-melt period. In 1962, trial feeding was done in Hokkaido. Because of the higher temperature of the upwelling stream compared with the river,

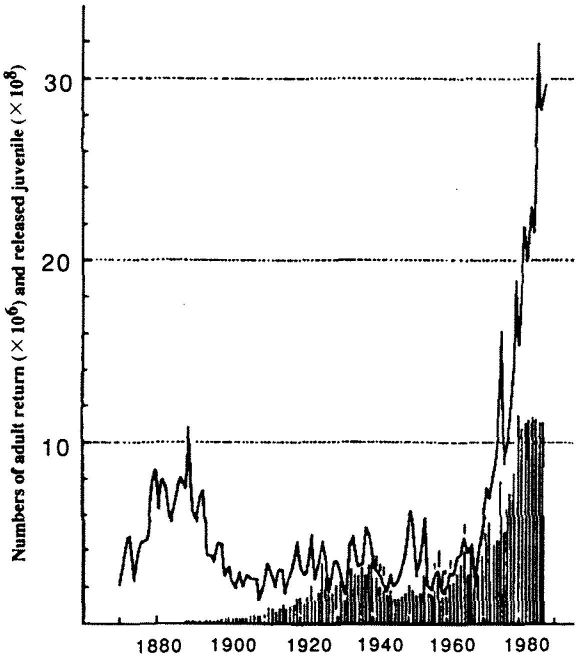


Fig. 2: Numbers of adult returns (solid line) and released juveniles (bar histogram) of chum salmon in Hokkaido, 1870-1987 (Kaeriyama 1989)

hatching was expedited, and because of the feeding the release season was delayed. Thus occurred a reproduction process very similar to that in nature.

The Hokkaido Salmon Hatchery took note of this technique and proposed to conduct a nationwide experiment. Accordingly, research on the improvement of the chum salmon return rate was conducted as a research project of the Ministry of Agriculture, Forestry, and Fisheries. Thanks to this project, techniques regarding feeding and proper-seasonal releasing (Kobayashi 1980) were established (personal communication from Akira Suda) and the present techniques were developed. For details of the development of the technique, please refer to the document written by Sato(1986).

Participating in the research project were not only the persons directly related to the hatchery-enhancement of chum salmon, but also researchers in the National Fisheries Research Institutes and in universities. It is reported that the exchange of wide-ranging scientific opinions contributed substantially to the improvement of the return rate.

For the secular changes in the number of returned chum salmon adults, the number suddenly began to increase in around 1975 (Fig. 2). Fig. 3 shows the simple return rates in Hokkaido as well as in Honshu. The return rate was calculated by dividing the number of adults returned after four years from release, by the number of released juveniles. The return rates began to rise around 1968 in Hokkaido and around 1975 in Honshu. For recent years the return rates have been stabilized at around 4% in Hokkaido and at around 2% in Honshu. It can be seen from Fig. 3 that feeding and releasing in the proper season have improved the return rates. Although it took about 100 years to develop a new technique based on the lessons learned from past failures, it has finally been proven that fishery resources can be created by the effective use of hatchery-enhancement techniques.

The seed-production cost per chum salmon is about $0.05 (personal communication from Masahide Kaeriyama, Hokkaido Salmon Hatchery). The seed-production cost for 2 billion chum salmon is there-

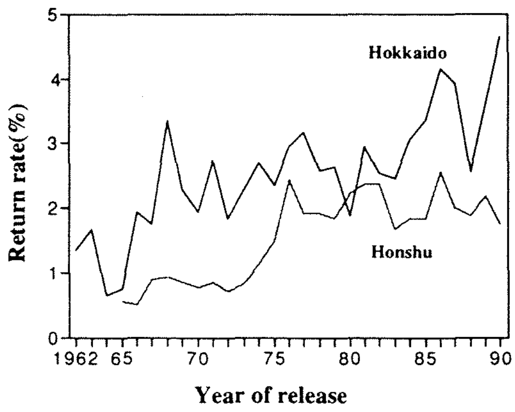


Fig. 3: Changes in the return rate of chum salmon (Data: Kaeriyama 1994)

fore \$100 million. The annual total cash value of landings varies between \$500 million to \$800 million. Thus seed production is profitable despite the recent decline in fish prices. The cash value of landing per released seed is \$0.25 to \$0.4, which means that the unit-seed-production cost has been recovered by five to eight times.

If a linear model were applied having the number of seeds released as the independent variable and the number of adults returned after four years from the release as the response variable, the coefficients of determination are 0.77 in Hokkaido (Fig. 4) and 0.95 in Honshu (Fig. 5). The coefficients of determination show that 95% of the changes in the number of adults returned can be explained by the number of seeds released in Honshu, while only 77% of the changes in the number of adults returned can be explained by the number of seeds released in Hokkaido.

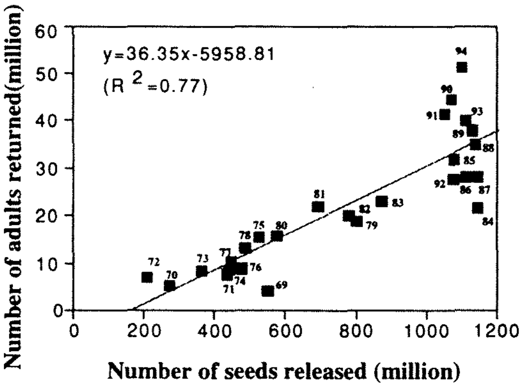


Fig. 4: Relationship between the numbers of seeds released and adults returned of chum salmon in Hokkaido. The numbers in the figure refer to the years of return (Data: Kaeriyama 1994)

The number of adults returned by year have exceeded the expected value of the linear model (calculated as above) every year except for 1992 (27.55 million) since 1989 (Fig. 4). The fluctuation in the number of adults returned shows the variability of the return rate, which represents the survival rate from release to return. In Hokkaido the survival rate has recently been improved. For the number of adults, however, returned in Honshu, there have been random variations relating to the linear model since 1989. The survival rate has not been recently improved. The recent improvement in the survival rate of chum salmon is a phenomenon only observed in the release group in Hokkaido.

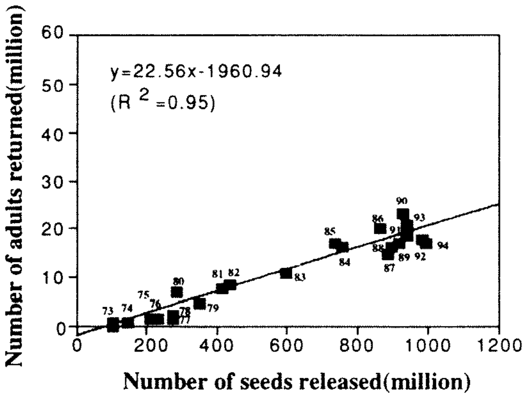


Fig. 5: Relationship between the numbers of seeds released and adults returned of chum salmon in Honshu. The numbers in the figure refer to the years of return (Data: Kaeriyama 1994)

In the North Pacific the catches of plankton feeders such as pink salmon, chum salmon, and sockeye salmon have increased remarkably. Based on this, it is insisted that the North Pacific environment has been improved for the habitation of salmon species (Kaeriyama 1996). The fact that the number of adults returned has risen along with the increase of the number of fish released attests to the improved environment. The return rate, however, has been generally stabilized for the past 20 years in Honshu (Fig. 3). The improved environment by itself cannot explain the improvement in the return rate in Hokkaido.

Furthermore, the change in the fishing intensity in the open sea is often regarded as another cause for the improvement of the return rate. In the North Pacific's open sea, the fishing of chum salmon was ended in 1992 and has been completely prohibited since 1993. For the changes in the number of adults returned in Hokkaido, the return rate was definitely high in 1993 and 1994. Attention must be paid, however, to the fact that the number of adults returned was large in 1990 and 1991, even though fishing was conducted in the open sea and the number of fish released was smaller than in 1993 (Fig. 4). Moreover, based on the data derived in Honshu, it is difficult to explain the improvement of the return rate by the fishing prohibition in the open sea (Fig. 5).

The recent improvement in the return rate of chum salmon in Hokkaido cannot be explained solely by the improved environment and fishing prohibition in the open sea. It would be reasonable to assume that the causes for the phenomenon are peculiar to Hokkaido. The average size of the release of chum salmon has been increased (personal communication from Masahide Kaeriyama), which suggests that the greater size of the release has contributed to the improved return rate.

Conversely, it is pointed out that the weights by ages of the returned chum salmon have diminished since 1975, and that it takes more years for the salmon to reach maturity (Kaeriyama 1996). Judging from this as well as from the fact that the observed number of adults returned has exceeded the expected values, we can assume the following. The density effect in the ocean has adversely influenced individual growth but has not led to lower survival rates. For the delaying of individual growth, similar examples have been reported (Kaeriyama 1996) for sockeye salmon in Bristol Bay (Rogers and Ruggerone 1993) as well as for pink salmon in Prince William Sound (Thomas and Mathisen 1993). Along with the success of the large-scale release of seeds, the importance of the carrying capacity has been specifically recognized. Examination of the release plans for salmon in the North Pacific has become an international issue.

Release plans considering the conservation of genetic diversity have also been discussed. In 1994 the total number of adults returned reached about 68.70 million, and there exist several problems including the price decline. To tackle such problems, review should be conducted of the release plans.

2.2 Scallop

The scallop catch in weight in Japan is about 200,000 tons. Almost of them are produced by stocking in Hokkaido. In addition to this, about 200,000 tons of scallops are produced by aquaculture in Hokkaido as well as in Aomori, Iwate and Miyagi Prefectures.

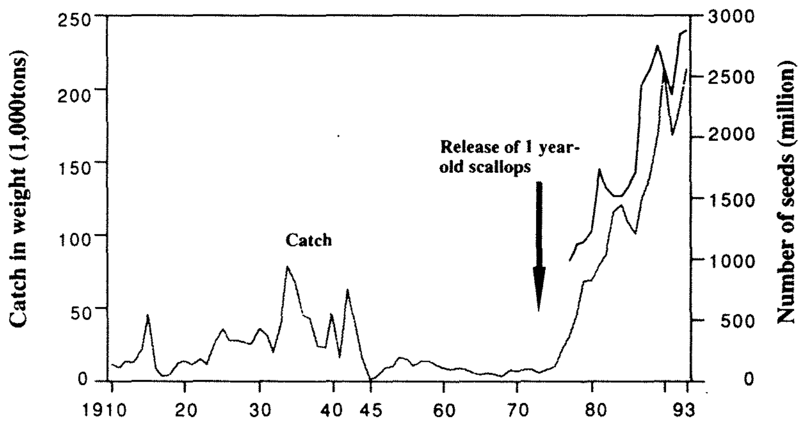


Fig. 6: Changes in catches and the number of scallop seeds released in Hokkaido

The catch of scallops in Hokkaido repeatedly shifted upwards to about 80,000 tons during the period of wild stock utilization. Since 1950, however, the catch remained small for a long time because of poor production of wild stock. During this period, fishing of scallops aged two years or younger was prohibited to protect spawning adults, and juvenile scallops were released (Nishihama 1995). No dominant year class, however, was produced and the catch failed to increase (Fig. 6). Such resource-management efforts had been continued for about 20 years, but the resources failed to increase. For the long-term changes in catch, the decline around 1917 was soon recovered. From the changes in catch, it is indicated that the annual number of recruited scallops was very unstable and that the survival rate of larvae shifted a great deal each year. As the reasons for the long-term unfavorable catch since 1950, the survival rate of larvae must have been low because of the unsuitable environment.

In the seventies the release of year-old scallops with 3.5-cm shell lengths after wintering was begun by the fishermen's cooperative associations. The catch dramatically increased (Fig. 6). To revitalize the extremely dull scallop fishing, the fishermen's cooperative associations themselves released the larvae. As seeds, natural larvae were collected ("wild seed-collecting"). The number of seeds released was favorably increased mainly because Saroma Lake became the supply source with its abundant larvae production, as well as because the seed collectors and the breeding nets were improved and popularized (Nishihama 1995).

For scallops, it was decided to release large seeds in May before the rise of water temperature, to prevent lowering of the survival rate. Another consideration for the survival rate is implementa-

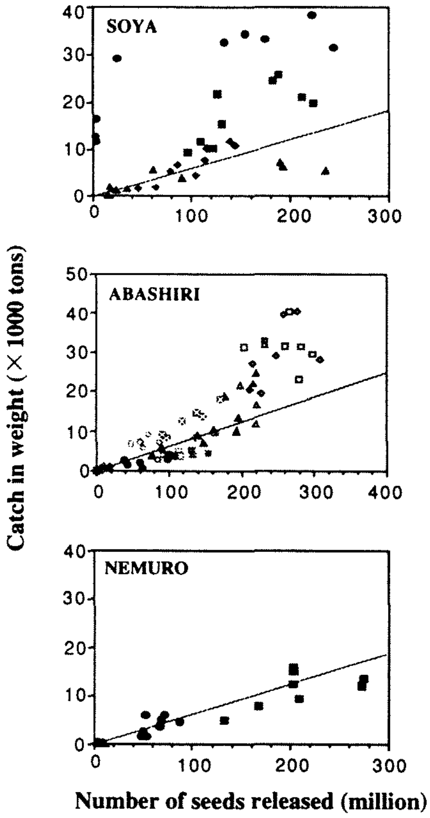


Fig. 7: Relationship between the numbers of seeds released and catches after three years of scallop for every fishermen's association in three regions of Hokkaido. The lines show the expected yield per release when the return rates is assumed to be 0.3 (Data: Hokkaido Prefectural Government)

tion of the fishing-ground rotating system. For the release of scallops, this rotating system is always adopted (personal communication from Hiroaki Fujishima, Hokkaido prefectural government). The fishing ground is generally divided into four areas in the system. Prerelease, predators (starfish) are removed by the use of dredge nets. Starfish are removed in large numbers, with a removal target of 10 tons per commercial fisherman. The seeds are then released every year by rotation in each of the four areas. Just after three years from the release, all the scallops are caught by dredge nets. This system brings about annual harvests while achieving three-year prohibition of fishing.

Fig. 7 plots the relationship between the number of seeds released and the catches after three years by fishermen's associations. The lines in Fig. 7 show the expected yield per release when the return rate is assumed to be 0.3 (Nishihama 1995), and the average weight of the individual catch is assumed to be 200 grams. Fig. 7 shows that the recovery rates differ considerably among fishermen's associations, and that some recovery rates far exceed 0.3. For scallops, every released seed is collected. It would therefore be appropriate to assume an exploitation rate of 1 for every fishermen's association. Changes in the recovery rate therefore depend on changes in the survival rate. The released seeds are year-old scallops after wintering. Stable survival rates can thus be expected. It is therefore difficult to explain the remarkable changes in the recovery rate solely by the changes in the survival rate of the released seeds. It would be reasonable to presume that the catches consist of the survived released seeds plus scallops naturally reproduced. The rotating system protects parent scallops, and the reproduction effect is incremented. The variations observed among the fishermen's associations in Fig. 7 indicate that the magnitude of juvenile recruitment differs by location.

The seed-production cost of scallops is \$0.029 per scallop of 3.5-cm size (Nishihama 1995). The cost of release is calculated by multiplying this unit cost by the number of seeds released. Fig. 8 shows the relationship between the cost of release and the cash value of landings for four fishermen's associations in the Soya region from 1983 to 1994. The costs of managing the harvest and the fishing ground are not considered, and the line in Fig. 8 shows the balancing limit of the cost and the cash value of landings. Based on Fig. 7 and Fig. 8, it can be surmised that the reproduction effect of the seeds released plays an important role in favorable-reproductive environments, while fishery production is maintained by the release of seeds in unfavorable-reproductive environments.

The total seed-production cost in Hokkaido amounts to \$87 million by multiplying 3 billion (seeds) by \$0.029. The cash value of landings amounts to \$200 million by multiplying 200,000 tons of landings by the assumed unit cost of \$1 per kilogram. The recovery rates considerably differ among the fishermen's associations, but as a whole, the stock enhancement of scallops is economically successful. The cash value of landing per released seed is \$0.067, which means that the unit seed-production cost has been recovered by 2.3 times.

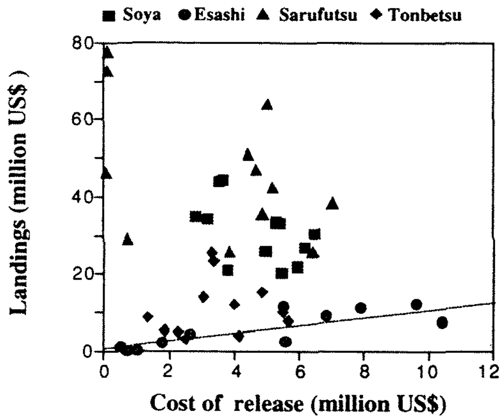


Fig. 8: Relationship between the cost of release and the cash value of landings for fishermen's associations in the Soya region 1983-1994 (Data: Hokkaido Prefectural Government)

3 Evaluation of the Release Scale Based on the Stocking-Impact Index

3.1 Stocking-impacts of representative species

As mentioned above, chum-salmon and scallop stock enhancement has been successful. One of the stocking features for these species is their large release scale. Have sufficient release scales been achieved for other species? This section will rate the stocking effectiveness of each species based on the release scale and the actual recovery situations.

In examining the influence of stock enhancement on wild stock, it is important to compare the number of seeds released with the amount of wild stock. For this comparison let us calculate the stocking-impact magnitude based on the annual number of seeds released and the catch in weight.

Table 1: Number of seeds released and Stocking-Impact Index(SII) of representative species (1993 data)

Species	Number of seeds released: A (×1,000)	Catch in weight (ton)	Individual weight(g)	Estimated catch in number: B (×1,000)	SII (A/B)
Chum salmon	2,052,090	204,439	3,300	61,951	33.12
Kuruma prawn	304,235	2,263	30	75,433	4.03
Scallop	3,123,771	223,844	200	1,119,220	2.79
Abalone	23,911	2,353	200	11,765	2.03
Swimming crab	27,562	2,958	200	14,790	1.86
Flounder	19,431	6,464	500	12,928	1.50
Red sea bream	20,610	14,160	500	28,320	0.73
Sea urchin	71,484	13,713	30	457,100	0.16

Nonaka (1984) calculated the number of released seeds per unit landing weight as a index. Suda (1987) proposed a index, which is obtained by dividing the number of seeds released by the number of natural recruitment (Suda 1991). Here taking individual weights in landings into account and for simplified calculation, the stocking-impact index (SII) is defined by

$$\mathrm{SII} = \frac{S}{C_n},$$

where S refers to the number of seeds released and C_n means the number of landings. SII thus indicates how many times of seeds have been released against the number of landings. This index shows the relative scale of the number of seeds released against the fishing resources.

Data on catch in weight C_w can be obtained from the statistics. It is therefore possible to estimate SII if the average individual weight of the catch $\bar{w}$ were revealed. The estimator of SII is given by

$$\widehat{\mathrm{SII}} = \left(\frac{S}{C_w}\right)\bar{w}.$$

According to the average individual weights of the catches shown in Table 1, the Stocking-Impact Indices are 33.1 for chum salmon and 2.8 for scallops. The Stocking-Impact Indices of kuruma prawns, abalones, red sea bream, and flounder are almost the same as for scallops (Table 1).

Table 1 shows the average Stocking-Impact Indices calculated based on the national number of seeds released and catch in weight. There are some prefectures where these species are not released, so it is necessary to check the values by prefecture as mentioned below. It is surprising, however, that many of the species have already achieved almost the same Stocking-Impact Indices as have scallops.

Fig. 9 plots the catches and Stocking-Impact Indices by prefecture. According to Fig. 9, the SII tends to be high in prefectures with smaller catches, and tends to be low in prefectures with larger catches regardless of the species. Furthermore, there are large variations in the Stocking-Impact Indices among prefectures even with similar catch levels. The seed-production quantities also differ markedly among prefectures. These facts indicate that stocking effectiveness differs substantially among species as well as among prefectures.

Fig. 10 shows the mean values of catches and Stocking-Impact Indices in Fig. 9. According to Fig. 10, the catch is large and the SII is high for chum salmon. For scallops, the catch is almost

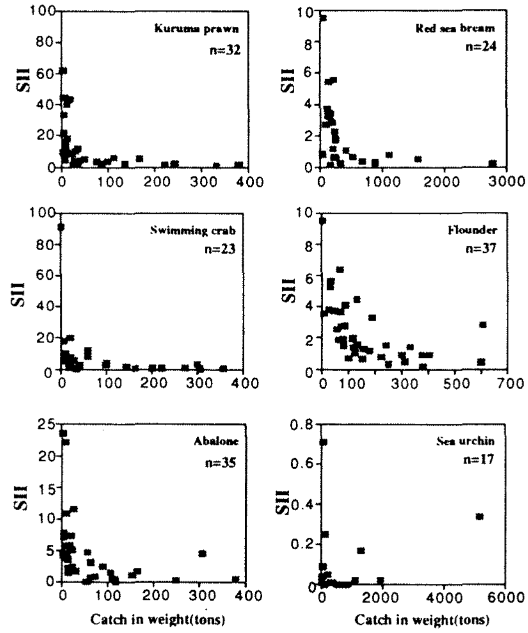


Fig. 9: Representative-species relationship between catches and Stocking-Impact Indeces by prefectures

the same as for chum salmon and reaches 200,000 tons but the SII is low. This is because large-scale release is conducted for chum salmon to secure yields despite the low survival rate, while small-scale release is efficiently conducted for scallops by raising the survival rate by using the fishing ground rotating system. In spite of the differences, both of the species show remarkable stocking effectiveness, as already mentioned. Accordingly, the stocking effectiveness of chum salmon and scallops is ranked as A.

The average catches per prefecture are a shade less than 100 tons for abalones and several hundred tons for red sea bream and flounder. The Stocking-Impact Indices are 4.7, 2.2, and 2.4, respectively. For the stocking impacts of these species, the level is almost the same as for scallops. Stocking effectiveness can be obtained if the survival rates of the released seeds remain high. Actually, however, the recovery rates differ by prefecture. It is reported that the recovery rates range from 8% to 51% for abalones (Kojima 1995), 8% to 12% for red sea bream (Imai 1996), and 8% to 31% for flounder (Fujita and Mizuno 1990; Fujita 1995). The Stocking-Impact Indices also considerably differ among prefectures as already mentioned. For these species the recovery rates can be appreciated, but there exists large variance in the Stocking-Impact Indices and recovery rates among prefectures. Accordingly, these species are ranked here as B.

For kuruma prawns and swimming crabs, the average catch per prefecture is about 100 tons. The Stocking-Impact Indices are 12.6 for kuruma prawns and 8.9 for swimming crabs, which are higher than for scallops, abalones, red sea bream, and flounder. To crustaceans, however, it has been impossible to apply proper tags and marks because of their molting habit. Precise estimation of the stocking effectiveness has thus been difficult. Accordingly, these species are ranked here as C. For sea urchins, the average catch per prefecture is about 900 tons. The stocking-impact index, however, is low at 0.1 because the individual weights are minimal and the number of landings are large. Because of the shortage in the number of seeds released, the stocking effectiveness of sea urchins is ranked as D.

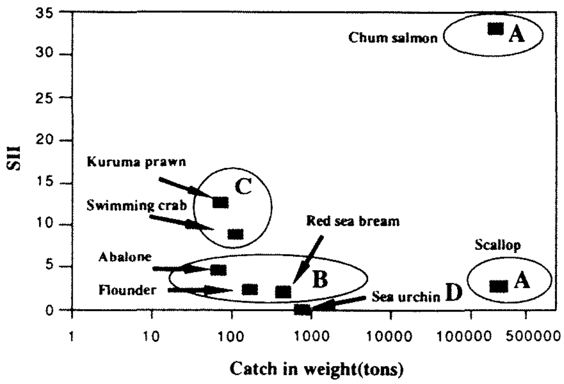


Fig. 10: Relationship between mean catches and Stocking-Impact Indeces for representative species

3.2 Stocking-Impact Indices and Ratios of Released Fish in the landings (RRF) of red sea bream and flounder

There are three species ranked as B following chum salmon and scallops in Rank A. Among these Rank B species that are expected to have high stocking effectiveness if the survival rates of the seeds released remain high, relatively abundant data are available for sea bream and flounder. Accordingly, let us examine the relationship between the SII and the RRF of these two species. The RRF indicates the relative magnitude of release and can be regarded as a kind of SII observed value.

In 1993, red sea bream were released in 24 prefectures, and flounder in 37 prefectures. For the relationship between the SII and the RRF of red sea bream, the RRF rises in accordance with the rise of the SII, although relatively large variations are observed (Fig. 11). For flounder the variation in the RRF is more remarkable than for red sea bream. The survival rates are surmised to be considerably different among prefectures (Fig. 12). Except for several prefectures, however, the RRF of flounder rises in accordance with the rise of the SII. As in the case of red sea bream, the RRF tends to be high in prefectures with high Stocking-Impact Indices (Fig. 12). In the next section, we will examine the case of red sea bream in Kagoshima Bay, and flounder in Fukushima Prefecture.

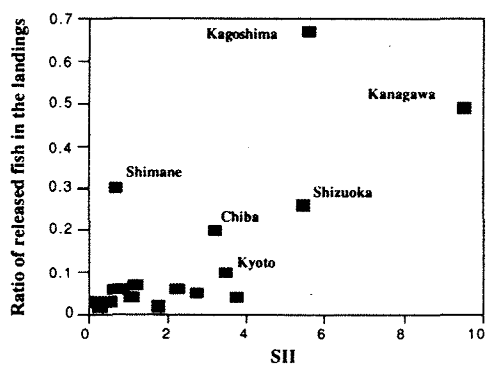


Fig. 11: Relation between Stocking-Impact Indeces and ratios of released fish in the commercial landings of red sea bream by prefectures

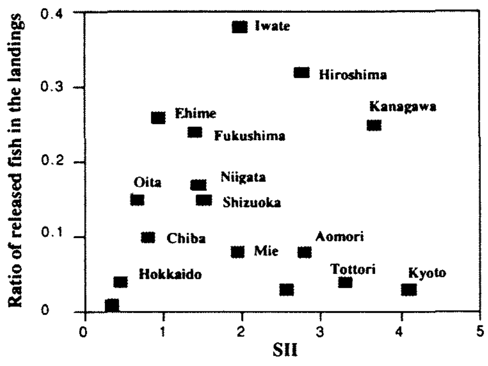


Fig. 12: Relation between Stocking-Impact Indices and ratios of released fish in the commercial landings of flounder by prefectures

4 Stocking Effectiveness of Red Seabream and Flounder

4.1 Red sea bream in Kagoshima Bay

The first fish-market survey on landings was conducted at Kagoshima Bay, targeting red sea bream, to determine the yield and recovery rate of the released seeds. At Kagoshima Bay, stock enhancement of red sea bream has been conducted since 1974. Kagoshima Bay is a closed bay. It is 20 kilometers from east to west and 80 kilometers from south to north. The inner portion is 243 square kilometers and the entrance portion is 886 square kilometers (Shiihara 1986). About 80% of the red sea bream caught within the bay are landed by the Kagoshima City Fishermen's Cooperative Association. Kagoshima Prefecture Fisheries Experimental Station performed a direct survey of the landings.

In the survey, anchor tags were attached to 20% to 30% of the seeds released. The recovery rates were estimated based on the results of the fish-market survey. There were no problems concerning the shedding of the anchor tags because the tags left traces even if they had become detached. Regarding the tag reporting rate, the survey was conducted by the staff of the fisheries experimental station. A 100% reporting rate was obtained. In the recent survey, however, anchor tags were not used. Instead the nostril feature of red sea bream's artificial seeds (nostrils are joined) was used as a tag. In another survey conducted in parallel with the above survey, the tag-reporting rate from the fishermen was estimated to be about 1% (Shiihara 1986). This illustrated the difficulty of estimating stocking effectiveness based on recapture reporting.

In the market survey conducted in six fish markets from 1989 to 1991, 27,747 to 49,775 red sea bream were annually surveyed (reference materials of Kagoshima Prefecture Fisheries Experimental Station). Such numbers are equal to about 41 to 77 tons in weight. For the ratio of the released red sea bream in the commercial landings (RRF), it is very high (0.64 to 0.83) in the inner part of the bay. In the central part of the bay, about 30% of the landings are released fish. For the entire bay, from half to three-fourths of the landings are of released fish. In outside the bay, however, the ratio of the released fish is very small, which shows that most of the released fish are caught within the bay (Table 2).

The numbers of landings at ages in the inner part of the bay indicate that high stocking effectiveness occurs even in the case of older fish (Fig. 13). Fig. 13 shows that the stocking effectiveness is remarkable in the inner part of the bay, which is also demonstrated in the secular changes in catch. The number of seeds released exceeded 1 million in 1981. More than 1 million have been released to date. The average

Table 2: Ratio of released red sea bream in the landings from Kagoshima Bay (Data: Kagoshima Prefecture Fisheries Experimental Station)

	Aug. 89 ~ Mar. 90	Apr. 90 ~ Mar. 91	Apr. 91 ~ Mar.92
Inner part of the bay	0.64	0.83	0.75
Central part of the bay	0.26	0.34	0.26
Total of the bay	0.54	0.74	0.67
Outside of the bay	0.03	0.07	0.06
Sample size	27,747	49,775	30,518

size of the seeds released is 60 mm or longer (total length). For the inner part of the bay, the catch in weight was 40 tons in 1974. The catch, however, has recently exceeded 100 tons in accordance with the increase in the number of seeds released. For the central part of the bay, however, the rise in the catch has been low, reflecting the differences in the RRF (Fig. 14).

The cash value of landings of released red sea bream in Kagoshima Bay in 1989 is estimated at $700,000. The annual number of seeds released is about 1 million, so the value of landing-per-seed released is $0.7. The unit-seed-production cost is about $0.27 (Kagoshima Prefecture Fisheries Experimental Station). The cost has thus been recovered by 2.6 times.

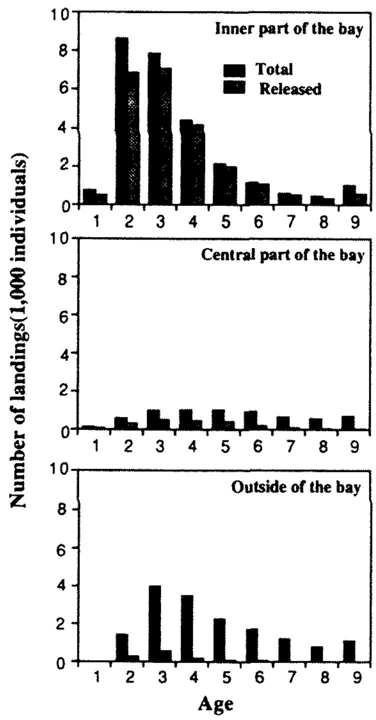


Fig. 13: Total number of landings and the number of released red sea bream landed from Kagoshima Bay in 1990 (Data: Kagoshima Prefecture Fisheries Experimental Station)

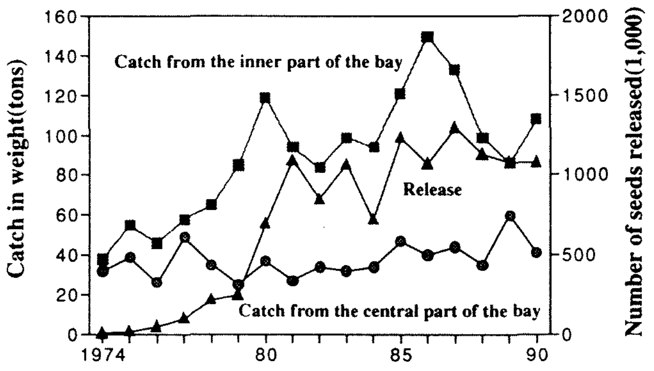


Fig. 14: Changes in catch and the number of red sea bream seeds released in Kagoshima Bay(Data:Kagoshima Prefecture Fisheries Experimental Station)

Table 3: Estimates of the total return of released flounder in Fukushima Prefecture (Fujita and Mizuno 1990, Fujita 1995)

Year class	Number of seeds released(A)	Total length (cm)	Number of returned fish	Return rate	Total income (US$) (B)	B/A (US$)
1987	246,300	7~10	40,000	0.16	831,500	3.38
1988	336,000	7	97,000	0.29	993,300	2.96
1989	227,000	10	67,000	0.30	816,900	3.60
1990	392,000	8	76,000	0.19	866,200	2.21
1991	428,000	7	34,000	0.08	715,400	1.67
1992	428,000	8	44,000	0.10	1,024,600	2.39
1993	328,000	8	59,000	0.18	1,122,200	3.42

4.2 Cases of flounder in Fukushima Prefecture

Kagoshima Bay is an enclosed bay and the survey could be conducted relatively easily. Because of the results obtained from the Kagoshima Bay survey, the reliability of market surveys began to be recognized and have become widely accepted.

In Fukushima Prefecture, in advance of other prefectures, market surveys on the landings have been aggressively conducted to estimate the stocking effectiveness of flounder. In the prefecture about 300,000 to 400,000 flounder seeds have been annually released in recent years. The total yield of the released flounder is estimated based on the market survey conducted by the fisheries experimental station (Table 3, Fujita *et al.* 1993; Fujita 1995). The unit value of a landing calculated by dividing the total cash value of the released flounder landed by the number of seeds released is $1.7 to $3.6 (Fujita 1995). The unit-seed-production cost is about $1.0, thus the seed-production cost has been recovered by 1.7 to 3.6 times. Accordingly, the cost is favorably recovered even in the present stock enhancement of flounder.

5 Stocking Effectiveness Evaluation Methods

5.1 Identification of individual released seeds and the effectiveness survey

Let us examine the stocking-effectiveness evaluation methods for chum salmon and scallops, whose stocking effectiveness has already been proven. For chum salmon, there is very little reproduction of wild salmon in the rivers into which artificial seeds are released. This therefore causes no problems in regarding all the returned salmon as released ones, and the use of tags is unnecessary. Among the fishermen's cooperative associations that land chum salmon, a reporting system has been established and the catch in number as well as in weight has to be reported every ten days. The Salmon Hatchery of the Fisheries Agency tabulates the reported results in Hokkaido, while the fisheries department of each prefecture tabulates the results in Honshu (personal communication from Masahide Kaeriyama, Hokkaido Salmon Hatchery). The tags are also not applied to scallops. This is because scallops are very sedentary and all the released scallops can be harvested. Although there is a problem of inseparable reproduction effectiveness, fishermen can recognize the stocking effectiveness from the catches.

In the survey on the stocking effectiveness for chum salmon and scallops, complete enumeration is basically conducted. The features concerning these species for the evaluation of the stocking effectiveness are (a) nonexistence of wild stocks in the release areas and (b) complete recovery of the seeds released. For other species, however, wild individuals usually exist in the release areas. To evaluate the stocking effectiveness, it is therefore essential to identify the released individuals from wild ones. Tags and marks are required for identification.

For abalones, the released ones have green shells because of the blended feeds given during seed production. The green shell parts are retained throughout their lives, making it easy to identify them from natural abalones (The green part is called the "green mark".).

Among migratory fish, the first survey on the stocking effectiveness was conducted on red sea bream. This is because large-scale seed production became possible for the first time for red sea bream. Since around 1975, tracing surveys on stock enhancement was conducted by the use of external tags and marks as represented by anchor-type tags. In such surveys, fishermen report the recapture of released fish carrying tags. Complete enumeration of the recaptures is pursued. The reporting, however, is imperfect and shedding of tags sometimes occurs. The survey method was therefore changed and the recovery rate was estimated by correcting the reported number of tags based on (a) the reporting rate and (b) the shedding rate of tags, which were estimated from another information. From the end of the eighties, however, the perception grew that this method was significantly biased and failed to provide accurate estimation (Kitada and Suda 1988). Surveys are presently conducted based on the sampling of the landings in fish markets.

In the fish market surveys, released fish are discerned from the landings. It becomes more difficult to find the released fish if their numbers are small compared with wild fish. It is therefore desirable in market surveys to apply tags to as many fish as possible. At first, instead of applying anchor tags, one of the abdomen fins was removed as a mark for red sea bream. Such marking, however, badly affected the survival rate and was abandoned. In the recent surveys on the recovery rate of red sea bream, the nostril feature (the nostrils are joined) has been used as a tag, replacing anchor type tags. For flounder, the black pigment appearing on the eyeless side is used as tag. The causes for such features have not been clarified but they are thought to be acquired features, and are used nationwide as harmless natural tags that do not detach.

For crustaceans such as kuruma prawns and swimming crabs, because of their molting habits there existed no effective tags that could be retained for a long time. The stocking effectiveness of crustaceans had thus remained unproven in a satisfactory manner. Recently, however, for kuruma prawns in Nagasaki Prefecture, coded wire tags made of gold have been applied to the survey of stocking effectiveness. In 1995, about 300,000 artificial seeds with average lengths of 40 to 70 mm were marked with such tags and released. The landings were surveyed by the sampling method and much attention has been accorded to the results.

As survey tags for sampling based on fish markets or fishing gear, ALC (Alizarin Complexone) is sometimes utilized. By dipping the fish into the ALC liquid, the otholith can be marked (Kuwada and Tsukamoto 1987). The tags are checked by looking through a microscope at the otholith of the recaptured fish. Such tags can be applied to small fish such as larvae and no attention is required to the shedding or fatal effects of tags. Because of such features, the marking is suitable for detailed surveys on the survival rates by sizes upon release (Tsukamoto *et al.*1989) and upon growth. It is rather troublesome to investigate otholith as tags. A recent report shows that the same marking method can be applied to scales (Nakamura and Kuwada 1994).

Estimation of migration, growth, and death will continue to be important. Development is impatiently awaited of external tags that will not shed or cause harm to the live samples. The JASFA is now developing a fish-friendly tag made of hydroxyapatite.

No practical tracing surveys using genetic tags have been conducted on marine releases. The methods are now under preparation, however, for estimating the mixing rate of the released group by the use of isozyme and mitochondria DNA as genetic tags. In this estimating method, partial likelihood is adopted. Also taken into consideration is the variance estimates of the genotype frequencies of the baseline population (Kishino *et al.*1994) that in traditional methods has been regarded as known (Miller 1987).

5.2 Estimation of the number of released fish landed based on a sampling survey

To estimate stocking effectiveness, it is essential to know how many of the released seeds were landed. Stocking effectiveness could be clearly determined if all of the seeds released were identified and complete enumeration of the landings were conducted. Released fish, however, migrate within a wide range, are caught by multiple fishing methods, and are landed at diverse fish markets. It is impossible in most cases to conduct a survey on every landed individual on every landing day in every fish market because such a survey would impose excessive burdens and costs. It was therefore a matter of course that sampling began to be conducted by selecting parts of the landings as samples in the stocking effectiveness survey on red sea bream and flounder.

Despite the nationwide dissemination of market surveys, there still remained many problems concerning the estimation methods. The first problem was how to use the results of the sampling surveys for the reasonable estimation of the total number of recoveries from the seeds released. The second problem was that sampling schemes could not be formulated because the precision of estimates could not be evaluated.

For the stocking-effectiveness surveys on red sea bream and flounder, the following survey method is usually adopted. First, several markets are selected among the markets to which the target species are landed within the stocking-effectiveness- evaluation area. Second, survey days are selected. Complete enumeration is conducted on the landed individuals of the target species on the survey day. Ages and presence/absence of tags are recorded for each landed individual. Ages are decided based on the individuals' lengths.

We have proposed an estimation method regarding the above sampling as two-stage sampling having

Table 4: Landing data for flounder (1987-year class) obtained in a survey of five selected fish markets in Fukushima Prefecture, conducted in 1988 (Data: Fukushima Prefecture Fisheries Experimental Station)

Market	Survey period	Survey days	Fishing gear	Sample size	Released fish in the sample	Mark ratio(%)
Haragama	Apr.-Nov.	46	Trawl	6305	1551	24.6
Ukedo	Jun.-Dec.	9	Gill net	950	580	61.1
Hisanohama	Jan.-Dec.	21	Trawl	1136	411	36.2
Yotsukura	Jan.-Dec.	18	Trawl	1354	264	19.5
Nakoso	Jan.-Dec.	10	Trawl	375	83	22.1
Total		104		10120	2889	28.5

the selection of markets as the primary sampling, and the selection of survey days as the secondary sampling. Estimable by the use of formulas are the total number of released fish landed, the sum of the total number of released fish and natural fish landed, the ratio of the released fish to the number of landings, the recovery rate, and the total amount recovered. Here the estimation method is outlined by giving an example of the release of about 240,000 seeds of flounder in Fukushima Prefecture in 1987 (Kitada *et al.*1992).

To conduct the survey on the 1987 release of seeds, five fish markets were selected from those to which flounder were landed within Fukushima Prefecture. The survey was conducted on 104 days in total in 1988. 10,120 flounder in the 1987-year class were surveyed. 2,889 of them were judged as released fish because of the pigment on the eyeless side (Table 4).

Based on the obtained data, the entire number of landings was estimated for the 14 fish markets within the prefecture (Table 5). Table 5 shows remarkable between-market variance. This is because the number of landings differs among the markets. The variance estimator consists of two components: within-market variance and between-market variance. The variance estimator of $\hat{M}$ for the total number of released fish landed is given by

$$\hat{V}(\hat{M}) = \left(\frac{K}{k}\right)^2 \sum_{j=1}^{k} D_{i(j)}^2 \frac{D_{i(j)} - d_{i(j)}}{D_{i(j)} - 1} \frac{\hat{\sigma}_{M_{i(j)}}^2}{d_{i(j)}} + K^2 \frac{K - k}{K - 1} \frac{\hat{\sigma}_{M_b}^2}{k} \quad (1)$$

Here, K refers to the number of population markets, k refers to the number of markets surveyed, $D_{i(j)}$ refers to the number of landing days of the $i(j)$th market selected, and $d_{i(j)}$ refers to the number of survey days. $\hat{\sigma}_{M_{i(j)}}^2$ refers to the within- variance unbiased estimator, and $\hat{\sigma}_{M_b}^2$ refers to the between-variance unbiased estimator of the number of released fish landed (Kitada *et al.* 1992).

$$\hat{\sigma}_{M_b}^2 = \frac{1}{k} \sum_{j=1}^{k} (\hat{M}_{i(j)} - \bar{\hat{M}})^2 - \frac{k-1}{k^2} \sum_{j=1}^{k} D_{i(j)}^2 \frac{D_{i(j)} - d_{i(j)}}{D_{i(j)} - 1} \frac{\hat{\sigma}_{M_{i(j)}}^2}{d_{i(j)}}$$

Based on the within-variance and between-variance values obtained from the survey, the estimation precision (standard errors) of the yield estimates of released fish is calculated by the use of Equation (1) for diversified numbers of survey markets and survey days. Fig. 15 shows the standard-error contour derived from such calculation. The asterisk in the Figure shows the precision in the case of the present numbers of survey markets and survey days. Fig. 15 shows that the increase in the number of the

Table 5: Estimates of the number of landings for released fish, total fish, the ratio of released fish in the landings, and their variances for14 markets in Fukushima Prefecture based on the data in Table3

	Released fish	Total fish	Ratio of released fish
Estimate	50,978	152,076	0.335
Within Variance (a)	$6,837 \times 10^4$	$29,268 \times 10^4$	
Between Variance (b)	$12,307 \times 10^4$	$33,504 \times 10^4$	
Total Variance	$19,144 \times 10^4$	$62,772 \times 10^4$	4.9×10^{-3}

(a)First term of variance equations

(b)Second term of variance equations

survey days does not improve the precision, but the increase in the number of survey days greatly improves precision.

This method is basically applied to the estimation of the total number in the two-stage sampling. The total number of landings including the released individuals as well as wild ones can be estimated by this generally applicable method. The method can thus be applied to a wide range of different surveys. For sedentary species such as shells, stocking effectiveness can be evaluated if the landings of the fishermen's cooperative association that have released the seeds are surveyed. It is often difficult, however, to survey all the landings on all the landing days. In Tokushima Prefecture, abalones have been landed in baskets, each of which carries eight kilograms of abalones. It was difficult to survey all the baskets because of the short shipment time. It was also hard to conduct a survey every day. The above estimation method has therefore been applied having the landing day as the primary sampling unit and the basket as the secondary sampling unit (Kojima 1995). For the estimation of the landings of the aforementioned kuruma prawns marked with CWT tags and released in large quantities in Nagasaki Prefecture, the estimation method can also be applied having the trawler as the primary sampling unit and the landing day as the secondary sampling unit. This method has also been used for the estimation of the stocking effectiveness of flounder in Aomori Prefecture, as well as for masu salmon in Hokkaido.

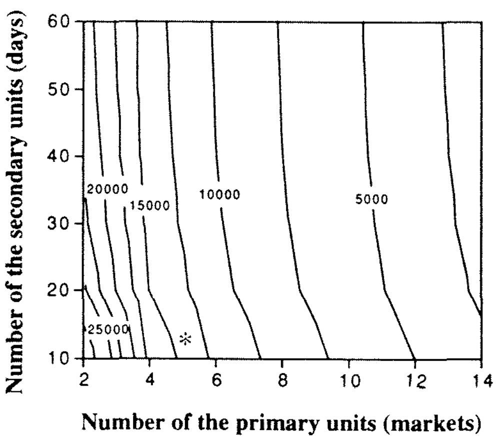


Fig. 15: Relationship between number of primary and secondary units for SE of yield estimates of released flounder in Fukushima Prefecture. The asterisk shows the present value of SE.

5.3 Evaluation of the survival rate

Stocking effectiveness directly depends on the survival rate of the released seeds. Paying attention to this fact, mark-and-release experiments have been widely conducted to compare the quality of the seeds released themselves or the effectiveness of the release methods and especially to estimate the postrelease survival rates. Estimation of the stocking effectiveness based on market surveys provides direct-yield estimates of released fish and is highly reliable. Such estimation, however, requires systematically conducted, large-scale surveys. In comparison, the survival rate can be estimated by conducting relatively small-scale surveys.

The methods for estimating instantaneous natural mortality rates and instantaneous fishing mortality rates based on the tag return data had been developed since the fifties (Beverton 1954, Gulland 1955, Paulik 1963, Farebrother 1985, Hearn *et al.*1987, Farebrother 1988). We have encountered problems, however, that are peculiar to stock enhancement.

To avoid fishery soon after release, seeds are sometimes released in the inner parts of bays where no fishery is conducted. Proposed for these locations is estimation of the mortality rates based on sampling by the use of experimental fishing gear (Kitada *et al.*1992). The mortality rates are considered to be high directly after the release but to be stabilized in a short time. Estimation methods responding to the changes in the instantaneous mortality rates have been proposed (Kitada *et al.*1994) to deal with the issues related to the stabilization period/degree of the mortality rate.

Adopted for statistical models has been multinomial distribution that assumes simple random sampling. Such an assumption, however, is generally difficult mainly because of the concentrated distribution of organisms. A statistical model considering the over-dispersion of the recapture has been proposed (Kitada *et al.*1994).

In the experiments on stock enhancement, it is important to compare the survival rates of release groups that are produced by different methods and have different sizes. In the experiments, two groups are concurrently released at the same location to compare the survival rates in the same environments. Fig. 16 shows the recapture data obtained in an experiment on red sea bream. In the experiment, red and white tags were applied to red sea bream with an average total length of 10 cm (20,000 each) produced at two different Sea Farming Centers. The numbers of recoveries shifted in similar patterns for the two release groups. This shows that the two groups were well mixed in the fishing area. The number of recoveries among the 20,000 red sea bream marked with red tags was 2,422, and recoveries among the 20,000 red sea bream marked with white tags was 2,294. The recapture rates were 0.12 and 0.11, respectively, and very similar among the two groups.

In these kinds of experiments, differences among release groups are frequently decided based on the survival and recapture-rate differences examined based on the obtained data. The recapture data, however, are highly correlated, and assumptions applied to the usual difference tests in independent experiments cannot be applied to the data. The risk of an erroneous conclusion would be heightened with over-dispersion.

Proposed to tackle the problem has been a statistical model that takes into consideration the correlation of the recovery data and the over-dispersion of the recapture (Kitada *et al.*1994). The likelihood function is as follows.

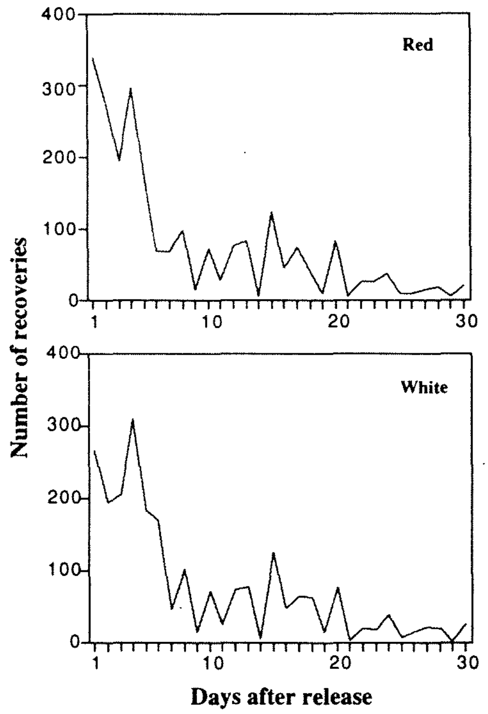


Fig. 16: Observed recoveries of red sea bream tagged with red and white tags for 30 days after release

$$L(\boldsymbol{\theta}_1, \boldsymbol{\theta}_2, \rho | n^{(1)}, n^{(2)}, N^{(1)}, N^{(2)}) = \frac{1}{(2\pi)^k (N^{(1)} N^{(2)})^{\frac{k}{2}} (\sigma_{(1)}\sigma_{(2)})^k (\prod_{i=1}^{k+1} P_i^{(1)} P_i^{(2)})^{\frac{1}{2}} (1-\rho^2)^{\frac{k}{2}}}$$

$$\exp\left[-\frac{1}{2(1-\rho^2)} \sum_{i=1}^{k+1} \left\{ \sum_{j=1}^{2} \frac{(n_i^{(j)} - N^{(j)} P_i^{(j)})^2}{N^{(j)} P_i^{(j)} \sigma_{(j)}^2} - 2\rho \frac{\left(n_i^{(1)} - N^{(1)} P_i^{(1)}\right)\left(n_i^{(2)} - N^{(2)} P_i^{(2)}\right)}{\sqrt{N^{(1)} P_i^{(1)} N^{(2)} P_i^{(2)}}\, \sigma_{(1)}\sigma_{(2)}} \right\}\right]. \quad (2)$$

Here $\boldsymbol{\theta}_1$ and $\boldsymbol{\theta}_2$ are the instantaneous mortality rates of the two groups, $n_i^{(1)}$, $n_i^{(2)}$ are the numbers of recoveries on ith day for Groups 1 and 2, respectively, $j = 1, 2$ means the group number, and $N^{(1)}$ and $N^{(2)}$ are the number of seeds released. $\sigma_{(1)}$ and $\sigma_{(2)}$ are the dispersion parameters for each of the groups and ρ is the correlation coefficient. $n_{k+1}^{(j)} = N^{(j)} - n^{(j)}$, $P_{k+1}^{(j)} = 1 - \sum_{i=1}^{k} P_i^{(j)}$. $P_i^{(j)}$ is the recapture probability. The recapture probability is the function of the instantaneous natural mortality rate and the instantaneous fishing mortality rate. Diversified forms are considered according to situations.

As a result of the analysis of the red sea bream data utilizing the likelihood in Equation (2), the correlation coefficient was estimated to be 0.9 or more, which meant significantly high correlation. Taking the correlation into consideration, the log likelihood ratio was calculated for the model assuming no differences in the instantaneous mortality rate to the model assuming such differences. The results were $-2 \times (-254.27 + 250.00) = 8.54$ and $p = 0.074$(df=4). Thus the null hypothesis was not rejected at the significant level of 5%, and no clear differences were detected in the instantaneous mortality rates.

If the differences in the recapture rates were tested by the 2×2 contingency table χ^2 test, the result would be χ^2=3.94, and the hypothesis that the recapture rates are equal would be rejected (df = 1, $p = 0.047$). A contrary conclusion is thus obtained. The conclusion, however, is invalid because the χ^2 test assumes the independence of the two groups and simple random sampling. Such assumption, however, is inapplicable to the obtained data.

For the data, the AIC of the model including the dispersion parameter is extremely small, and it is confirmed that the assumption of simple random sampling is irrational. Moreover, because the two groups are released concurrently at the same location, the premise of independent experiments cannot be applied. It is therefore inappropriate to apply the recapture-rate-difference test to such data without the χ^2 test premise. In the estimation of the recapture-rate differences among the groups concurrently released, it is necessary to pay attention to the recapture correlation and over-dispersion.

5.4 Simulation

In relation to the evaluation of stocking effectiveness, a simulation model was utilized to examine the release schemes. The Fisheries Agency and the JASFA developed a simulation model to estimate the influences that stock enhancement and fishing regulations would exert on the yield. The model has been used for the planning of releases and for the formulation of fishing regulations (Kitada and Okouchi 1992, Kitada and Okouchi 1994). In the model, future yields are calculated based on the initial numbers of stock for every age and death or reproduction-equation parameters. The estimated yields, however, are uncertain mainly because the reproduction random errors are not considered.

Effective release methods have also been considered (Matsumiya and Ohnishi 1989).

6 Hatchery Enhancement and Recreational Fishing

6.1 Estimation of total catch by recreational fishing

Recently in relation to stocking effectiveness, much attention has been paid to recreational fishing, especially for red sea bream. According to the government's fishery census, the total number of recreational sea fishermen reached 31.35 million in 1994. It is also estimated that there are 2,000 recreational fishermen in the aforementioned Kagoshima Bay. It is therefore important to know the number of red sea bream caught by such sports fishermen.

In Kanagawa Prefecture the hatchery enhancement of red sea bream was begun in 1978 and a total of about 16 million red sea bream had been released by 1994. In around 1980 the number of recreational fish dealers mainly targeting red sea bream began to increase. In the 1988 survey the number of recreational fishing-business entities in Kanagawa Prefecture was estimated to be 896. The annual number of recreational fishermen utilizing fishing vessels was estimated to be about 1.38 million in total. For recent years, the annual catch in weight by commercial fishing has been estimated to be about 50 tons, while that by recreational fishing has been estimated to be about 80 tons in Kanagawa Prefecture (Imai *et al.*1994,Imai 1996) (Fig. 17). It has been shown that the recreational catch of red sea bream also surpasses the commercial catch in Shizuoka and Chiba Prefectures in addition to Kanagawa Prefecture.

In inland waters, about 50 species are released including ayu, which is a representative target of recreational fishing. Let us examine the positioning of hatchery enhancement in the management of a fishermen's cooperative association by introducing the example of four fishermen's cooperative associations around the Nakagawa River in Tochigi Prefecture. For the income and expenditure of the four associations that set the fishing rights around the river, 65% to 89% of the income is obtained from the license fees for angling and casting nets (Table 6). The license fees are paid by the members of the associations as well as by recreational fishermen, principally for the fishing of ayu. Concerning expenditures, the seed cost occupies 33% to 46% of the total. In seed cost, that for ayu is the highest. Released in 1995 were about 25 tons (3.5 million to 4 million fish) of ayu. The unit cost of ayu seed

Table 6: Income and expenditure of the fishermen's cooperative associations around the Nakagawa River, Tochigi Prefecture (unit: US$)

Item of expense	Fishermen's cooperative association			
	A	B	C	D
Total income	243,290	713,830	145,040	1,439,630
Recreational license fee(a)	159,910	483,390	128,380	997,430
Member fishing fee(b)	23,650	130,430	12,460	70,690
Others	59,730	100,010	4,200	371,510
Total expenditure	265,980	713,830	145,040	1,439630
Released seeds	88,230	295,880	59,460	659,050
Fishing ground management	30,660	50,430	8,880	246,600
Managing expense	129,700	345,600	73,830	488,870
Others	17,390	21,920	2,870	45,110

(a) for angling and cast net

(b) for fish traps

weighing 5 grams is $0.3. The management of fishermen's associations around rivers mainly depends on the income obtained from license fees for the recreational fishing of ayu, etc. Hatchery enhancement is indispensable for such management.

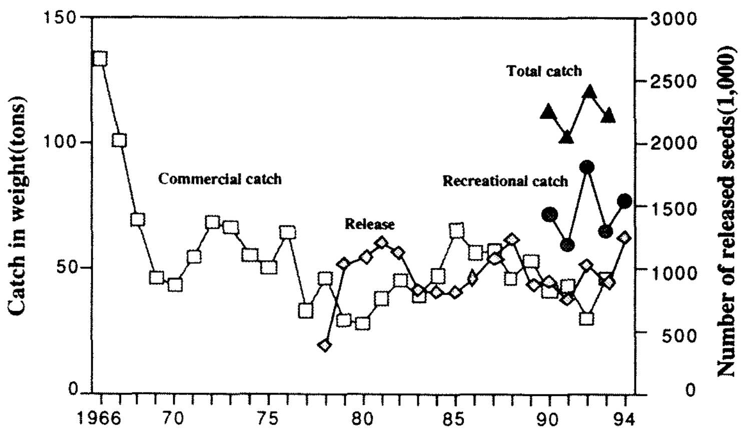


Fig. 17: Change in catches and the number of released seeds of red sea bream in Kanagawa Prefecture(Data:Imai,1996)

Although it is very important to know the total catch by recreational angling, there are no statistics on this. Instead, the prefectural fisheries experimental stations conduct surveys on the recreational catch. These surveys can be divided into two kinds: (a) sampling surveys on recreational fishing boats or recreational fishermen to obtain the records of the catch in number on the fishing day; and (b) surveys on the total number of recreational fishing boats or fishing days to obtain or to estimate the total recreational fishing effort.

A method to estimate the total catch based on the data obtained from the surveys mentioned above has been proposed (Kitada 1993, Kitada 1996). Based on analysis of the 1993 data on ayu in the Nakagawa River, it was estimated that there were 480,000 (CV=0.072) recreational fishermen in total, and the catch of ayu was about 5.2 million (CV=0.12) in number and 260 tons (CV=0.12) in weight (Kitada 1996). This was the first estimate of the total catch of ayu, and the figures were surprisingly large. The survey was conducted on a sampling of 120 recreational fishermen. The survey also showed the relationship between the precision of the estimated catch and the required sample size, providing good references for examining survey plans. Such surveys on recreational catch have been started in some prefectures. It is expected that the recreational catch of red sea bream and ayu will be scientifically estimated in the future.

6.2 Bearing seed-production costs

It is generally required to pay license fees for recreational fishing in inland waters. For most of the rivers providing sports fishing, fishermen's cooperative associations set the fishing rights. License fees are required for river fishing. The Fisheries Act obliges the propagation of the species included in the targets of the fishing rights. Accordingly, the fishermen's cooperative associations that charge the license fees conduct hatchery enhancement. In the case of ayu, fishermen's cooperative associations release the seeds. Members of the associations as well as recreational fishermen pay the license fees for angling ayu. There thus exists a naturally established system whereby the persons who catch the fish bear the seed- production cost.

There is, however, no license system applied to marine recreational fishing. In Japan, sedentary aquatic creatures such as abalones and sea urchins are managed by fishermen's cooperative associations. Recreational fishing of these species is prohibited. Recreational fishermen, however, can freely catch any fish in the sea. Also for commercial fishing, fishing professionals can catch fish in the sea without paying license fees only if they have obtained fishing authorization from prefectural governors. Although it had long been insisted that fishermen should share the seed-production cost, it was actually difficult to impose such burdens. At sea, however, where large-scale seed release is done and stocking effectiveness has been analyzed, discussion about cost sharing by beneficiaries has of course been promoted.

In Kanagawa Prefecture, at the forefront of other prefectures, a system of sharing seed-production cost has been in place since 1988. In the system, recreational-fishing dealers pay cooperative money to the Kanagawa Prefecture Sea-Farming Association. Fixed amounts are collected as cooperative money according to the quotas of recreational fishing vessels. For vessels accommodating 20 or more people, the cooperative fee is $5 per year per capita. For vessels accommodating fewer than 20 people, the cooperative fee is $4 per year per capita. In the system, commercial fishermen also share the cost of sea farming. Each of the regular members of fishermen's cooperative associations pays $5 per year and each of the associate members pays $3 per year. Burden charges are also assessed according to the size of fishing vessels. The charges are $5 for vessels weighing less than one ton, $10 for vessels of one to less than three tons, $15 for vessels weighing three to less than five tons, and $25 for vessels weighing five or more tons (reference materials provided by Kanagawa Prefecture).

7 Stocking Effectiveness and Commercial Fishermen's Consciousness of Resource Management

7.1 Hatchery-enhancement programs begun at commercial fishermen's expense

There are some 300,000 commercial fishermen engaged in coastal fishery in Japan. Assisted by the Tokyo Fishery Promotion Foundation, from 1992 to 1994 we conducted a nationwide survey on the consciousness of these fishermen. Thirty-seven fishermen's cooperative associations in ten prefectures were selected as survey samples. 5,993 families of commercial fishermen belonging to the associations completed and returned the questionnaires for a return rate of 80%. According to the results of the survey, the fishermen's daily problems are (a) decreased resources (67%), (b) unstable yield (62%), (c) price decline caused by a large catch (52%), and (d) large price differences between the production and consumption sites (37%). Reflecting such problems, fishermen think that the focus of fishery-management improvement should be (a) arrangements for selling at higher prices (53%), (b) resource management (52%), (c) hatchery enhancement (35%), (d) expansion of distribution channels (34%), and (e) countermeasures for poaching (33%). These survey results indicate that the main problems in coastal fishery recognized by commercial fishermen are those relating to resources and distribution, and that resource management and hatchery enhancement are expected to provide effective countermeasures for resource problems.

Investigated in the survey by the Japan Fisheries Resource Conservation Association were 542 fishery organizations engaged in resource management. According to the results, in addition to the enforcement of diversified fishing regulations, the organizations are taking different measures to meet the local fishing or resource situations. Included in the measures are (a) preservation of the fishing areas (65 organizations, 11.9%); (b) improvement of fishing grounds (182 organizations, 33.6%); (c) hatchery enhancement and transplantation (339 organizations, 62.5%); (d) supervision of fishing areas and practices (32 organizations, 5.9%); and (e) removal of predators (45 organizations, 8.3%). Regarding the above measures, the number of organizations that conduct hatchery enhancement is the largest. For the species targeted in the measures, 76% are sedentary species such as abalones, top shells, sea urchins, lobsters, and sea cucumbers. This fact implies that hatchery enhancement and resource management have been promoted among the species that directly reward the efforts of hatchery enhancement or of fishing regulations. In addition to these sedentary species, many fishermen's cooperative associations release purchased seeds of kuruma prawns and swimming crabs.

Also, for highly migratory fish there are some cases in which fishermen's cooperative associations and other fishermen's organizations bear a part of the seed-production costs. Recently, moreover, cases similar to the aforementioned case of red sea bream in Kanagawa Prefecture have been observed, in which individual commercial fishermen bear a part of the seed-production costs. In Aomori and Fukushima Prefectures, individual commercial fishermen bear the costs of releasing flounder in proportion to the number of landings.

In Aomori Prefecture large-scale release of flounder was begun in 1992, and from 3.5 million to 4 million seeds of flounder have been annually released. In 1992 the commercial fishermen paid an amount equivalent to 1.5% of the cash value of the landings of flounder as their share of the seed-production cost. The percentage of share was raised to 3% in 1994 and has been 4% since 1995. In 1995 the catch in weight of flounder was 719 tons and the cash value was about $14 million. Commercial fishermen paid $560,000 as their share of the seed-production cost. The seed-production cost including personnel expenses was about $1.2 million (Aomori Prefectural government), so the fishermen paid 47% of the cost. The personnel expenses included in the cost were for two persons, and the actual expenses were higher. The percentage of the fishermen's share in the total seed-production cost should therefore be smaller than 47%. By sharing the cost, consciousness towards resource management has been promoted among fishermen. As a result in Aomori Prefecture, the fishing of flounder (both released and natural) with a total length of less than 35 cm has been prohibited.

Also, in Fukushima Prefecture the new release project of flounder was started in 1996. The commercial fishermen presently pay 5% of the cash value of the landings of flounder as their share of the seed-production cost. The annual-release scale is 1 million in number and the seed-production cost including personnel expenses is about $1 million according to the Fukushima Prefectural government. The cash value of the landings of flounder is about $6 million, so the commercial fishermen pay about $300,000 as their share of the seed-production cost. The fishermen thus bear 30% of the cost. Also, in Fukushima Prefecture it has been voluntarily prohibited by commercial fishermen themselves to catch, sell, or eat flounder with a total length of less than 30 cm, including wild specimens.

7.2 Restriction on fishing based on the length of fish, promoted by stock enhancement

In accordance with the verification of stocking effectiveness, the restriction on the fishing of flounder based on length started in Fukushima Prefecture has been promoted nationwide. According to the reference materials of the Fisheries Agency, flounder were released in 37 prefectures in 1993 and the fishing of flounder was restricted in 23 prefectures, based on total length (Fig. 18). The minimum length for catching was 35 cm in two prefectures, 30 cm in seven prefectures, 25 cm in eight prefectures, and 20 cm in six prefectures. The fishing of flounder with lesser total length was prohibited. Flounder with a total length of 30 cm are estimated to be one-year old.

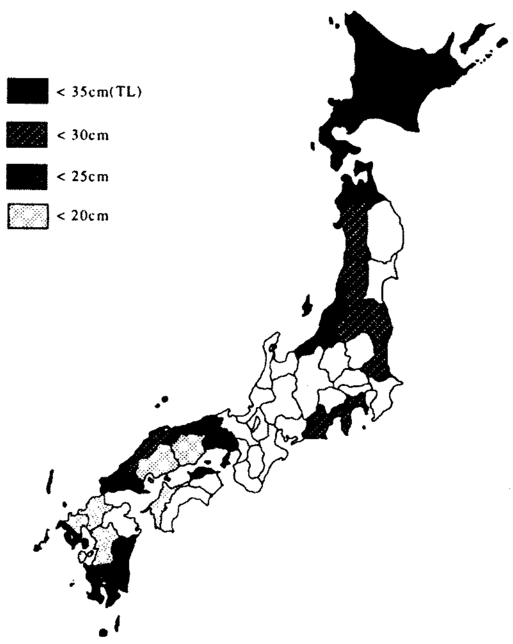


Fig. 18: Prefectures(23) prohibiting young flounder fishing

In 1993 red sea bream were released in 24 prefectures, and the fishing of red sea bream was restricted based on their total length in 30 prefectures (Fig. 19). Resource management has thus been promoted even in prefectures where no hatchery enhancement is done. Red sea bream with a total length of 15 cm are estimated to be about one-year old. In the three prefectures of Kanagawa, Chiba, and Shizuoka, the minimum-length is 17 cm and the corresponding age is more than one-year old. Fishing of one-year-old fish, however, is generally prohibited nationwide.

Fishing regulations cannot be imposed without the approval of commercial fishermen. One of the main reasons for the success of the fishing regulations on flounder and red sea bream was that hatchery enhancement played an effective role in raising the consciousness of commercial fishermen regarding resource management.

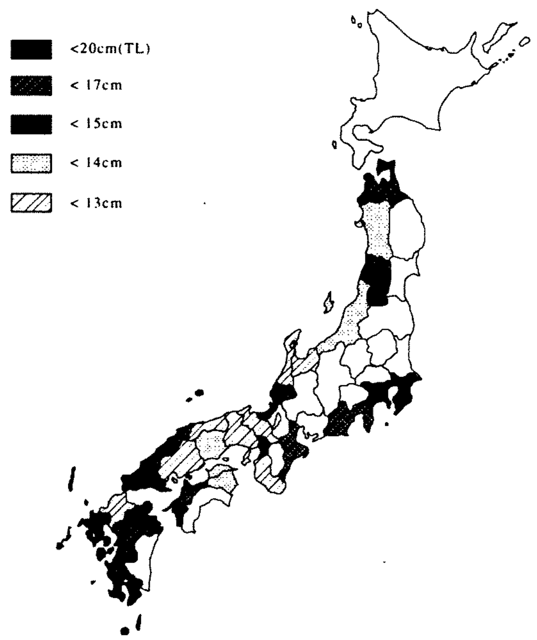


Fig. 19: Prefectures(30) prohibiting of young red sea bream fishing

8 Hatchery Enhancement Program Challenges

8.1 Accumulation of stocking-effectiveness analysis

Stocking effectiveness has been verified for some of the species. It has been proven that yields can be increased by hatchery enhancement. Table 7 shows the cost benefits of the examples already introduced in this paper in terms of the recovery of seed- production costs. Let us give attention to the magnitude of the money recovered from seed-production costs (B/A in Table 7). The most profitable is chum salmon (recovery of five- to eight-fold), followed by other species (recovery of 1.7- to 3.6-fold). Although the seed-production cost of scallops is the smallest thanks to natural seed-collecting and because they need no feed, the profitability is rather low because of their low prices.

The seed cost of chum salmon includes personnel expenses and facilities' depreciation costs, but the details of the seed costs of other species are unknown because of the lack of official reference materials. It would therefore be necessary to assume that the seed costs shown in Table 7 are the lowest possible.

Table 7: Seed costs and landing cash values per released seed

Species	Cost per seed(US$) (A)	Seed size (cm)	Landing per seed(US$) (B)	B/A
Chum salmon	0.05	5.0	0.25~0.40	5.0~8.0
Scallop	0.029	3.5	0.067	2.3
Red sea bream	0.27	8.0	0.70	2.6
Flounder	1.00	7.0~10.0	1.7~3.6	1.7~3.6

The four examples shown in Table 7 can be regarded as the most successful cases in Japan. Table 7 roughly shows the upper limit of present stocking effectiveness in Japan. There are, however, insufficient analytical examples to discuss the economic effectiveness of hatchery enhancement. It is necessary to estimate more cases regarding stocking effectiveness, including economic analysis.

Hatchery enhancement not only contributes to fishery harvests but is also very effective in raising and strengthening the consciousness of commercial fishermen regarding resource management. Hatchery enhancement also is effective concerning recreational fishing. To evaluate the value of hatchery enhancement it would be necessary to consider diversified effects other than the contribution to fishery production.

8.2 Review of release plans

As mentioned earlier, the release scales judged from Stocking-Impact Indices are insufficiently large in many prefectures even for representative species, with the exception of chum salmon and scallops. The release scales in prefectures with plentiful wild stocks are especially low, which at the same time indicates that stock enhancement is conducted even in prefectures with abundant wild stocks. It is necessary to estimate the present resource situations and to review the necessity of stock enhancement. Adaptive plans should also be made, which will allow (a) the suspension of releases when the yields have increased, as well as (b) the recommencement of releases when the yields have diminished. It is also necessary to evaluate the reproductive ability of natural fish in examining the release plans. Concerning the release plans with consideration given to the reproduction of released as well as of wild fish, theoretical research was conducted (Harada and Matsumiya 1992).

For depleted species for which hatchery enhancement seems to be effective, aggressive release plans should be devised to rebuild the resources. In Japan, herring would be a representative species for such planning. The seed production of herring has been enabled, and trial release is presently conducted. The features of herring (migrating to the coasts for spawning, and feeding on plankton) are considered to be suitable for such release.

8.3 Technical problems

If the released seeds survive and are harvested or reproduced, the release has been successful. The following are the fundamentals for such success.

1. Mass production of high-quality, sound seeds

2. Survival and reproduction of the released seeds

3. An environmental carrying-capacity that allows the growth, survival, and reproduction of the released seeds

4. Profitability of the catches derived from the released seeds

5. Scientific verification of stocking effectiveness

It is necessary to devise and promote techniques for achieving the above conditions. The seed-production technique is particularly indispensable for hatchery enhancement, and the production of healthy, sound seeds should be pursued in tandem with cost reduction. As mentioned earlier, the economic effectiveness of chum salmon is higher than for other species because of the lower seed-production cost.

The seed-production cost is closely related to the level of the seed-production technique. In the case of chum salmon, the survival rate from eggs to the seeds to be released is as high as 83% (calculated based on Salmon 23, 1994 of the Hokkaido Salmon Hatchery), which shows the advanced state of technical levels. Furthermore, the larvae of chum salmon can be nourished on mixed feeds soon after the absorption of yolk sacs. Live feeds such as rotifers, however, are vital for other species, which necessitate extra expenditures. For species other than salmon and scallops, feed cost reduction as well as improvement of the seed-production technique would further be required.

Even if seeds are healthy and disease-free, proper stocking effectiveness will not be obtained if the postrelease survival rate is low. In the release of chum salmon, much attention was paid to high-survival rate and on the quality of the seeds released (Sato 1996). Recently much importance has been accorded to the good survival quality also in the seed production of red sea bream and flounder (e.g., Tsukamoto 1993).

To release healthy seeds, to have them survive, and to obtain satisfactory yields, it is necessary to promote the seed-release technique, to improve fishing ground conditions, and to enforce new fishing regulations. For the evaluation of stocking effectiveness, it is indispensable to conduct scientific surveys and evaluations by the use of the marking techniques. For the improvement of surveys' precision and efficiency, it is desirable that fishing statistics will be prepared that include data for resource evaluation such as fish length.

8.4 Considerations for ecosystem

Recently the influences of hatchery enhancement on wild resources have become discussion topics. Unfavorable influences that are especially worrisome are competition for feed, phagotrophy, genetic effects, and infections. Increased worries and criticisms have surfaced regarding the possibility that hybridization of released and wild fish may diminish the genetic diversity of the natural resources (Bartley 1995).

As to the competition between the releases and wild individuals, theoretical studies have already been conducted (Watanabe 1983, 1986, 1988a, 1988b, 1990). Although there are sparse field data, the number of landings of representative species of hatchery enhancement have been decreasing, and the past's largest numerical catches are considered to represent carrying capacities. It is difficult to investigate actually the competitions within and between species, but it is at least necessary to pay attention to the supply of feed and to the number of wild fish and competitive species around the areas in which the seeds will be released.

In the mass production of seeds, there are always risks of infections and genetic simplification. The influence of hatchery enhancement on genetic elements has already been pointed out within Japan

(Harada 1992, Harada 1993, Matsuishi *et al.*1995). From now on it would be necessary to promote the production and release of seeds with attention accorded to the conservation of genetic diversity. Appropriate guidelines should be prepared. The Fisheries Agency commenced the research and development of the seed-production technique, taking into account the conservation of the ecosystem.

9 Conclusion

It has been proven that hatchery enhancement contributes to the increase of fishery production. Except for chum salmon and scallops, however, there are remarkable prefectural variations in release scale and stocking effectiveness. It would therefore be necessary to evaluate the resource situations and to review the necessity of hatchery enhancement and the selection of target species.

Successful examples have demonstrated the profitability of hatchery enhancement, but there exist insufficient evaluation data on stocking effectiveness. It is thus necessary to accumulate scientific analyses including information on economic effectiveness. Technical challenges include (a) mass production of high-quality seed, (b) reduction of seed-production costs, (c) improvement of seed-release techniques, and (d) ecosystem consideration.

Hatchery enhancement contributes to the stabilization of resources as well as to the increase of fishery harvests. In addition to such basics, hatchery enhancement also raises the consciousness of commercial fishermen towards resource management and attracts recreational fishermen. Based on hatchery enhancement, a new direction of resource management has been indicated. This is to manage wild and released resources in a comprehensive manner for commercial as well as for recreational fishing. The present challenge is how to promote hatchery enhancement for the sustainable use of coastal marine resources. The importance of scientific approaches has risen accordingly.

Acknowledgments

I extend my gratitude to Masahide Kaeriyama, Hirohisa Kishino, Akira Suda, for their useful comments on this manuscript. I also thank Hiroaki Fujishima, Masaaki Nakano, Jun Machiba, Koji Imamura, and Seiichi Watanabe; as well as to the staff of the Fisheries Agency, AomoriPrefecture, Fukushima Prefecture, and the Japan Sea-Farming Association for having kindly offered me invaluable documents and helpful information.

Literature Cited

Bartley, D. M. 1995. Marine and coastal area hatchery enhancement programmes: food security and conservation of biological diversity. International conference on sustainable contribution of fisheries to food security, pp. 27.

Beverton, R. J. H. 1954. Notes on the use of theoretical models in the study of the dynamics of exploited fish populations. Misc. Contr. Biol. Lab. Beaufort, 2, pp. 159.

Blankenship, H. L., and K. M. Leber. 1995. A responsible approach to marine stock enhancement. *In*H. L. Schramm Jr. and R. G. Piper (eds.), Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society Symposium 15:165-175.

Farebrother, R. W. 1985. Weighted least-squares estimates of mortality rates from single-release tagging studies. J. Cons. int. Explor. mer. 42: 166-170.

Farebrother, R. W. 1988. Maximum likelihood estimates of mortality rates from single-release tagging studies. J. Cons. int. Explor. mer. 44: 229-234.

Fujita, T., and T. Mizuno. 1990. Effectiveness of a flounder enhancement program of Fukushima Prefecture. Saibai Giken 18: 91-99. (In Japanese).

Fujita, T. 1995. Present status of a flounder enhancement program of Fukushima Prefecture. Suisan Zosyoku Kenkyukaiho 11: 12-20. (In Japanese).

Gulland, J. A. 1955. On the estimation of population parameters from marked members. Biometrika 42: 269-270.

Hearn, W. S., R. L. Sandland, and J. Hampton. 1987. Robust estimation of the nautral mortality rate in a completed taging experiment with variable fishing intensity. J. Cons. int. Explor. mer. 43: 107-117.

Harada, Y., and Y. Matsumiya. 1992. A theoretical study on resource enhancement by stocking, with special reference to its intergenerational effects. Nippon Suisan Gakkaishi 58: 1833-1842.(In Japanese with English summary).

Harada, Y. 1992. Genetic difference between wild and released individuals and the resource enhancement effect of stocking: A theoretical analysis. Nippon Suisan Gakkaishi 58: 2269-2275.

Harada, Y. 1993. Genetic characteristics of the released fish juveniles that affect the stocking effect. Fisheries Engineering 30(1): 69-74. (In Japanese).

Imai, T, H. Takama, and I. Shibata. 1994. Estimates of the total amount of red sea bream seeds caught by recreational party boat in Kanagawa Prefecture. Sibai Giken 23(1): 77-83. (in Japanese).

Imai, T. 1996. Estimates of the return rates of red sea bream seeds released around Kanagawa Prefecture. Sibai Giken 25(1): xx-xx. (in Japanese, in press).

Kaeriyama, M. 1989. Aspects of salmon ranching in Japan. Physiol. Ecol. Japan, Spec. Vol. 1: 625-638.

Kaeriyama, M. 1994. Enhancement program and stock management of salmon in Japan. J. Food, Agricul. 17(2): 16-21.

Kaeriyama, M. 1996. Population dynamics and stock management of hatchery-reared salmons in Japan. Bull. Natl. Inst. Aquacult., Supl. 2: 11-15.

Kitada, S., and A. Suda. 1988. Evaluation of restocking effectiveness of sea farming through the ratio of marked fish in the sampled cammercial catch. Suisanzoshoku 36(2): 107-112.(In Japanese).

Kitada, S., and H. Okouchi. 1992. A simulation model for evaluating resource management strategies with hatchery releases. Saibaisigen Chosa Kento Siryo 10, p.3-41. Japan Sea-Farming Association, Tokyo, Japan. (In Japanese).

Kitada, S., H. Kishino, and K. Hiramatsu. 1992. Estimation of mortality rates from tag recoveries by survey sampling. Nippon Suisan Gakkaishi 58: 1399-1403.(In Japanese with English summary).

Kitada, S., Y. Taga, and H. Kishino. 1992. Effectiveness of a stock enhancement program evaluated by a two-stage sampling survey of commercial landings. Can. J. Fish. Aquat. Sci. 49:1573-1582.

Kitada, S. 1993. Methods for estimating the total catch of marine recreational fishery by sample survey of party boats. Nippon Suisan Gakkaishi 59: 75-78.(In Japanese with English summary).

Kitada, S., and H. Okouchi. 1994. A simulation model for strategies of hatchery releases with application to red sea bream. Nippon Suisan Gakkaishi 60: 235-240.(In Japanese with English summary).

Kitada, S., K. Hiramatsu, and H. Kishino. 1994. Estimating mortality rates rates from tag recoveries: incorporating over-dispersion, correlation and change points. ICES J. mar. Sci. 51:241-251.

Kitada, S. 1996. Estimating total catch of recreational fishing with application to Ayu, *Plecoglossus altivelis*. Saibaisigen Chosa Kento Siryo 12, pp. 30, Japan Sea-Farming Association, Tokyo, Japan. (In Japanese).

Kishino H., S.Kitada, and K. Hiramatsu. 1994. Sampling scheme for the estimation of the stock composition in the mixed population based on genetic data. Nippon Suisan Gakkaishi 60: 359-364.(In Japanese with English summary).

Kobayashi, T. 1980. Salmon propagation in Japan. p. 91-107. *In*J. E. Thorpe (ed.) Salmon ranching. Academic Press, London.

Kojima, H. 1995. Evaluation of abalone stock enhancement through the release of hatchery-reared seeds. Mar. Freshwater Res. 46: 689-695.

Kuwada, H. and K. Tsukamoto. 1987. Otolith-tagging of red sea bream larvae with alizarin complexone-1. Optimum concentration and mark retention. Saibai Giken 16(2):93-94. (In Japanese).

Matsuishi, T., H. Kishino, and K. Numachi. 1995. A model of gene displacement by stocking activities. Nippon Suisan Gakkaishi 61:326-330. (In Japanese with English summary).

Matsumiya, Y., and S. Ohnishi. 1989. Effective releasing program of artificial fingerlings using a simulation model. Nippon Suisan Gakkaishi 55: 1759-1765.

Millar, R. B. 1987. Maximum likelihood estimation of mixed stock fishery composition. Can. J. Fish. Aquat. Sci. 44: 583-590.

Nakamura, R., and H. Kuwada. 1994. Detection of alizarin complexone label in scales in the mass marking system of larval and juvenile fish. Saibai Giken 23(1): 53-60. (In Japanese).

Nishihama, Y. 1994. Scallop fishery in the Sea of Okhotku. pp. 218, Hokkaido Univ. Press., Sapporo, Japan. (In Japanese).

Paulik, G. J. 1963. Estimates of mortality rates from tag recoveries. Biometrics 49: 28-57.

Rogers, D.E., and G. T. Ruggerone. 1993. Factors affecting marine growth of Bristol Bay sockeye salmon. Fish. Res. 18: 89-103.

Sato, S. 1986. The salmon- challenges to sea ranching. Iwanami Shinsyo 360, pp. 212, Iwanami Syoten, Tokyo, Japan. (In Japanese).

Shiihara, H. 1986. Results and further problems of releasing in Kagoshima Bay. p.106-126. *In*M. Tanaka and Y.Matsumiya (eds.) Sea farming technology of red sea bream. Koseisya koseikaku,Tokyo, Japan. (In Japanese).

Solemdal, P., E. Dahl, D. S. Danielssen, and E. Moksness. 1984. The cod hatchery in Flodevigen- back ground and realities. p. 17-45. *In*E. Dahl, D. S. Danielsses, E. Moksness, and P. Solemdal (eds.) The propagation of cod Gadus morhua L.. Institute of Marine Research Flodevigen Biological Station, Arendal, Norway.

Suda, A. 1987. Discussions on the index of eficiency of stocking operations with method of brief calculation. Saibai Giken 16(1): 37-46. (In Japanese).

Suda, A. 1991. Present status and projects on sea ranching operations in Japan. p.11-26. *In*T. N. Pedersen, and E. Kjorsvik (eds.) Sea ranching- scientific experiences and challenges. Proc. Symp. and workshop, Institute of Marine Research, Bergen, Norway.

Taniguchi, N. 1986. Genetical problems in seed production. p.37-58. *In*M. Tanakaa and Y.Matsumiya (eds.) Sea farming technology of red sea bream. Koseisya koseikaku, Tokyo, Japan. (In Japanese).

Taniguchi, N. 1993. Genetic problems. p.63-74. In C. Kitajima. a (ed.) Healthy fry for release, and their production. Koseisya koseikaku, Tokyo, Japan. (In Japanese).

Thomas, G. L., and O. A. Mathisen. 1993. Biological interactions of natural and enhanced stocks of salmon in Alaska. Fish. Res. 18: 1-17.

Tsukamoto, K., H. Kuwada, J. Hirokawa, M. Oya, S. Sekiya, H. Fujimoto, and K. Imaizumi. 1989. Size-dependent mortality of red sea bream, Pagrus major, juveniles released with fluorescent otolith-tags in News Bay, Japan. J. Fish. Biol. 35(Supplement A): 59-69.

Tsukamoto, K. 1993. Fry quality. p.102-113. *In*C. Kitajima. a (ed.) Healthy fry for release, and their production. Koseisya koseikaku, Tokyo, Japan. (In Japanese).

Watanabe, S. 1983. Population growth models within a constant restocking operation. J. Tokyo Univ. Fish. 70: 59-69.

Watanabe, S. 1986. Effects of restocking on a two-species competition system when one species has a minimum density for population growth. Res. Popul. Ecol. 28: 117-133.

Watanabe, S. 1988a. Stocking effects on a fish population growth with time lag regulation. Nippon Suisan Gakkaishi 54: 183-186.

Watanabe, S. 1988b. Minimum density for population growth and stocking effects on a two competing species system. Nippon Suisan Gakkaishi 54: 607-611.

Watanabe, S. 1990. Individual variations in resource use and stocking. Nippon Suisan Gakkaishi 56: 1573-1577.

MARINE RANCHING IN ISHIKAWA PREFECTURE: MANAGEMENT TECHNOLOGY FOR SEA FARMING

Noriyuki Okei and Michio Tajima*
Ishikawa Prefecture Fisheries Research Center

INTRODUCTION

Ishikawa Prefecture began the seed production of red sea bream (*Pagrus major*) in 1972. The hatchery-produced red sea bream were released into the sea and researched until harvested. The study revealed the dispersal and migratory movements and the recapture pattern of the released fish. We also compared the catch of the recaptured fish with the expense of seed production. The economic effectiveness was much lower than we had expected. One of the main reasons was the loss of released fry. Accordingly, we concluded that we should devise a method to prevent the released fry from migrating from the stocking area, and that the area should be designated as a marine preserve. We consequently began to discuss marine-ranching and adopted a method for controlling fish migration by conditioning to sound and feed. The Fisheries Division of Ishikawa Prefecture launched the Mobile Marine Ranching System Experimental Project in fiscal year 1987. We released into the marine ranching area the hatchery-produced fry that had been conditioned to sound and feed . We researched the sound-conditioning method, migration behavior of the released fry, and the effectiveness of the project.

MATERIALS AND METHODS

Characteristics of the marine ranching area

The marine-ranching area was located at about 1 km off Manzaki (Magari, Notojima) in the Nanao North Bay, which is a part of the Nanao Bay enclosing Notojima at the center of the Noto peninsula. This area is surrounded by four islets, and the depth of the water is 10 to 15 m. The sea bottom is sandy sediment with communities of eelgrass (*Zostera caespitosa*). Because the habitat appears to be ideal for the fry, the hatchery-produced fry have been released into this area every year since 1977. In 1982, artificial reefs were established in this area to provide nursery grounds for juvenile fish.

Marine-ranching system

A float structure with a programmable sound emitter, underwater illuminator, and automatic feeder was used for the marine-ranching. This system's functions enabled onshore monitoring of environmental condition over time (surface temperature, current direction, and current speed). Solar batteries were employed as the power source.

Measurement of the sound-arrival area

The sound-arrival area was measured at nine stations on December 4, 1987. Each station was situated 1 m above the sea bottom. The temperature of the surface water was 12.2.. Sound was emitted intermittently at a frequency of 300 Hz.

Sound-conditioning method, and sound emission and feeding for the released fish

The sound-conditioning of the fry was conducted at the intermediate culture ground behind Notojima Aquarium (Magari, Notojima). In fiscal year 1989, 100,000 fry (50-60 mm in fork length) were placed in six net cages (4\4\4 m) equipped with four loudspeakers and six automatic feeders. Feed was provided for 15 min six times a day with intermittent sound emissions of 300 Hz. Fry were accustomed to the sound and feeding conditions until September 21. At the completion of conditioning, the fry had grown to 74-mm maximum fork length, at which time the fry were released into the marine-ranching area. In this area, feeding began 3 min after the start of the emission of 300 Hz intermittent sound, and feeding and sound emissions continued for 5 min. The sound emission and the feeding were done fourteen times a day. The sound-conditioning method was similar each year, but slightly modified in accordance with circumstances.

Migration behavior of the released fry

From fiscal years 1972 to 1987 the hatchery-produced fry were released without being conditioned to sound. In fiscal years 1985 and 1987 the recapture patterns of the released fry were investigated by use of traps. The loss of the non-sound-conditioned fry in the marine ranching-area was estimated from the results obtained in fiscal years 1985 and 1987. The fork length and number of the released fry were 40 mm and 150,000 in 1985, and 50 mm and 160,000 in 1987, respectively. The traps used were oval-shaped folding basket nets (50 cm (W) x 90 cm (L) x 60 cm (H); mesh: 9 mm). Three or four ±300-g frozen jack mackerels (*Scomber japonicus*) or frozen sardines (*Sardines melanosticta*) were used as feed. The traps were set up on the survey station at about 7 a.m. and collected at 3 p.m. and the captured fry were counted.

From fiscal years 1988 to 1990, 50,000 to 80,000 individuals of the sound-conditioned fry (70 mm in fork length) were released. The loss of the sound-conditioned fry was estimated from the results obtained in fiscal year 1989.

Effectiveness of the marine-ranching

Market examinations were conducted to observe and measure red sea breams landed at the Nanao Fishery Cooperative, the Nanao public market, and the Notomachi Fishery Cooperative. In this study we used the data obtained during twelve years: for four years before and for eight years after the establishment of the marine-ranching system. The number of landed released fish and the effectiveness of the marine-ranching were estimated based on the examinations.

RESULTS

Sound-arrival area

The sound-pressure level decreased with the distance from the sound source, and varied with the direction. The decline rate of the sound-pressure level was the lowest in the direction of the shallows. A sound-pressure exceeding 98 dB was measured in the marine-ranching area except when the sound was interrupted by high banks. It is assumed that the minimum level of sound that fish can detect is 90 dB. The fry can thus detect the sound in the area.

Sound-conditioning the fry

In 1989 the fry were conditioned to sound and feed from August 31 to September 18. According to the sound emission the fry demonstrated circular movements and aggregated at the surface where feeding would occur.

Migration of the fry from the marine-ranching area

Non-sound-conditioned fry

In fiscal year 1985 the fry were released on August 15. The number of recaptured fry per trap was 15.3 on August 21, 4.4 on September 5, 2.0 on September 17, 1.4 on October 2, 0.7 on October 22, and 0.057 on November 14. In fiscal year 1987 the fry were released on August 25. The number of recaptured fry per trap was 29 on August 28, 7.6 on September 7, 3.9 on September 18, 2.5 on September 28, 3.1 on October 19, 1.6 on October 29, 1.1 on November 11, and 0.086 on November 25. Thus the number of recaptured fry of both years markedly decreased during the research period. These results indicate that the non-sound-conditioned fry immediately migrated from the marine ranching area.

Sound-conditioned fry

In fiscal year 1989 the sound-conditioned fry were released on September 21. The number of recaptured fry per trap was 4.6 on September 26, 2.9 on October 5, 3.8 on October 16, 1.9 on November 1, and 3.5 on November 10. From September 26 until November 10 the released fry were widely recaptured throughout the marine-ranching area. On November 21 the recaptured fry were 13.2 per trap. Thereafter the number of recaptured fry decreased, being just 2.1 per trap on December 21. From November 21 until December 21, the released fry were intensively recaptured around the sound source. Thus the number of recaptured fry failed to decrease until December. This indicates that the majority of the sound-conditioned fry remained within the ranching area until December. In January of the next year, however, the number of recaptured fry was 0.15. In February and March no released fry were recaptured. The fry thus seemed to have migrated from the ranching area in winter, and the migration may be because of the drop in water temperature.

Marine-ranching Effectiveness

Non-sound-conditioned fry

We calculated the recapture rate of released fry on the basis of the data obtained from the market examinations in fiscal years 1984, 1985, 1986, and 1987 when the non-sound-conditioned fry were released. The recapture rates of yearling fish were 0% in 1984, 0.13% in 1985, 0.16% in 1986, and 0.43% in 1987. The respective rates were 0.65%, 2.14%, 1.26%, and 0.43% for one-year-olds; 0.23%, 0.54%, 0.29%, 0.16% for two-year-olds; 0.10%, 0.20%, 0.05%, and 0.04% for three-year-olds; 0.04%, 0.06%, 0.01% and 0.01% for four-year-olds; and 0.02%, 0.02%, 0.01%, and 0.04% for five-year-olds and above. The total recapture rates of red sea bream were 1.04% in 1984, 3.08% in 1985, 1.77% in 1986, and 1.12% in 1987.

Sound-conditioned fry

We used the same method as in 1) and calculated the recapture rate of red sea bream in fiscal years 1988, 1989, and 1990 when the sound-conditioned fry were released. The respective recapture rates were 0.1%, 0.02%, and 0.77% for yearling fish; 2.21%, 3.75%, and 2.80% for one-year-olds; 1.46%, 1.77%, and 0.39% for two-year-olds; 0.38%, 0.38%, and 0.39% for three-year-olds; and 0.02%, 0.02%, and 0.01% for four-year-olds. The total recapture rates were 4.17% in 1988, 5.93% in 1989, and 4.36% in 1990.

The recapture rate of the sound-conditioned red sea bream ranged from 1.28 to 5.7 times higher than that of the non-sound-conditioned fish. Large differences in the recapture rates were observed especially in one-, two-, and three-year-old fish between the sound- and non- sound conditioned fry.

DISCUSSION

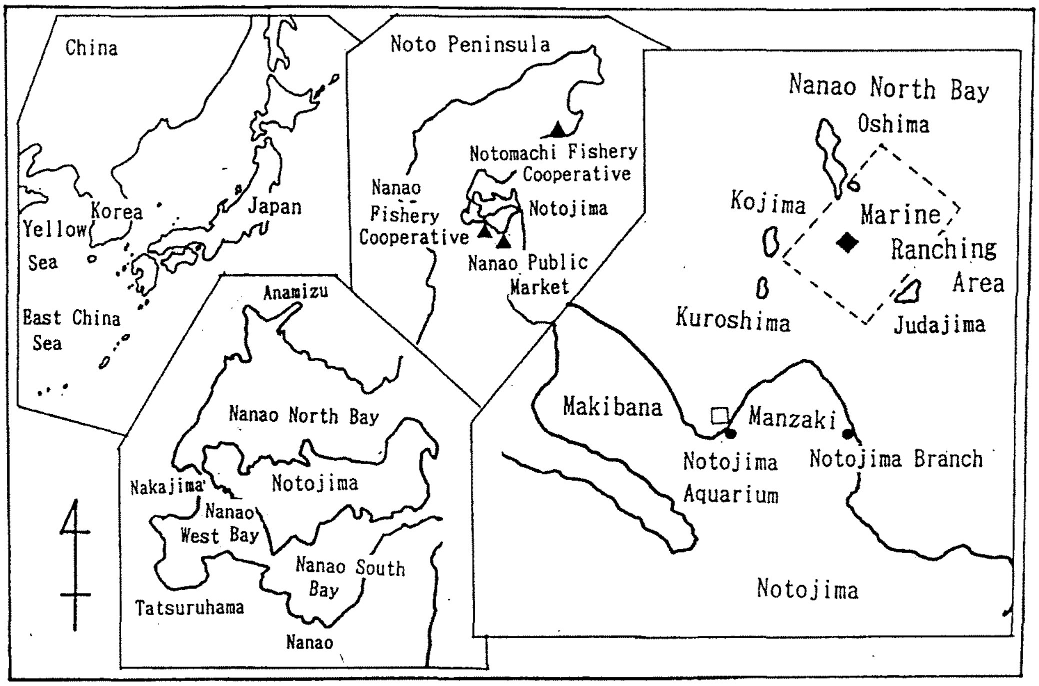
In fiscal years 1985 and 1987, we examined by the use of traps the recapture pattern of the non-sound conditioned fry. In both years the number of recaptured fry rapidly decreased shortly after the release and then diminished more gradually. Thereafter very few fry were recaptured in November. The number of recaptured fry thus declined exponentially. Conversely, in the case of the sound-conditioned fry released in fiscal year 1989, the number of recaptured fry failed to decrease until the end of December. It is estimated that the sound-conditioned fry only minimally migrated from the marine-ranching area. These results indicate that sound-conditioning is effective to retain released fry within the marine-ranching area.

We examined the difference in recapture rates between the non-sound-conditioned and the sound-conditioned fry. The recapture rates of the non-sound-conditioned fry released from fiscal years 1984 to 1987 varied from 1.04% to 3.04%, and those of sound-conditioned fry released from fiscal years 1988 to 1990 varied from 4.17% to 5.93%. The recapture rates increased by 1.28 to 5.7 times as the result of sound-conditioning. Based on these results, we concluded that sound-conditioning suppresses the dispersion of released fry and increases the recapture rates.

Little progress has recently been made in the release project of red sea bream despite improvement in the method of release, such as by marine-ranching. In the present project, red sea bream are reared from the egg stage to 30 mm in fork length at the Notojima Branch of the Ishikawa Prefecture Fisheries Research Center. Thereafter the fry are transferred to local fishery cooperatives, grown to about 50 mm in fork length, and then are released into the sea. Although those processes require a great deal of labor and cost, only limited effects can be achieved. Accordingly, measures are implemented such as nursery-ground development and marine-ranching area. These managerial methods improve the effectiveness of release, but are expensive. Practical effectiveness is thus lower than we had expected.

It is also reported that red sea breams of older than four years released in Ishikawa prefecture were recaptured in Akita prefecture, about 400 km from the release area. This illustrates the wide extent of red sea bream migration. These account for the slow progress of release project of red sea bream.

To promote future cultural-fishery of red sea bream, it is necessary (a) to reduce the cost of seed production and intermediate rearing, (b) to establish an inexpensive method for minimizing in the loss of released fry, and (c) to design a method that retains the fish in the neighborhood of the release area until they attain fishing-eligible size ..

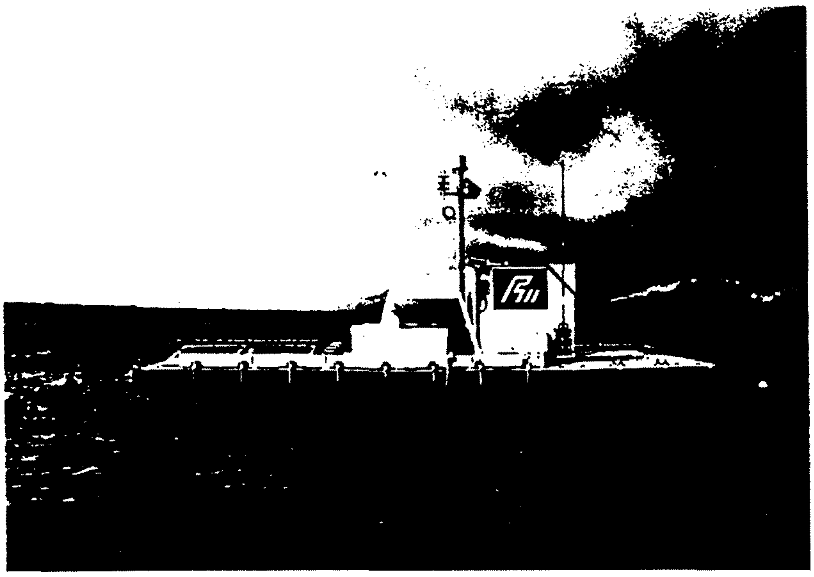


Location of the marine-ranching area in Nanao North Bay and the market examinations.

■ Float structure with automatic feeder, sound emitter, etc.

□ Intermediate culture ground for red sea bream fry to be conditioned to sound and feed.

▲ Markets where are conducted to observe and measure red sea bream landed.



Float Structure with automatic feeder, sound emitter, etc.

STATUS AND PROSPECTS ON THE DEVELOPMENT AND IMPROVEMENT OF COASTAL FISHING GROUND

Toru Morikawa, President
Marino-Forum 21

INTRODUCTION

Japan is an archipelago surrounded by the sea. The total length of its shoreline is 34,400 km. Cold and warm currents mix in the surrounding waters, generating highly productive fishing grounds suitable for plankton growth (Figure 1). Japanese have been harvesting the sea since ancient times and have a piscivorous culture that stands out in the world, depending for 40 percent of their animal proteins on marine products. Japanese fisheries play a significant role in maintaining healthy and rich dietary habits. The conservation of fisheries is important not only in terms of enhancing fishing productivity through fishery development and environmental preservation of the surrounding waters, but is also vital for producing and supplying safe marine products consumed as food.

WHY IS FISHERY DEVELOPMENT NECESSARY?

First I will describe the present state and problems of Japanese fisheries. Our country has a population exceeding 1.2 million, concentrated on flat land that comprises less than 30 percent of its territory. After the end of World War II in 1945, Japan's coastal regions underwent the creation of seaside industrial zones, prioritizing its industrial reconstruction. Seaside metropolises attracted a rapid concentration of population during the high-economic-growth period of the sixties and early seventies.

Many tidelands and seaweed beds were lost through reclamatory land development. The contamination load of sea areas increased because of factory and household effluents. In recent years, moreover, such development projects as the waterfront enhancement of seaside cities, marine-resort creation, and the construction of offshore airports and large bridges have been energetically pursued. Such development not only overran fisheries in the reclaimed areas, but also destroyed natural beaches. Environmental changes ruined many seaweed beds and tidelands, producing a highly negative impact on the reproduction of fishery resources.

This negative impact is clearly demonstrated in closed sea areas such as the Inland Sea, Tokyo Bay, Osaka Bay, and Ise Bay where seaside cities and industrial zones are concentrated (Figure 2). The contamination load of nitrogen, phosphorus, etc. in these closed-sea areas generated red tides and oxygen-deficient water masses. Considerable harm was done to cultured fish. Damage surpassing ¥2 billion was experienced (Figure 3).

Japan has been aggressively coping with the environmental preservation of offshore fisheries by establishing (a) a water-quality standard based on the Basic Law for Environmental Pollution Control; and (b) a drainage-quality standard for businesses in specified water areas based on the Water Pollution Prevention Law. The restoration and improvement, however, of once-lost or deteriorated fishing grounds, are not progressing smoothly. Accordingly, although the standard for a total catch of 2 million tons is maintained, the state of marine resources in the Japan's coastal waters in terms of useful high-grade fish such as demersal fish is generally deteriorating. This is also because of the imbalance between resources and the volume of fishing activity (Figure 4).

The United Nations recognizes the importance of preserving marine resources and sustainable production in the offshore waters of every country. In Japan's coastal waters under the above-stated conditions, instead of conventional "production-oriented fisheries," "aquaculture and fisheries based on stock enhancement" are aggressively promoted to aim at rational fisheries while striving to increase and cultivate resources.

What are Fisheries-Development and Improvement Project?

Fishery development projects target grounds that increase (a) marine living resources in reefs and tidelands, and (b) seaweed that uses rocky shores for adhesion. Projects expand or newly develop the fishing grounds of such biological resources. Used in the past were techniques such as constructing artificial fishing beaches, demolishing rocky shores, and forming rocky surfaces by the application of concrete. With the postwar progress of related technological development, the number of techniques grew and have been playing a significant role in supporting national projects aimed at advancing coastal fishing and propagating shallow-sea living resources. As a result of strengthened restrictions on overseas fisheries, the importance of coastal fishing grounds has increased in Japan. Since 1976, "aquaculture and fisheries based on stock enhancement" such as sea farming, sea ranching, and marine aquaculture fishing have been effectively promoted. Concurrently implemented have been "Coastal Fishing Ground Improvement and Development Projects." Their principal focus is the development and improvement of fisheries so that natural marine living resources can be aggressively expanded. According to the coastal-fishing-ground improvement-and-development plan based on the "Law of Coastal Fishing Ground Improvement and Development" that is designed to contribute to the stable development of coastal fisheries through suitable fishing ground creation and increased marine-product supplies, the programs are conducted as public enterprises by prefectures, cities, towns, and villages as business entities. This is accomplished by promoting coastal-fishery improvement and development projects. The reasons for conducting fishery-development projects as public works financed by public funds are that the deterioration of coastal fisheries was the by-product of national policies promoting coastal development that gave priority to economic development. Marine products as well as rice are extremely important as basic food for Japanese people. A stable supply must be secured to ensure existence.

The substance of the projects can be largely classified into three categories: (a) work to establish artificial fish reefs to expand fishing grounds for coastal fishing in seawater that should become abundant coastal fisheries (Figure 5); (b) work to develop aquaculture grounds to promote the reproduction of marine living resources along coasts and to protect and propagate them (Figures 6 and 7); and (c) work to conserve coastal sea fisheries (Figure 8) to repair the effects of coastal fisheries in waters where production is declining, by removing accumulated sludge and by creating fairways.

The predictable effects of implementation of such work to develop fisheries include increased production; reduced operating costs and improved freshness of the catch resulting from nearer fisheries; and heightened consciousness among fishermen concerning resource-control and business-management sense through planned operations. The projects thus greatly contribute to fishing-community promotion. Examples are as follow.

Increased production (direct effect of projects)

a. Efficient catch by gathering and staying fish around fish reef development of fish-reef grounds)

b. Resource cultivation and increase through development, etc. of spawning areas for fish and seashells, and of protection and nursing areas for juveniles and fries (development of rearing areas)

c. Increased production of cultured fish and shellfish through development, etc. of tranquil waters (development of aquacultural grounds)

d. Restoration of reduced-fishery functions (conservation of fishing ground)

Socioeconomic effects such as reduction of production costs, and life-planning for fishermen (indirect effects)

a. Reduction of commuting hours by placing fishing grounds nearer, etc. reduction in fuel-oil consumption, improvement in freshness of catch), planned operations, reduction in working hours (increased recreation time,life-planning for fishermen), enhanced operational safety (development of fishing grounds in the lee of islands, etc.)

b. Development of fishing grounds nearer the coast and in shallow propagation sites (drilling-type propagation grounds for abalones and sea urchins, propagation grounds for short-neck clams) to lighten labor burdens (enabling operations by the aged, etc.)

c. Development of new fishing grounds to enhance awareness for resource-management-oriented fisheries (coordinating utilization of fishing grounds, effective use of resources, and introduction of resource-management-oriented fisheries, etc.)

d. Expansion of related industries through increased harvests (increase in volume handled by local distributors and processors, etc.)

e. Promotion of fishing as a means for contented living through increased and tabler income.

Environmental improvement of coastal areas by means of cleansing the marine environment, etc.

a. Cleansing of coastal waters through dredging sludge, creating fairways, etc. (improvement of bottom quality, promotion of seawater exchange)

b. Prevention of eutrophication of coastal waters through development of seaweed beds, tidelands, etc. (intake of nutrient salts by organisms, etc.)

c. Preservation of ecosystems through providing habitats for marine living resources in coastal waters

Artificial fish-reef-installation project

Learning from the habit of fish aggregating at natural-fish-reef areas on the seabed, etc., which results in forming good fishing grounds, this project is implemented to install durable structures such as concrete blocks in the ocean to form good artificial fish-reef fishing grounds. The project is divided into the following in accordance with the purpose or size.

a. Small-fish-reef-installation project: This is small-scale work that in principle supplements/expands natural reefs in the waters of common fishing right. The size of one project accounts for fewer than 2,500 cubic meters including inner-space capacity. Concrete blocks are mainly used. The objective is to develop a fishery for line and longline fishing from small craft. Such artificial fish reef is usually used by a single fishermen's cooperative association.

b. Medium-fish-reef-installation project: This is middle-scale work that in principle supplements/expands natural reefs outside the waters of common fishing right. The objective is to develop a fishery for line and longline fishing from small craft.

The size of one project accounts for more than 2,500 cubic meters including inner-space capacity. In addition to concrete blocks, steel structures are used. The fishing reef is utilized by more than one fishermen's cooperative association.

c. Large-fish-reef-ground construction project: A fishery with an artificial fish reef that is similar in size to natural reefs (more than 30,000 cubic meters including inner-space capacity) is developed in waters that although situated along the migratory circuits of a fish shoal, cannot provide good fishing because no natural reefs exist. The project aims at developing fisheries in previously unused deep coastal waters.

d. Floating-fish-shelter-installation project: Noting the habit of migratory fish such as skipjacks and tuna to be attracted by floating objects on the ocean, this work creates a catch ground by installing an artificial floating structure.

Artificial fish-reef roles

Artificial fish reefs were initially understood as fish-attracting facilities designed to expand an existing fishery or to develop a new fishery. These reefs formerly had the character of auxiliary fishing gear. Simultaneously, because line and longline fishing operations were employed there, the auxiliary role was to protect fishing grounds from high-power fishing operations such as trawling and Aguri-purse-seine fishing. Compared with net fishing, line fishing is low in efficiency. Because line fishing avoids catching immature fish whose product value is low, and concentrates on catching mature fish, it naturally protects immature fish attracted to a fish reef. This method is useful to some extent as a propagation facility that rationally uses resources. Work that focuses on the propagation function of artificial fish reefs is included in the work on the creation of ground for propagation of fish outlined in the next section. The species of fish gathered around a fish reef installed on the ocean floor are those that have a relatively small migratory range and are mainly of local stock. Typical are sea bass, three-lane grunts, black sea breams, greenlings and scorpion fish. Red and crimson sea breams also become attached to a specific area.

Japanese striped knifejaws, leatherfish, and Japanese sting fish are attracted to drifting seaweeds in their fry period, but when they begin benthonic life they become locally attached. These species live in their fry period in or around the seaweed beds of shallow coastal waters. It is important in resource cultivation to designate such water areas as protected by installing an artificial fish reef. A protective reef sunk for installation must have a structure and installation method suitable for the fish attracted to it. To accomplish this, it must be ascertained which ecological features attract fish--living sites apropos to growing stages and the actual state of fishery formation. A fish reef can contribute to resource cultivation if a series of artificial fish-reef-installations are created whose habitability ranges from juvenile protection to the nurturing and breeding of mature fish. Provided in addition to sinking and installing is a fish reef that functions (a) as a nursery ground with a poaching-preventive structure to encourage the propagation of seaweed; or depending on conditions (b) as a habitat for juveniles by attaching artificial seaweed, etc. Such fishery-development work helps to breed juveniles by seeking to increase food-chain prey. It is a general tendency of fish to move their habitats deeper in the ocean in accordance with growth. Although differing from fish to fish, the habitat levels from juveniles to mature fish are depths of around 30 to 60 meters. A fish reef exclusive for catch is installed in this breeding ground, whose main purpose is to catch fish.

Many researchers have been studying why fish are attracted to a fish reef. Such factors include the prey effect, the shade effect, and the whirlpool-flow-generating effect. The primary factor for fish aggregation, however, remains to be clarified.

More than 70 kinds of fish are known to aggregate around a fish reef. The distribution around the fish reef differs in accordance with the fish species, which also changes by period, time, and growth stage. To explain the reasons why fish are attracted to the reef, investigation must be made into the fish species and life stage, and the period of the year and time of day. The general reasons why fish are attracted to the reef are that the fishing reef functions as a feeding place, hiding place, and spawning ground. Their sense of hearing responds to such auditory stimuli as vibrations caused by currents around the fishing reef, sounds generated by epizoa, and sounds generated by fish living near the reef--especially feeding sounds. The senses of sight and touch recognize the reef while migrating. The senses of smell and taste respond to organic secretions generated by epizoa--conspecific and relative species (figure 9 and Figures 10 and 11).

Accordingly, ideal fish-reef development means constructing a venue to attract fish and have them reside, to protect juveniles and fries, and efficiently to catch fish by installing a structure on the sea bed. Such a sea-bottom edifice provides strong mobile stimuli for fish and other marine fauna because of the generation of whirlpool flows, etc. to which fish respond and react.

Fish-reef effects

In evaluating the effects of a fish reef, its direct effects as stated earlier include that by attracting and habituating fish, it enables efficient fishery and provides places for cultivating and increasing resources (Figure 12). Indirect effects include factors such as increased safety resulting from bringing fisheries closer to the market, reduced fuel costs, enhanced freshness, and greater income. Quantitative description, however, is difficult. I will outline the effects by demonstrating several examples that have achieved results.

Kawajiri district, Ibaraki Prefecture

A small fish reef was established in 1973. A fishery test was conducted regularly by the prefecture six times in 1991 and 1992. The types of fish caught were 18 compared with seven in the surrounding sandy areas. The catch was 118.7 kg, which was 7.6 times that of the sandy areas (Figure 13).

Nushima district, Hyogo Prefecture

By systematically utilizing an artificial-fish-reef fishery that had been continuously installed since 1964, the production volume of the Nushima fish reef by pole and line fishing, etc. steadily increased. Conversely, the working hours for a given fisherman's family counted in fishing days decreased by about 40 percent from 250 to 260 days to 150 to 160 days a year in 1983 when improvement work progressed substantially from the prefisheries-development years. Yearly working hours were reduced by about 22 percent. The artificial fish reef thus contributed greatly to eased working conditions and fishermen's improved lifestyles (Figure 14).

Usuki district, Oita Prefecture

The main fishery of the Usuki district includes red sea breams, yellowtails and horse mackerels caught by pole and line, and gill-net fishing. Production had been increasing steadily because of the fish-reef fishery. The district's recent catch grew by about three times as compared with before reef installation (Figures 15-1 and -2).

Ryotsu district, Niigata Prefecture

The catch of sea bream in the Ryotsu district was between zero to two tons until 1979, a yearly harvest representing about 0.5 percent of the entire prefectural catch. The catch increased since 1980, the year following the start of fish-reef-installation work. The annual harvest came to about five or six tons in recent years, and was roughly 1.5 percent of the entire prefecture's. The catch by gill-net and longline fishing that often is concentrated around the fish reef recorded an increase (Figures 16-1 and 2).

Ariakekai district, Saga Prefecture

The fish catch of Saga Prefecture remained stable in general. The catch at Ariakekai remained at around 1,500 tons until implementation of the fish-reef-installation project. After completion the catch gradually rose. The catch in 1987 doubled, with more than 3,000 tons, and its portion of the prefecture's catch increased from 3 percent to 6 percent (Figures 17-1 and 2).

The examples stated above show the effects of the small fish-reef-construction projects. The following are examples of medium and large fish-reef-installation projects.

Kozushima district, Tokyo metropolitan area

The catch in the entire Tokyo metropolitan area in recent years showed little increase, but the district's catch with fish-reef fishery has been increasing, especially from pole and line fishing. The proportion of this district's catch in pole and line fishing, of the entire Tokyo total, has been gradually increasing by 30 percent to 40 percent each year (Figures 18-1 and 2).

Atsumi Gaikai (Open Sea) district, Aichi Prefecture

A fish reef was introduced in this area in 1977 to supplement a natural-reef fishery utilized for pole and line fishing. The district's pole and line-fishing catch grew steadily postconstruction. The catch in 1987 reached 430 tons, and the district's catch percentage by pole and line fishing has reached 30 percent or 40 percent of the entire prefecture's harvest (Figures 19-1 and -2).

Yotsukura district, Fukushima Prefecture

The fish-reef fisheries-development project was conducted for five years from 1979. Since completion in 1984, the district's catch increased while the prefecture's catch declined. In 1986 the district's catch was more than double the preproject total (Figures 20-1 and -2).

Sado Hoppo (Northern Part) district, Niigata Prefecture

The prefecture's catch of sea bream remained stable or decreased. The catch of the coastal water district that frequently uses this fish reef steadily increased since 1983 when the fish-reef-development work was completed. The percentage the district occupies in the entire prefecture's catch increased to about 10 percent (Figures 21-1 and -2).

Artificial-fish-reef variations

An artificial fish reef is devised and produced by technicians in the construction industry, concrete-making industry, steel industry, etc., each of which utilizes personal experience and technological development. Each is trying to maximize fish-reef effects, such as stability, aggregational nature, whirlpool and upwelling-flow generation, and shadow-cast areas. Reinforced concrete is a major material but some use steel. FRP is employed for some floating fish reefs. The height of a fish reef is considered adequate if it occupies a level equivalent to about 10 percent of the depth of the water. Some have a height of ten meters as a single unit. Let me show you some examples of artificial fish reefs (Figures 22 1-4).

New fish-reef technological development (floating fish shelter)

Fish reefs installed on the ocean floor have been improved and actually utilized in marine-ranching operations. New ideas have been adopted for improvements in structures, forms, materials, etc. that are dedicated to spawning, the protection of larvae and juveniles, residence, induction, harvest, etc. Fishing that uses the habit of migratory fish to aggregate around floating oceanic objects has been conducted since olden times. Line-fishing and purse-seine fishing vessels catch fish offshore by zeroing-in on floating objects. In coastal fishery, fish shoals that gather around moored floating objects placed for shelter-fishing were caught by purse seine. No design method was established, and the fishing industry insisted on the development of durable floating fish shelters. To make use of ocean space for diversified purposes, the Marino-Forum 21 has been promoting the development of artificial structures moored on the ocean surface or under the ocean (floating fish shelters) that actively utilize such habits for gathering, settling, and inducing fish (Figure 23). In development, both (a) a gathering test using a feeding system and a fish-attracting lamp, and

(b) a durability demonstration test were conducted in the course of a comprehensive investigation. Durability was as a result improved with no damage sustained even after the passage of a typhoon. Although some cutting damage of mooring line occurred because of weather-unrelated external factors, the design method for a floating fish shelter has been established. The aggregation effect was confirmed as a result of angling tests conducted by a remote-controlled submarine television and sampling vessel. Large migratory fish such as skipjacks, yellowtails, amberjacks, and dolphin fish were found aggregating around a surface-floating fish shelter. At a midwater floating fish shelter, amberjacks and leatherfish were aggregated. A floating fish shelter is thus expected to be utilized for improved efficiency of coastal and offshore fishing. Floating fish shelters can be divided into single- and multifunctional types. Whereas the former aims merely at effective aggregation, retention, and induction of fish, the multifunctional version is a floating fish shelter installed with equipment for feeding, water spraying, light emission, etc. It is loaded with observation equipment used to develop effective utilization of offshore waters. The surface-type floating fish reef is of two types. One type floats continuously while the other sinks below surface level during extraordinary conditions such as tumultuous waves or strong currents.

I will mention the Tosa Kuroshio Ranch Buoy installed in Kochi Prefecture as an example (Figures 24 and 25). In this prefecture, nine net-made large-scale floating fish shelters were installed offshore by 1992, based on the Tosa Bay Area Kuroshio Ranch Initiative formulated in 1985. The project achieved great success in gathering and catching surface-layer migratory fish such as skipjacks, yellowfins, and dolphin fish.

In 1991, the fourth and fifth buoys of the Kuroshio Ranch were loaded with marine meteorological observation equipment. With the No. 1 buoy that had been operating since 1988, a system was established to transmit information on hydrographic conditions to the Marine Fishing Center via the prefectural-government disaster-prevention wire circuit from the three Kuroshio Ranch buoys. Also established was a system that relayed information on hydrographic conditions to fishermen as well as to the general public six times a day (every four hours) through telephone-response reporting equipment (Figure 26). In addition to the information from the buoys, information collected from the meteorological satellite NOAA, the Marine Safety Agency, the Fishery Information Service Center, etc. was processed by workstation so that it could be provided (a) to fishermen as the latest information for efficient operations and (b) to experimental fishery stations as research data. The floating fish shelters are thus utilized efficiently for multipurposes in addition to gathering fish (Figure 27).

The fishery effects of a floating fish shelter are outlined below in an example from Okinawa Prefecture. In this prefecture, 177 floating fish shelters were recognized in accordance with Marine Zone Fishery Coordination Committee instructions.

Presently about 160 units are installed at sea depths of 50 to 2,000 meters, all of which are simple types with low production costs as described in Figure 28. These reefs have repeatedly been carried away and reinstalled, and their durability is considered to be about one year. When the fishery effects of a floating fish shelter are considered in the agriculture and forestry statistics depicting chronic changes in overall trolling-line fishing output, while other angling fisheries have remained at a low level, the output of trolling-line fishing surged from the level of 1,000 tons pre-1985 when floating fish shelters were installed, to the level of 3,000 tons in 1989. This clearly demonstrates the magnitude of the effect (Figure 29). The catch conditions before and after the floating fish shelter in the example of the Itoman Fishery Association are noted below. Preinstallation, the association caught shoal fish in natural shoals and shelves around the island. The catch was formerly mainly black marlins and Spanish mackerels as well as yellowfins, skipjacks, and dolphin fish. The small vessels hardly utilized the skipjacks, dolphin fish, etc. that were abundantly distributed offshore. Postinstallation of the floating fish shelters, however, fisheries were formed offshore and such species as yellowfins, black marlins, dolphin fish, and skipjacks were caught (Figures 30 and 31). The output increased dramatically from about 40 tons to 360 tons maximum (Figure 32). The use of floating fish shelters therefore incurs the following effects.

a. Offshore resources of yellowfins, skipjacks and dolphin fish can be efficiently harvested (Figure 33).

b. Yellowfins that inhabit depths of 50 to 100 meters could be caught by such fishing methods as drift angling. Consequently a floating fish shelter could be utilized three-dimensionally. The harvest increased of medium and large yellowfins that formerly were caught by longline tuna fishing.

c. Fishing opportunities expanded because fisheries could be active year-around. As for black marlins, dolphin fish, and small yellowfins, the fishing season was extended (Figure 34).

Propagation and aquacultural ground development project

The project divides into two types:
i. propagation-ground-development and
ii. culture grund development project

a. Propagation-ground-development project

This project promotes in a natural environment the reproduction of marine living resources by sinking stones, installing concrete blocks, developing seaweed beds and tidelands, installing detached breakwaters, etc. The project also enhances resources by improving habitats, hiding places, feeding places, etc., vital for protecting and cultivating released artificial seeds. The project divides into the following apropos to the objectives.

Work for propagating non-migratory resources

Propagation-grounds-development work for non-migratory resources such as shellfish, sea urchins, Japanese spiny lobsters, and seaweed.

Work for propagating migratory resources

Propagation-grounds-development work for such migratory resources as fish and sea arrow squids .

Work for increasing waters' basic productivity

Installing a structure to raise the nutrient salts of the unused bottom layer to an effective level and to propagate phytoplankton.

Work utilizing audio signal training facility

Developing aquacultural grounds focusing on an audio signal training buoy system for sea bream and Japanese flounder by utilizing audio signal training techniques developed by the Marino-Forum 21, etc.

Culturing-ground-development project

Creating culturing grounds for marine living resources by installing wave-damping dikes, by dredging, by forming fairways, etc. in waters difficult to be used for culturing grounds because of unsettled conditions (Figure 35).

(1) Examples of propagation- and aquacultural-grounds-development work and effects
Many propagation- and aquacultural-grounds-development projects have been undertaken nationwide as part of coastal-fishery improvement-and-development projects. Examples and effects of the project are outlined below.

Short-neck clam propagation grounds in the Fukue district of Aichi Prefecture

In the Fukue district of Mikawa Bay, as a result of 68 hectares of tideland-development from 1982 to 1985, 1,500 tons of short-nick clams were produced in 1989 after the work was completed. The grounds were formerly worthless for fishery because of steep undulations (Figure 36).

Nobeoka Hokubu (Northern Nobeoka) district, Miyazaki Prefecture

The district was traditionally poor in sea-bream resources. During three years since 1982, however, a sea-bream protection and cultivation ground of 22.7 hectares was developed by sinking concrete blocks, etc. Also implemented were seed releases and fishery restrictions in propagation-ground waters. As a result the 1991 sea-bream harvest increased by three to four times the preproject level (Figures 37-1 and -2).

Entire Kanagawa Prefecture

The growth of juveniles was promoted by developing propagation grounds (a) as a feeding and growing site for sea-bream juveniles, and (b) for reducing the initial diminution of seed releases. Also by creating growing grounds for larvae and juveniles to improve the effects of seed release, harvests have been increasing (Figures 38-1 and -2).

Oshima district, Fukuoka Prefecture

The waters of this district are off a flat, rocky beach and were not good for fishing in terms of abalone habitat. Postpropagation-ground development, the habitat was improved and seaweed forests of Eisenia bicyclis excellent for feeding were formed.

The district has thus become a major abalone fishery. In addition, because abalone seed-releases were conducted and fishermen engaged in resource management, etc. to promote abalone cultivation, both resources and production have drastically increased (Figures 39-1 and -2).

Tsukinada district, Kochi Prefecture

For four years since 1981, propagation-ground development was done on 250 hectares. Installed were 300 units of prawn-postlarval reef and 723 units of mature-prawn reef. Preproject harvests remained at a level of from one to three tons. In the second year of work, however, production rose to a level of five to nine tons (Figures 40-1 and -2).

Oma district, Aomori Prefecture

Kelp in this district are biennial and the output used to change greatly every other year. After the propagation ground was developed (in the five years from 1982), the annual average output increased by ±1,100 tons to ±3,800 tons compared with that of the prework period. Initially no increase in sea-urchin production was envisaged. Frequently noticed in recent years, however, was the natural generation of sea urchins (kitamurasaki). The natural harvest surged dramatically beginning in 1985 (Figures 41-1 and -2).

Taneichi district, Iwate Prefecture

This district is a rocky beach where at ebb tide flat base-rock predominates. Before the construction work, reef resources such as sea urchins and abalones were only rarely caught. The development work implemented in the district aimed at systematically producing sea urchins and abalones high in product value. Comb-shaped ditches were carved in the base rock to promote seawater exchange by utilizing wave energy. Except for 1984's incident when extraordinarily cold coastal water killed the shell larvae and output drastically decreased, production has been growing steadily (Figures 42-1 and -2).

I have introduced examples of propagation-grounds-development work. The following examples are of projects forming cultural grounds.

Tojima district, Ehime Prefecture

A project to construct a wave-damping structure 480 m long continued in the district for four years starting in 1984. Created was a new tranquil-water area of 36.9 ha. The culturing of yellowtails and striped jacks thus became possible. The harvest from culturing tripled from 400 tons preproject to about 1,200 tons postproject-completion in 1991 (table 43).

Senzaki district, Yamaguchi Prefecture

Traditionally seawater of the Shizuura Bay cultural area failed to exchange well. The reduced amount of dissolved oxygen in the seawater, etc. caused low productivity. Environmental improvement within the fishing ground was thus considered necessary.

To improve the situation, a new wave-damping structure was constructed to expand the seawater cultural area, and a seawater-exchange facility was installed. Consequently it became possible to grow healthy cultured fish, which increased the harvest of produced fish in volume by 188 percent, and in value by 144 percent (Figures 44-1 and -2).

Itanma district, Okinawa Prefecture

A bank enclosure-type culturing ground was developed within the district's coral reef, the construction taking four years from 1979. The purpose was to culture Kuruma prawns. Seeds of 15,000 Kuruma prawns were provided by the Okinawa Experimental Fishery Station. Cultivating them for some ten months until reaching the shipment size of 150 mm, the Kuruma prawns could be shipped to market. This contributed substantially to development of the local culturing industry (Figures 45-1 and -2).

New technological development concerning aquacultural-ground development

The Marino-Forum 21 since its establishment has been developing technology to create several aquacultural grounds. Major examples are introduced below.

Seaweed-bed technological development in a muddy-sand area

Desert-like muddy-sand areas that are relatively flat and lack base rock, etc. are easily affected by ocean waves, drift sands, etc. In such areas it is difficult to form a seaweed bed that provides a feeding place, hiding place, and maturation venue for juveniles and fries. Accordingly, such areas' fishery productivity is lower than that of rocky-beach locations. If, however, a foundation is installed where the spores of oceanic algae and plankton can easily attach and grow, and if technological development artificially to develop a seaweed bed can be established, a flourishing seaweed community will not only provide a growing venue for fish juveniles and fries but also will provide feed for abalones, spiny top shells, and sea urchins. The established structure will also be expected to provide a reef effect and to propagate plankton, which can increase their productivity to the level of rocky-beach areas. In development, verification experiments were implemented on four types of matrix. The characteristics and validity of each matrix were demonstrated.

Lattice-table matrix (Figure 46)

a. Because it is an FRP-made lattice type, it can easily settle seeds and has good light acceptance.
b. Because it is platform-type and three meters distant from the seabed, it cannot easily be affected by herbivorous animals.
c. It can permit easy tidal flow, and has minimal ocean-wave pressures.
d. It will not corrode or be worn out.
e. Square-trapezoid anchor concrete can prevent burying and scouring.

Electrodeposition matrix (Figures 47-1 and -2).

a. It is chemically stable, corrosion-resistant, and durable.
b. The foundation surface is porous so that marine algae can easily settle.
c. The foundation face is a meshwork structure that provides good seawater circulation so that it does not allow substantial floating mud to accumulate.
d. It is not easily affected by ocean waves and drift sand. The weight of the gravitation-system foundation can be reduced.
e. It is easy to manufacture.

Masonry matrix (Figure 48)

a. Because it is a combination of natural stones and square reefs, materials are easily available and cheap.
b. Natural stones are united with a basket easily to ensure stability.
c. Because the foundation is erected with square reefs, burying can be prevented and interstone tidal circulation is good.
d. It can prevent predators from creeping up.

Hollow matrix (Figure 49)

a. It can be manufactured ashore and is easy to install.
b. Because it is erected with pier studs, it is unaffected by drift sand.
c. Because it is hollow and bottomless, seawater circulation is good.
d. Because there is a foundation frame, seaweeds are not easily affected by ocean waves.
e. Ropes that comprise the foundation can be changed easily.

Other specific methods to create seaweed beds are the futon-cage method (Figure 50), steel-pipe-pile method (Figure 51), FRP-cage-method erection style (Figure 52), FRP-cage-method laying style (Figure 53), concrete-block-method (Figures 54-1 and -2), vertical-longline method (Figure 55), and steel-made floating-shelf method (Figure 56). Specific methods to develop the Sargassum zone include the floating-rack cultural method (Figure 57), concrete-block method (Figure 58), net-raft method (Figure 59), and FRP-cage method (Figure 60). The implementation techniques of seaweed bed development in muddy-sand areas have been compiled in a manual. If requested by local governments, these techniques can be utilized in coastal-fishing-ground improvement-and-development work.

Development of a large-scale artificial upwelling-flow-generation technique

In natural environments, many excellent fisheries nourished by natural-upwelling flows exist offshore of Peru, California, and Japan's Tottori and Shimane Prefectures. It is clearly understood internationally that upwelling-flow waters can provide good fisheries. By installing a structure at the sea bottom that artificially generates upwelling flows, and by utilizing tides to draw up nutrient salts that are abundant in the bottom layer of the coastal water to the surface where sunlight is available, plankton generation can be promoted and the water's basic productivity can be strengthened. We have thus been conducting technological development that would develop good fisheries. The Marino-Forum 21 selected the sea bottom of Uwakai, Ehime Prefecture at depths of 46 to 50 m and with tidal-circulation speeds of 40 to 50 cm/sec. To conduct verification experiments, an upwelling-flow-generating structure was installed (plural-column panel-style, Figure 61). It was thus confirmed that around the structure, the density of nutrient salts became higher than preinstallation (i.e., the DIN increased 2.63 times); and that during the spring tide when the flow is rapid, high-density nutrient salts are distributed extensively on the plane.

When compared with the preinstallation time, an increase in phytoplankton (up 7.5 to 25 times in number of cells) and zooplankton (up 2.3 to 2.6 times) was confirmed even in the photic zone. As for benthos, the number of individuals decreased although wet weights increased, and there was a tendency that they were becoming larger. When the summer fisheries distribution and output were compared pre- and postinstallation of the structure in accordance with an investigation result obtained from sample-vessel research, compared with preinstallation a new fishery was found to exist where operation began postinstallation within a range of 12 x 12 m around the structure. The harvest per fishing (CPUE) within the effective seawater area when compared with outside the effective seawater area was 33.36 kg/fishing and 1.7-fold. The number of fishing departures and fish species in the catch also expanded. As stated above, it was confirmed that the structural installation generated upwelling flows (vertical-mixing whirlpool, ascending flow), vertical mixing of nutrient salts, increased phytoplankton and zooplankton, aggregation of fish, and diversity of emerging fish species. The installation work of an upwelling-flow-generation structure has been implemented by the coastal-fishing-ground improvement-and-development work.

Promoted recently in Nagasaki Prefecture of Japan have been verification experiments of technological development to create mound fishing grounds. By utilizing coal ash (fly ash) that was conventionally used for reclamation as industrial waste, concrete blocks were made. These were used en masse to create a large-scale fish reef similar to a natural reef. Upwelling flows were generated in the mound-fishing-ground-development work (Figures 62 and 63). This technological development aims at (a) constructing an ideal mound by manufacturing safe and strong, low-cost concrete blocks; and (b) accurately, simultaneously casting them onto the seabed at greater depths than before (Figure 64).

Offshore-cultural-system technological development

The surface-culture industry in Japan has been developing mainly in tranquil inner bays, etc., but is easily affected by urban and industrial effluents. The deterioration of fishery environments, however, has greatly reduced productivity and quality. In addition, because of low fish prices, aging fishermen, and lack of successors, fishing-industry business management is facing an extremely difficult situation. To improve this environment and to strengthen management, it is urgent that a new type of culturing system be introduced that adopts new engineering techniques. The new system must target modernization and develop it in offshore waters. In Japan, therefore, a new offshore-culturing marine station system was extensively developed for energy saving, streamlining, and economic and quality improvement (Figure 65). Presently verification experiments are underway in offshore areas of Kumamoto Prefecture and Hokkaido. In every case a marine station will be installed in the clean-flowing offshore waters by the tension-leg method or jack-up method. On the platform the station is equipped with an automatic feeder using dry pellets. The station also has measuring instruments and equipment that monitor the marine environment, including water temperature, salt, dissolved-oxygen volume, current direction and speed, wind direction and velocity, and cultured fish in the net cage. The automatic feeder inputs information monitored from the station and is connected to a computer. Input into this computer are necessary data such as the number of released fry, size, health condition, and required-nutrient volume of the fish. The appropriate feed volume will be calculated and automatically supplied at the designated time and occurrence frequency by the computer. Moreover, the feeder is operated either from an onshore control building via optical-fiber cable installed at the sea bottom, or from shipboard by wire. From a silo on the platform a fixed amount of feed is airborne through a pipe to each net cage.

The development of the system enables feeding by a single operator. It also prevents excessive feeding, and thus has provided positive results not only in energy saving, but also in cost reduction and self-contamination prevention.

Coastal-fishery-preservation project

The work is to restore coastal-fishing-ground functions where (a) because of contamination by household drainage, etc., the environment has been damaged; and (b) fishery utility has been diminished by the generation of red tides, etc. The work is conducted through such operations as accumulated sludge removal, bottom-quality improvement through tilling, dredging, fairway forming, and guide-wall installation to promote seawater exchange. Also implemented are such tasks as seaweed-bed and tideland creation to induct nutrient salts via organisms, etc. to prevent coast-water eutrophication, and as habitat development for coastal marine living resources to preserve the ecosystem. An example of such work can be seen in Miyagi Prefecture's Kesennuma Bay. The bay is narrow at the entrance and the seabed is high, which hampers seawater exchange. Because of years of inflow of many kinds of wastewater, organic substances accumulated. Excessive nutrient salts dissolved from the sedimentary bottom layer caused red tides. In summer a nonoxygen layer was formed at the bottom. These factors comprised a great barrier to fishing production such as oyster culture. To overcome the barrier, 191,000 cubic meters of mud in an area of 32.6 ha was removed from the bottom mud layer in ten years. This was the equivalent of removing 3,060 tons of COD and 229.5 tons of all sulfides. As a result the amount of nitrogen dissolved from the bottom deposit decreased by 42 percent and water quality was improved. Before the commencement of the work, red tides were generated for six months of each year. This period was shortened after the work. No generation of oysters turned red as a result of red tides in the latter portion of the work. The ultimate prevention of red tides was thus achieved. Moreover, the output of benthic Japanese flounders increased and fishing became possible even in summer when bottom-layer water quality deteriorates. Kelp-cultural production was begun in the deep bay, which indicated fishing-harvest improvement (Figures 66-1 and -2).

Inhabiting Nemuro Bay in Hokkaido were large colonies of star fish that are deadly enemies of scallops. The on-bottom release of shell larvae was ineffectual and the bay continued to be a low-productive water area. Seabed cleaning work began in 1979 to exterminate the star fish, and the survival rate of released shell larvae improved dramatically. The production volume of about 100 tons preproject increased to several thousands of tons (Figures 67-1 and -2).

Ocean currents around Japanese Islands

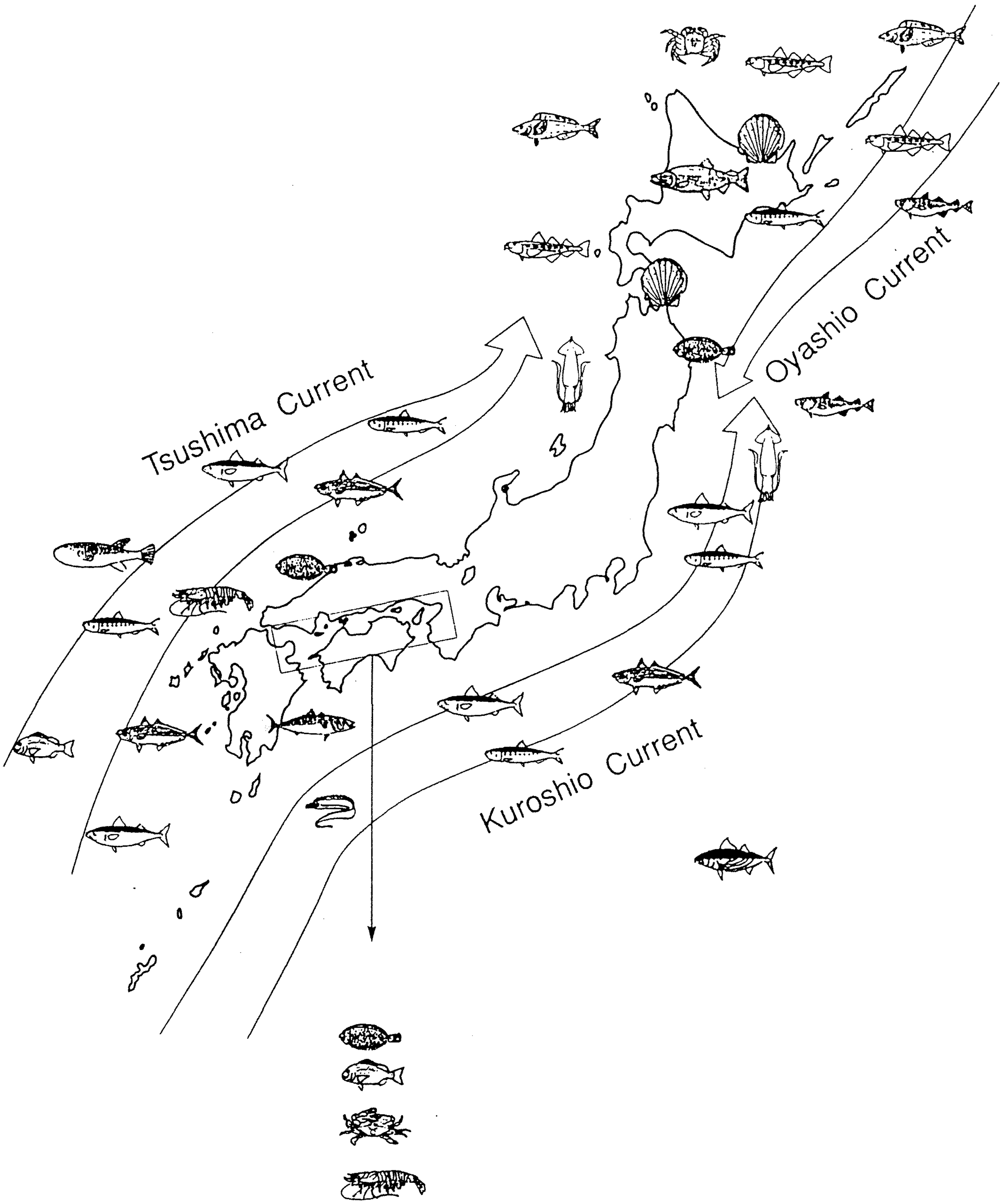


Figure 1

Disappearing tideland

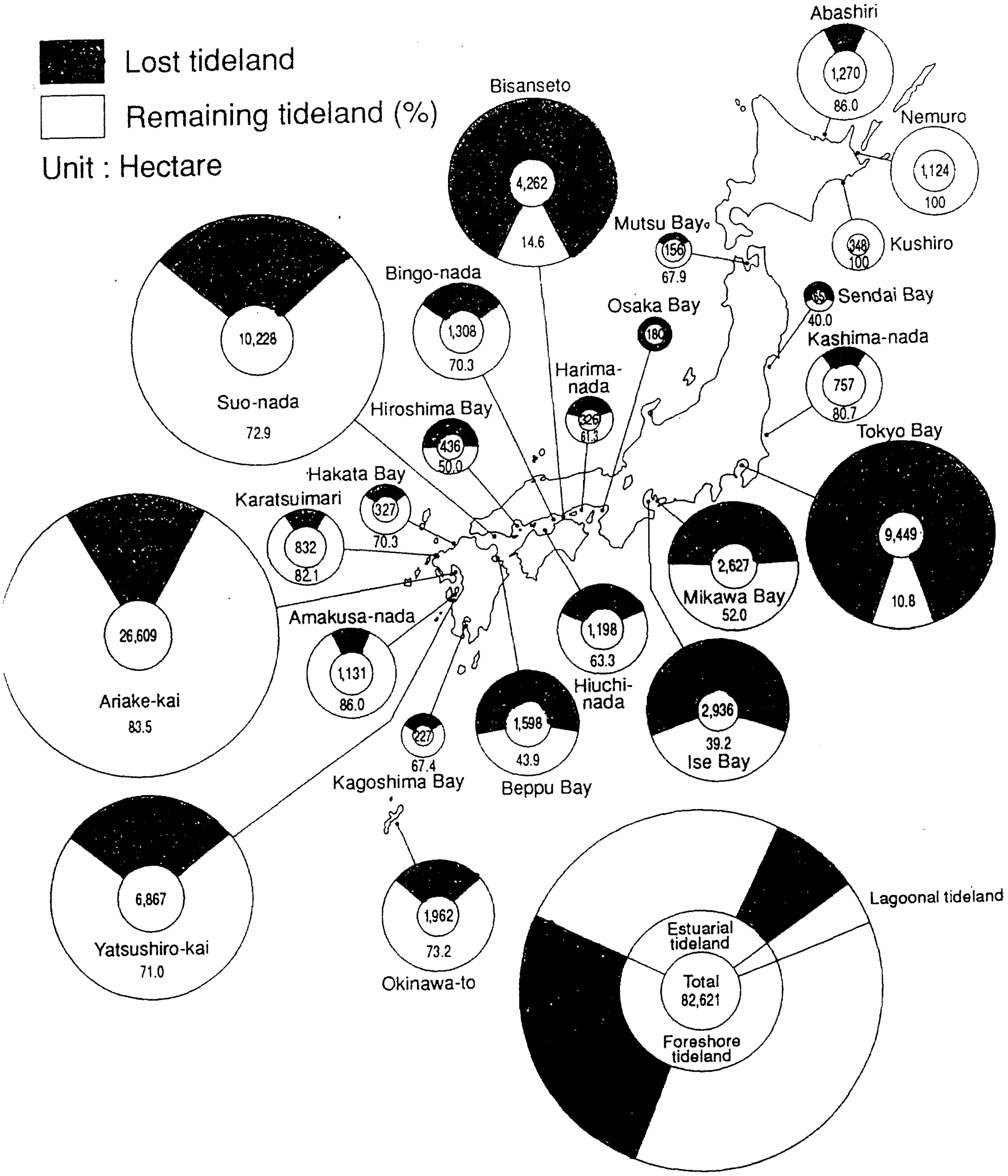
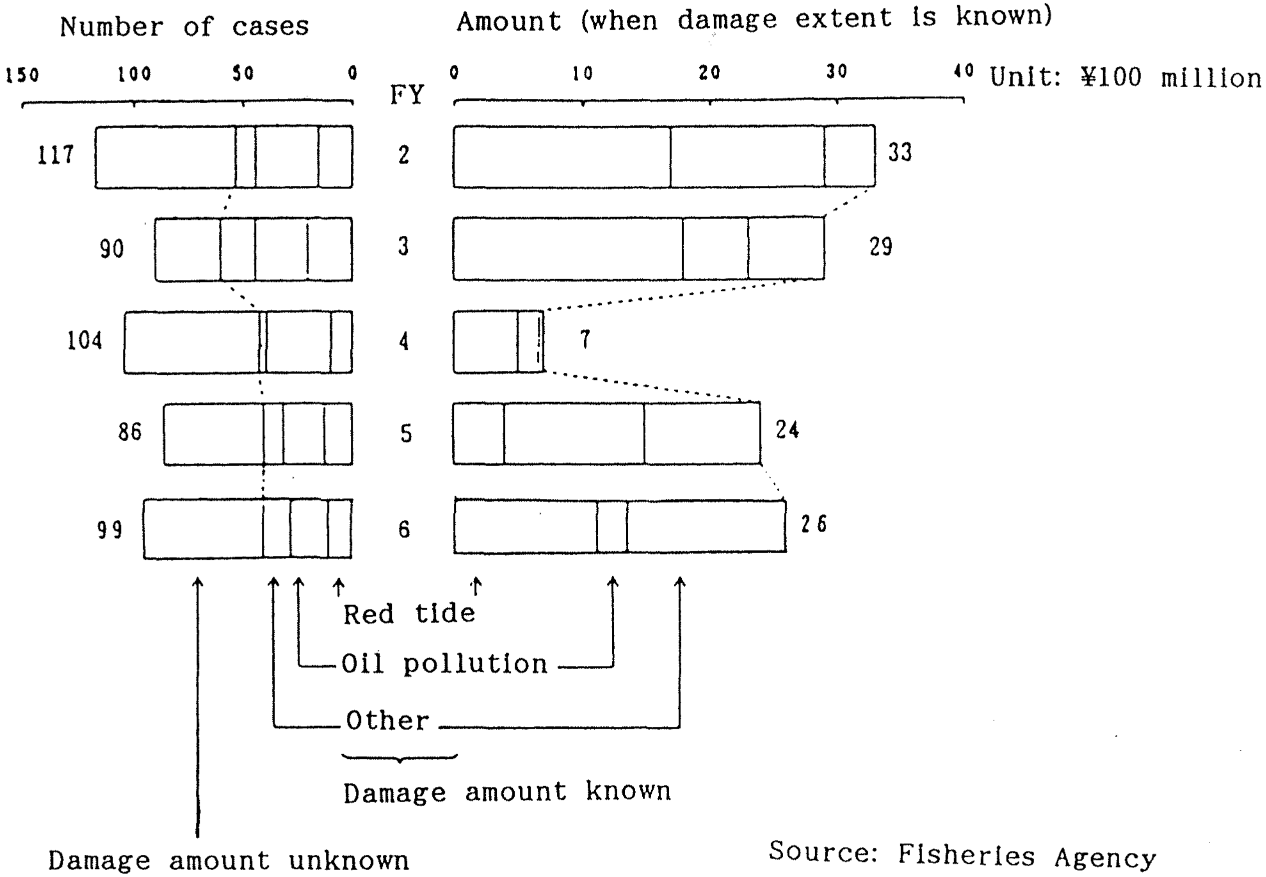
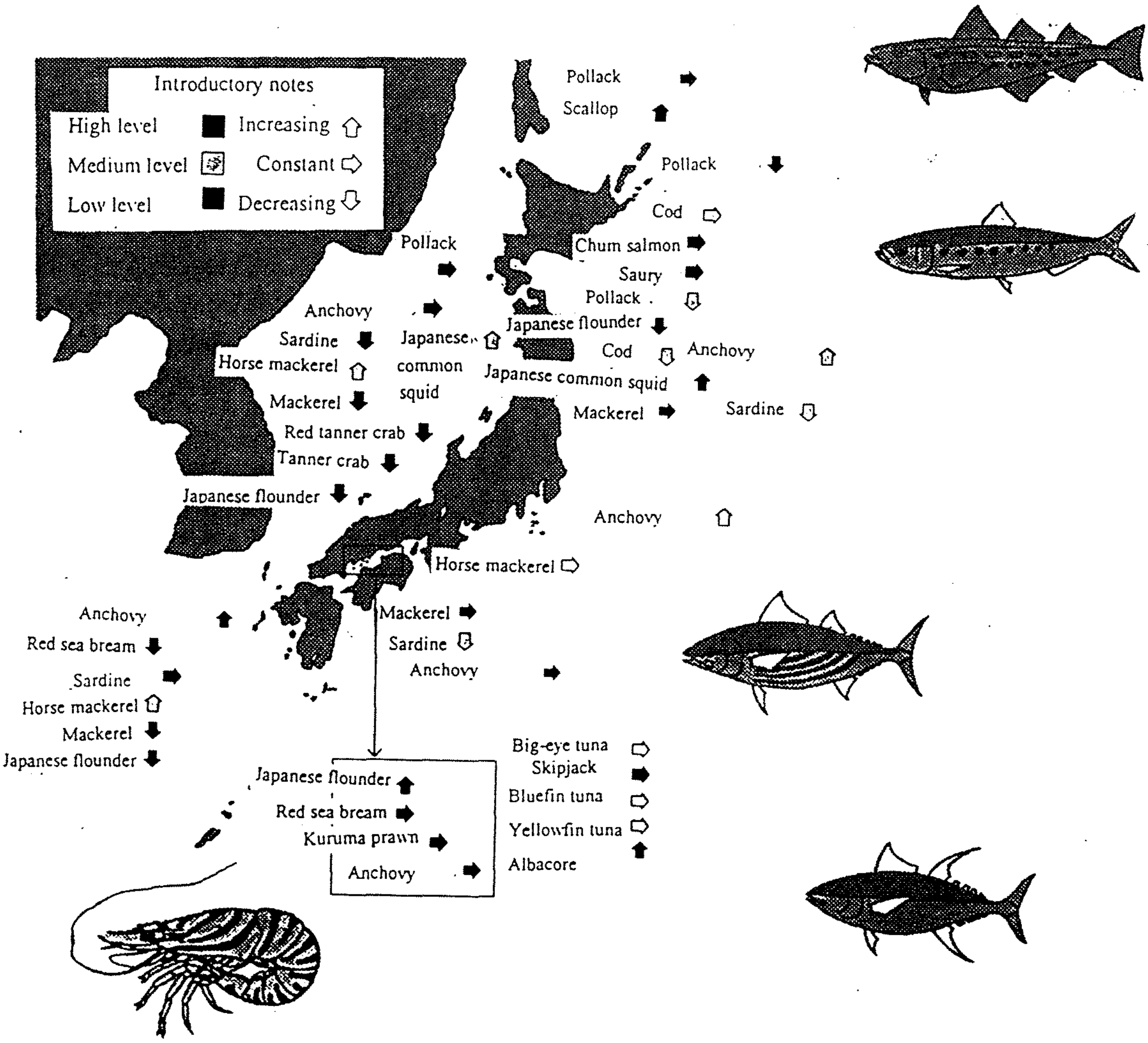


Figure 2

Figure 3: Changes in the generation of sudden fishery damage incurred from seawater pollution, etc. (surface level)



Source: Fisheries Agency



Source: Fisheries Agency

Figure 4: Trends of major marine resources

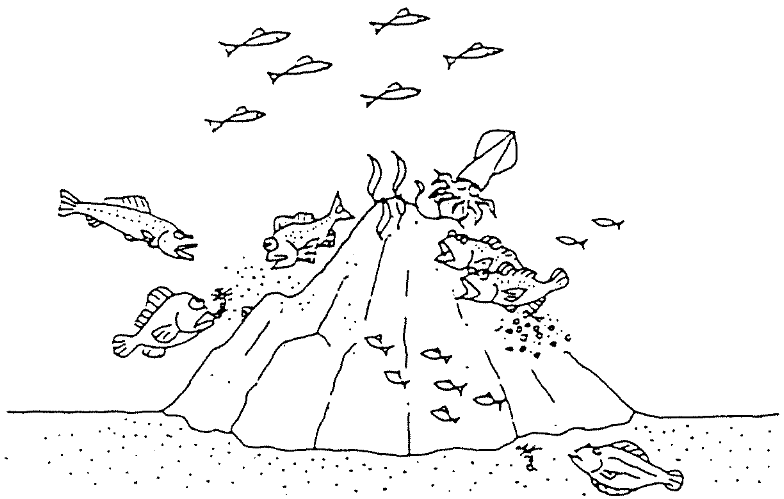
Natural rocky beach, etc. (natural reef)

* Natural reefs form a good habitat and fishing ground.

Feeding area

Hiding area

Spawning ground



Flat seabed, etc.

* Productivity is generally low.

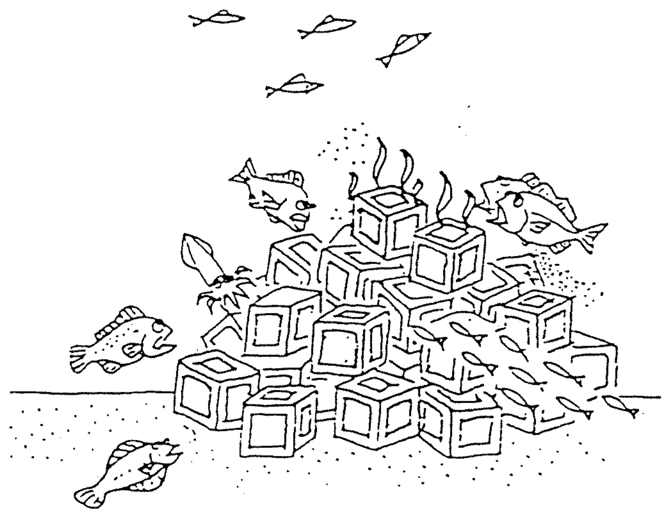
⇓

Installation of artificial fish reef

* Appearance of effects comparable to natural reefs

⇓

Development of good fishing ground



Fish congregate at rocky beaches, etc. of the seabed and form a good fishing ground. Accordingly, the work is to artificially develop a good fishing ground by installing concrete blocks, etc. on the seabed.

Fig. 5 :Artificial-Fish-Reef Installation Project

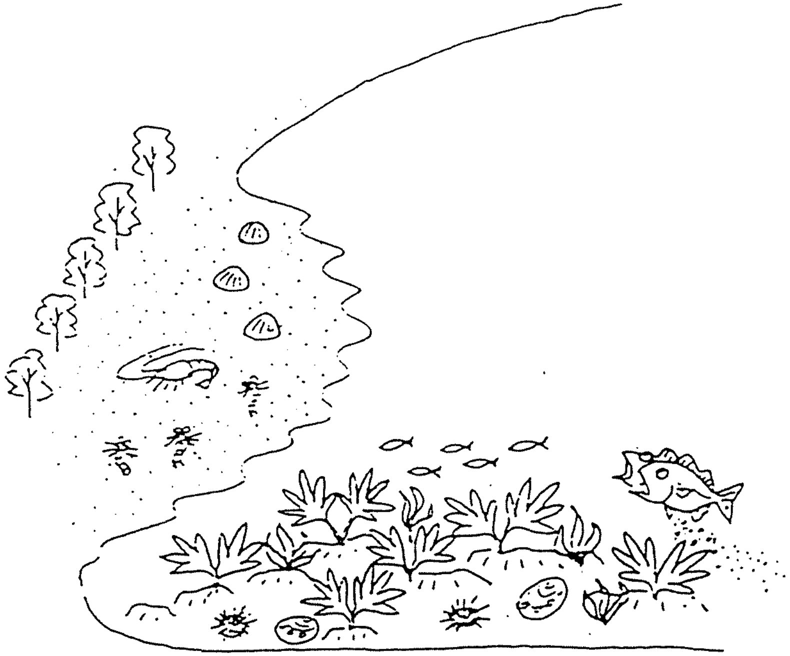
Natural seaweed bed/tideland

* A "cradle" for juveniles, fries, etc. that are especially poor in swimming and feeding capabilities

Habitat

Hiding area

Feeding area



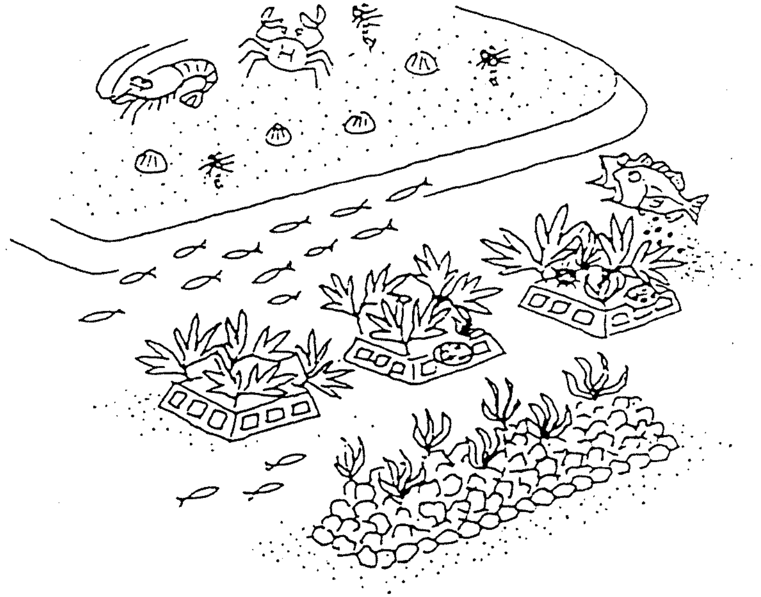
Coastal areas excluding seaweed beds and tidelands

⇓

Development of seaweed bed and tideland

⇓

Increased marine living resources



By developing habitats, hiding and feeding areas, etc. that are vital for growth, an increase in resources is targeted with more numerous fish and seaweed.

Fig. 6 :Propagation-Ground Development Project

Nonutilized fishing ground facing the open sea

* Water quality is good but wind-driven waves are high.

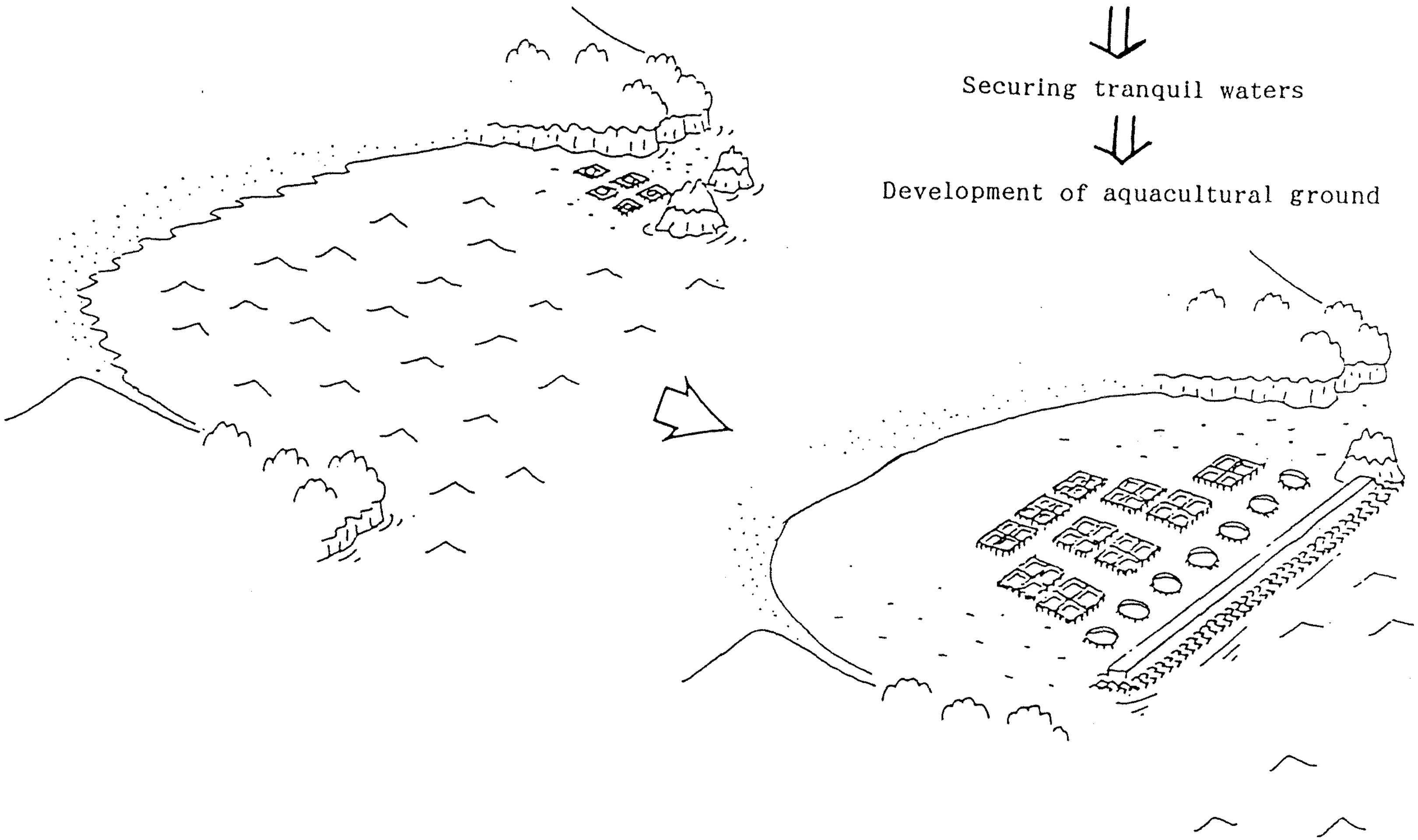
Installation of wave-damping dikes

⇓

Securing tranquil waters

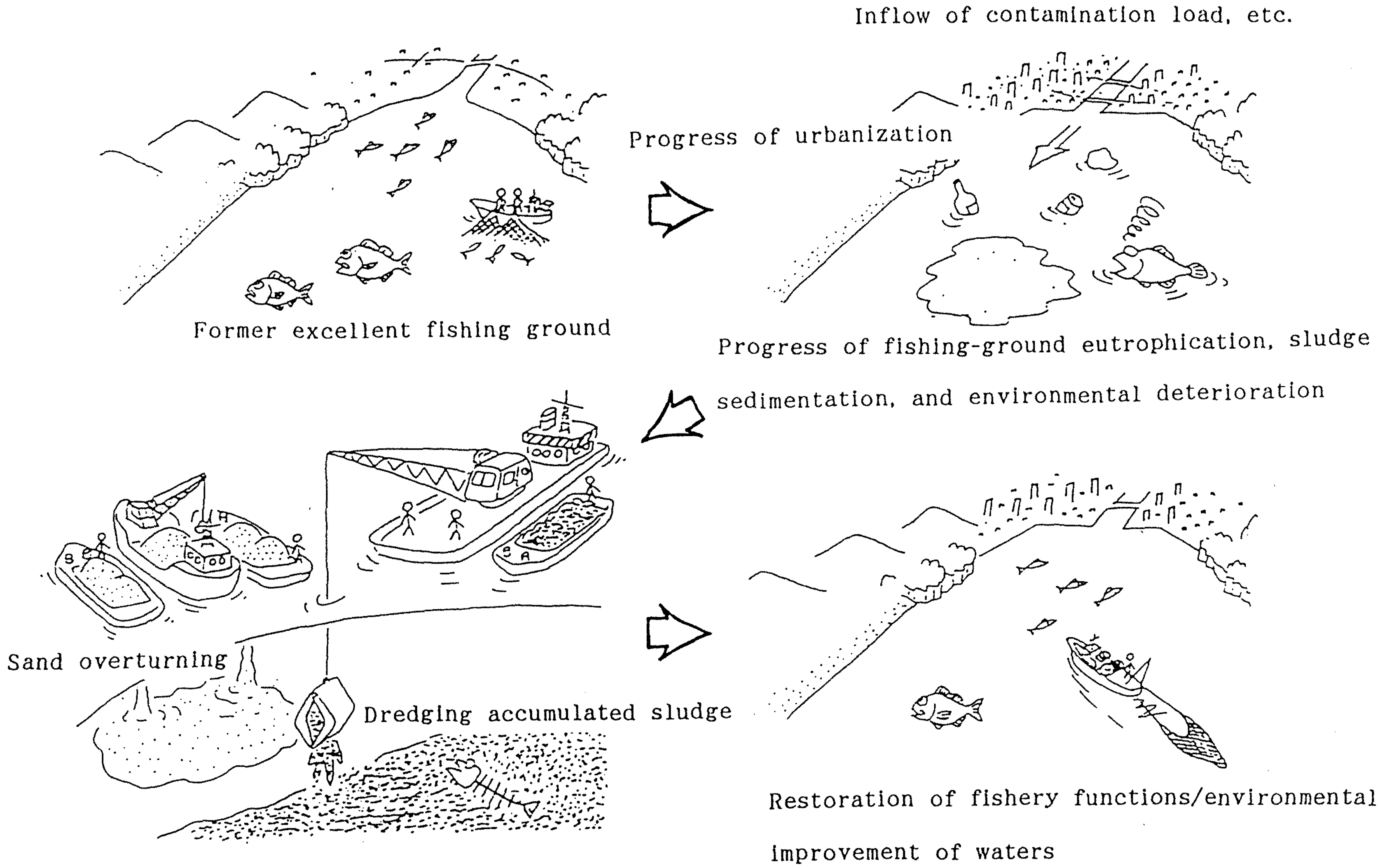
⇓

Development of aquacultural ground



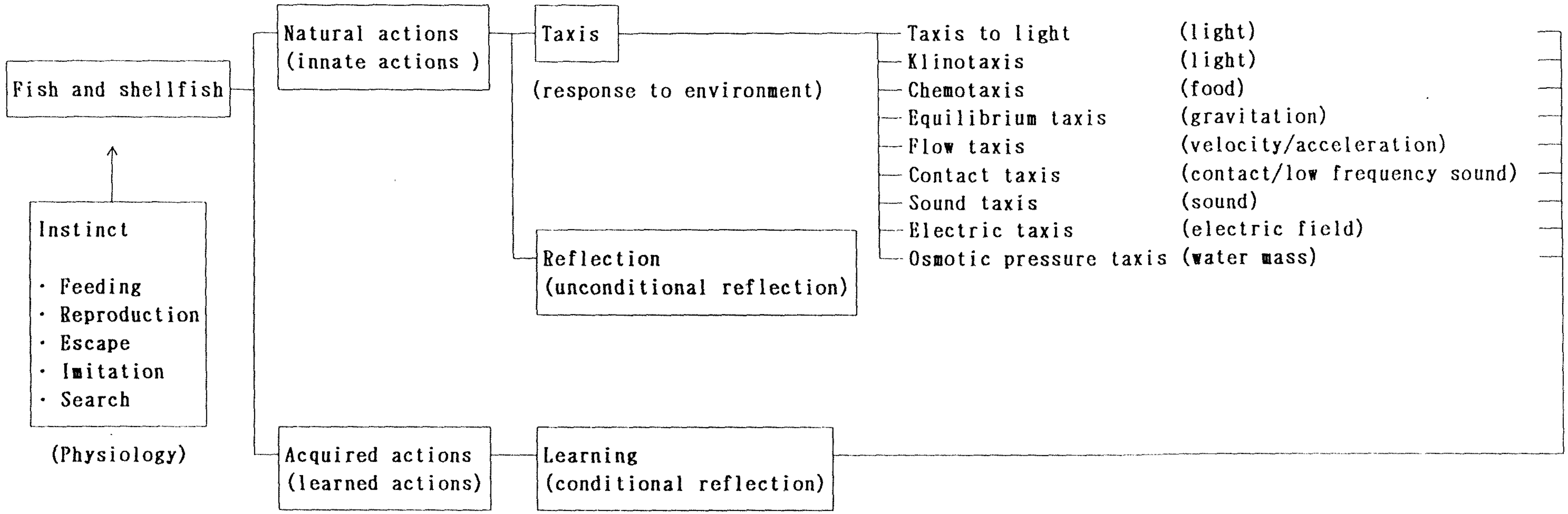
By installing wave-damping dikes, etc., grounds for aquaculture, etc. using fish cages will be constructed in water areas with tranquil waves.

Fig. 7 :Aquacultural-Ground Development Project



By improving bottom quality by dredging accumulated sludge, etc., and by promoting seawater exchange, etc., the restoration of fishery functions and the environmental improvement of coastal waters are sought.

Fig. 8 :Coastal-Fishing-Ground Preservation Project



Environmental stimuli and fish actions

Type I
Fish attracted to reef openings, including groupers, Japanese stingfish, and greenlings. This action originated from contact and flow taxis.

Type II
Fish that do not enter a reef but swim around it, including red sea breams and three–lane grunts. This action originated from taxis to light and flow.

Type III
Fish that remain high above a reef in the upper and middle layer, including yellowtails, sardines, and sauries. This action originated from flow taxis.

Fish–reef structure and fish species

Figure 9: Habitat improvement through fishing–ground development

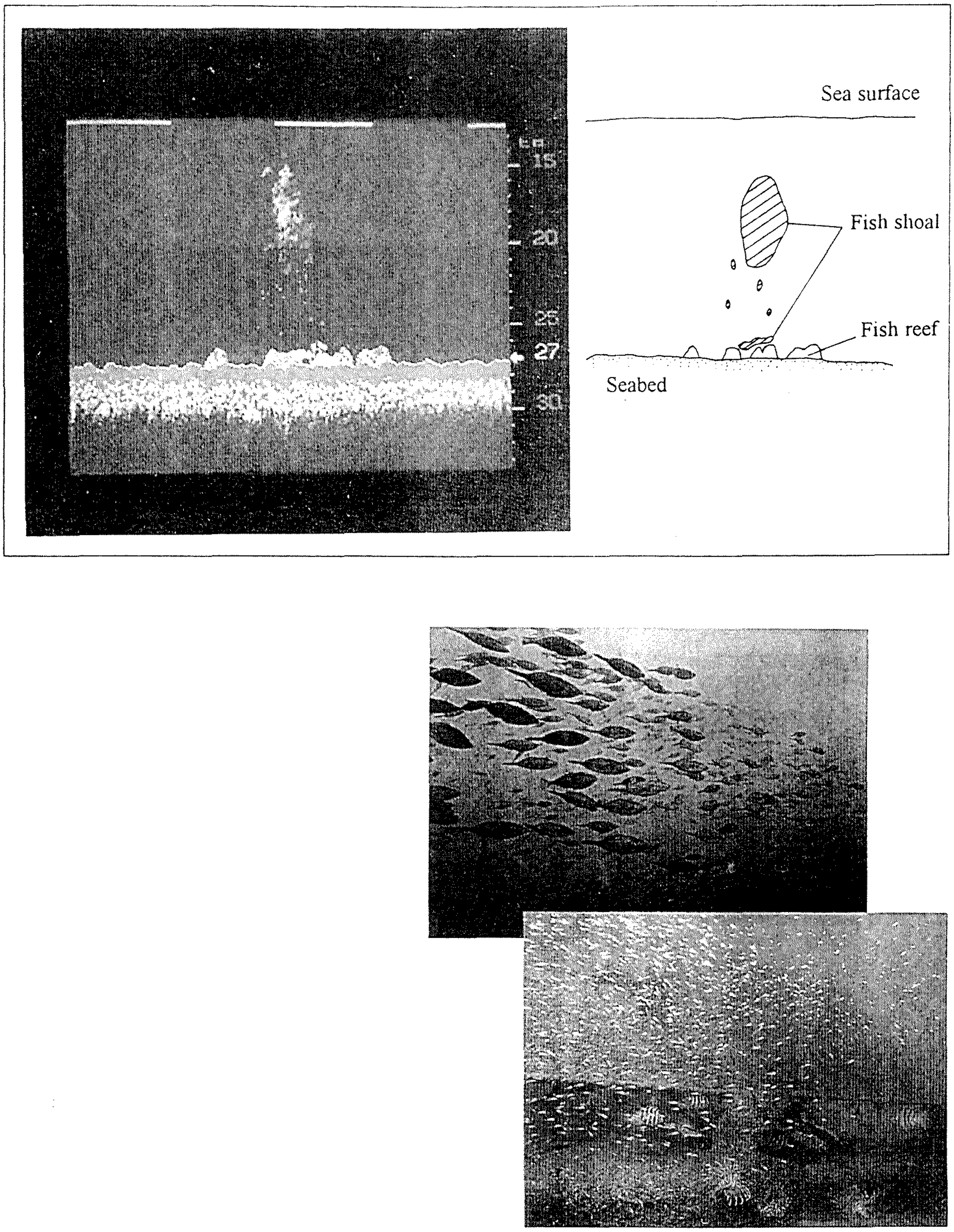
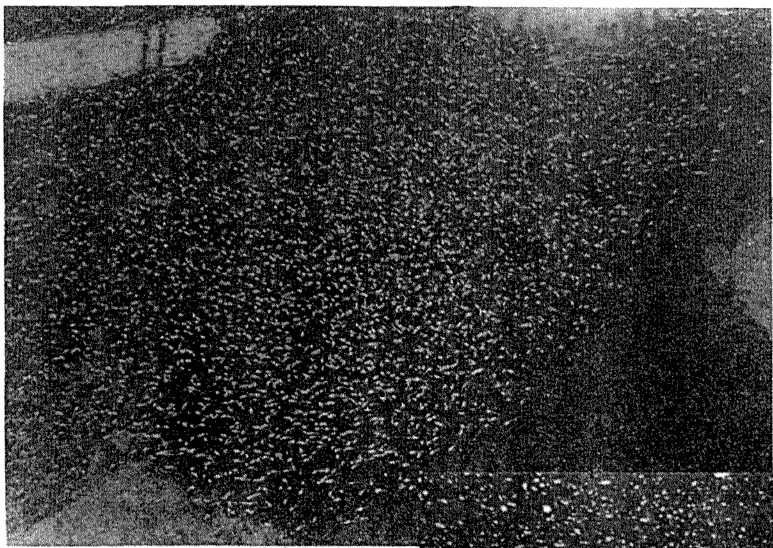


Figure 10: **Aggregation Environment**

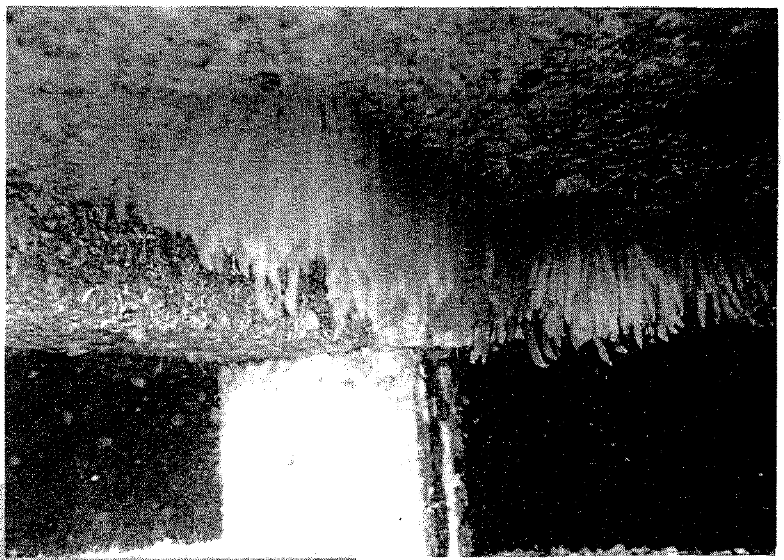


▲ Swarm of mysids formed in fish-reef whirlpool-and-flow waters

▼ Swarm of mysids in a seaweed bed

Figure 11: **Feeding Environment**

Kelp propagating on
▼ propagation blocks



▲Loligo's egg mass spawned on a spawning reef

Figure 12: **Propagation Environment**

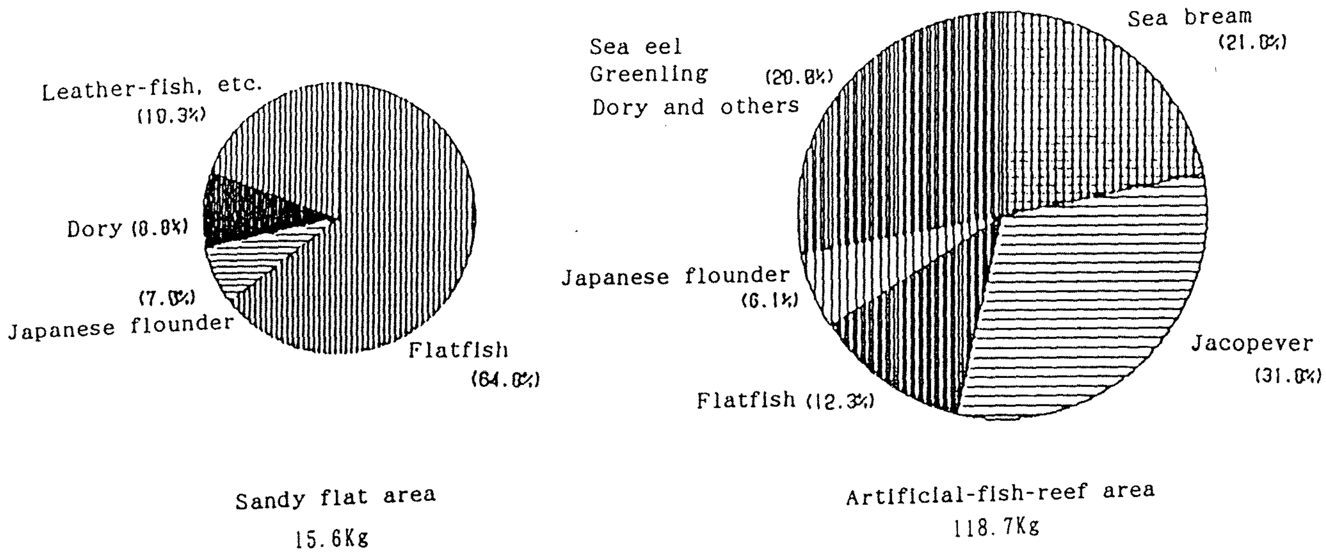


Fig. 13:Comparison of Catch Composition between Sandy Flat Area and Artificial-fish-reef Area

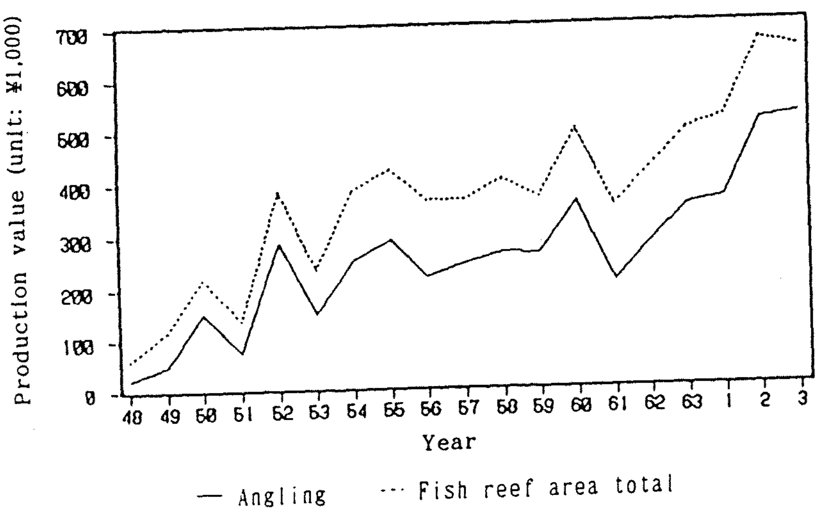
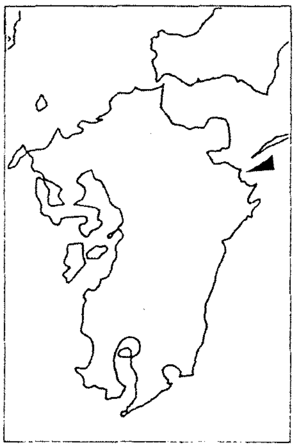
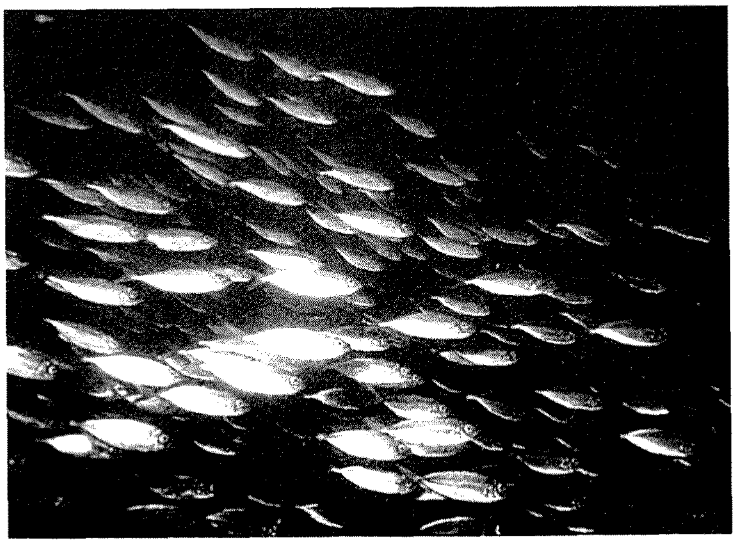
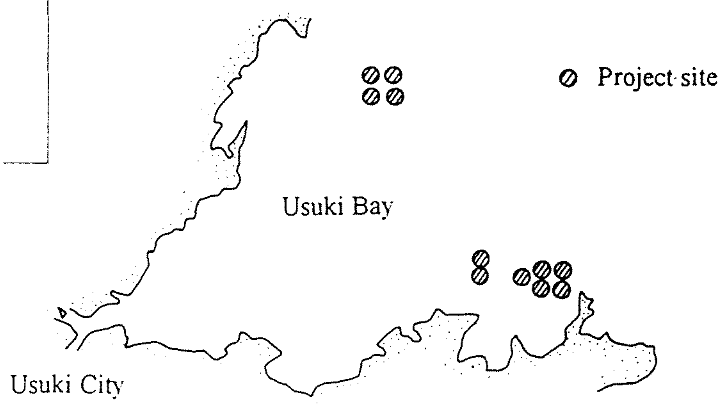


Fig. 14:Changes in amount of Artificial-fish-reef Production

Name of district/ prefecture	Usuki City, Oita Prefecture
Type of fish	Sea bream, yellowtail, horse mackerel
Type of fishing	Angling, gill net, purse seine, trawl net







■ **Project summary**

	Fish-reef-installation work
Project district	Usuki City, Oita Prefecture
Project period	FY 1976-1987
Total work volume	5,089 m³

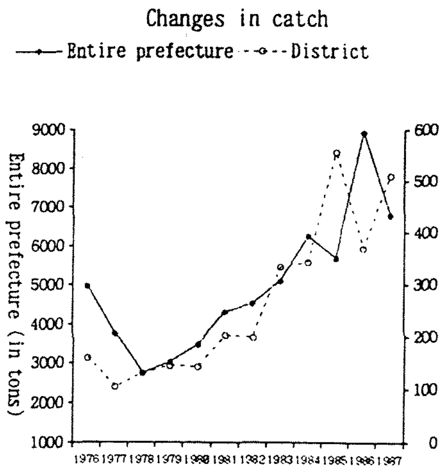
Figure 15-1

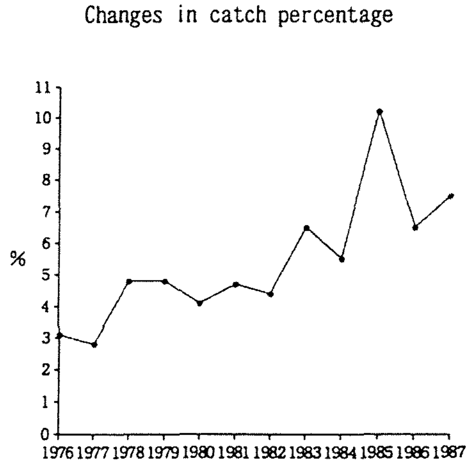
■ Changes in catch by prefecture and project district

☐ : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	4,971	3,751	2,736	3,028	3,466	4,302	4,516	5,094	6,243	5,676	8,934	6,787
Catch by district	159	105	131	145	142	204	199	333	343	557	370	511
District's catch by percentage	3.1	2.8	4.8	4.8	4.1	4.7	4.4	6.5	5.5	10.2	6.5	7.5

* Catch by district/catch of prefecture × 100 = district's catch by percentage





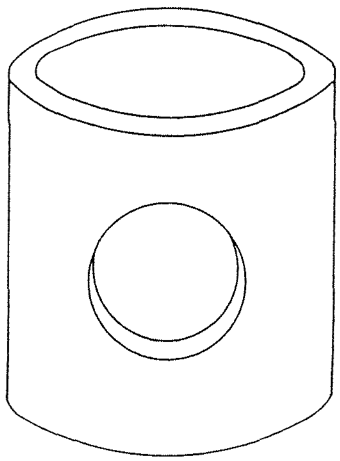
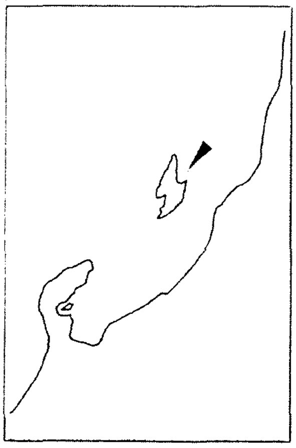
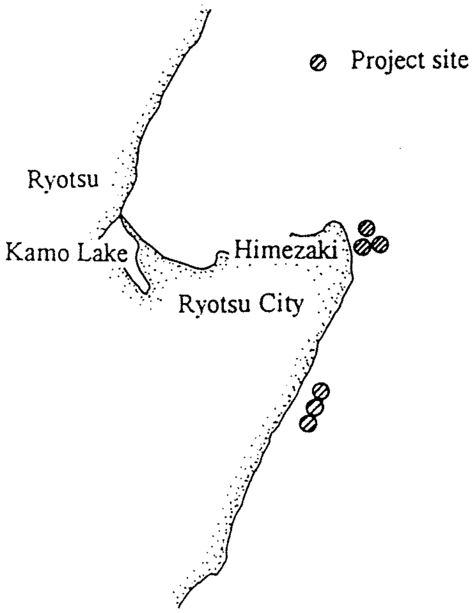


Figure 15-2

Name of district/ prefecture	Ryotsu City, Niigata Prefecture
Type of fish	Red sea bream, yellowtail, Japanese flounder
Type of fishing	Angling, gill net, longline





■ Project summary

	Fish-reef-installation work
Project district	Ryotsu City, Niigata Prefecture
Project period	FY 1979-1985
Total work volume	2,580 m³

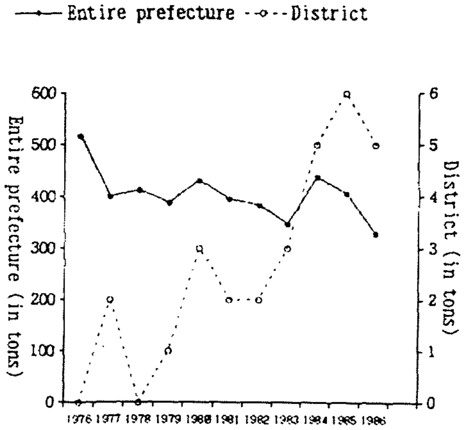
Figure 16-1

■ Changes in sea bream catch by prefecture and district ☐ : Project year (unit: tons)

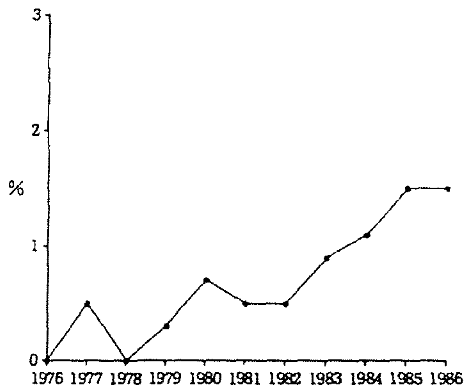
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Catch by entire prefecture	515	400	413	389	430	396	384	348	438	407	329
Catch by district	0	2	0	1	3	2	2	3	5	6	5
District's catch by percentage	0	0.5	0	0.3	0.7	0.5	0.5	0.9	1.1	1.5	1.5

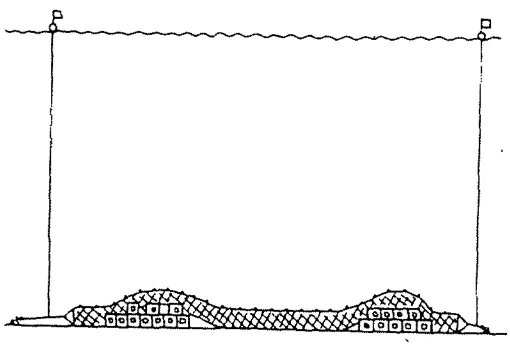
(Niigata Prefecture's Chronological Table of Agriculture and Fisheries Statistics)

Changes in catch



Changes in catch percentage

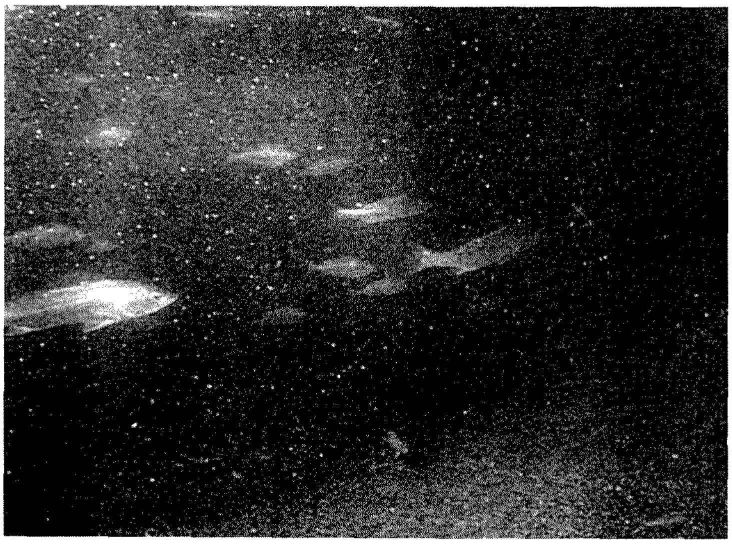


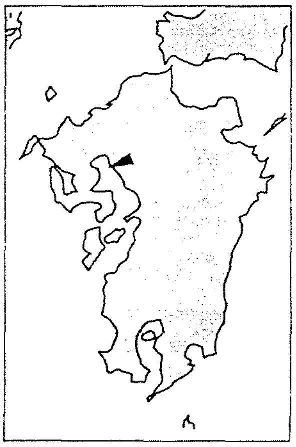


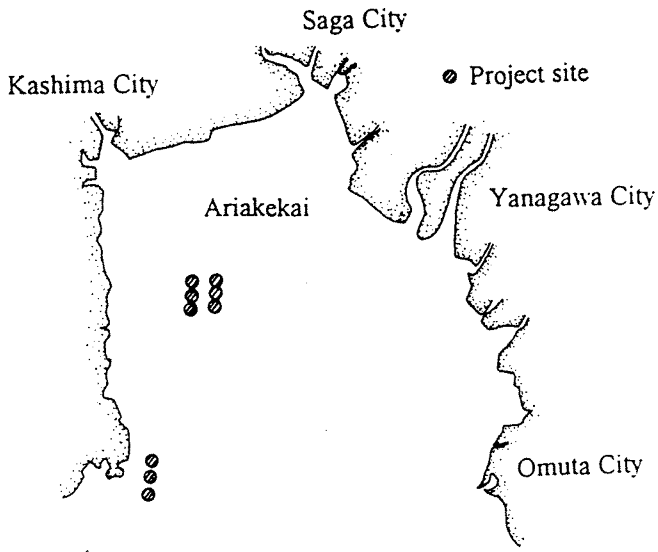
Bottom gill net

Figure 16-2

Name of district/ prefecture	Ariakekai, Saga Prefecture
Type of fish	Sea bass, etc.
Type of fishing	Angling







■ **Project summary**

	Fish-reef-installation work
Project district	Ariakekai, Saga Prefecture
Project period	FY 1978-1987
Total work volume	5,021 m^3

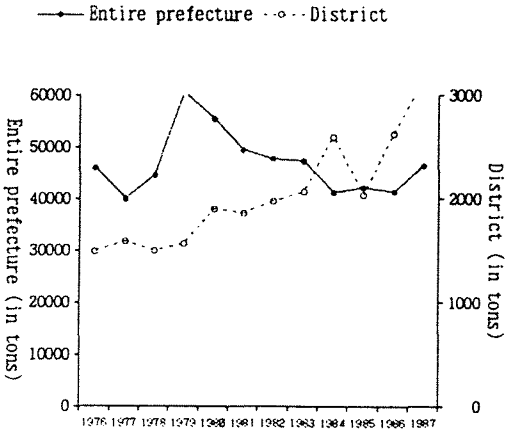
Figure 17-1

■ Changes in fish catch

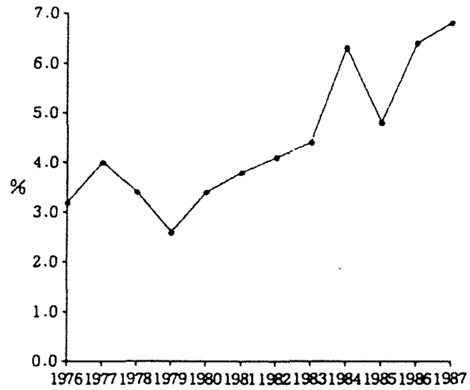
☐ : Project year (unit: tons)

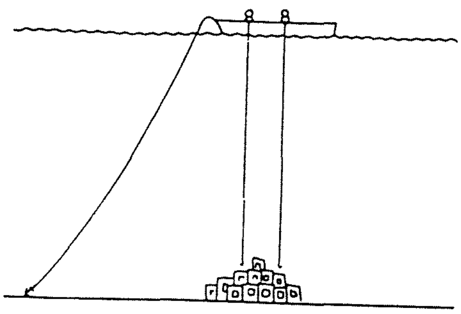
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	45,973	39,988	44,562	60,455	55,474	49,511	47,809	47,354	41,222	42,213	41,353	46,397
Catch by district	1,490	1,595	1,503	1,567	1,902	1,863	1,975	2,074	2,598	2,036	2,634	3,159
District's catch by percentage	3.2	4.0	3.4	2.6	3.4	3.8	4.1	4.4	6.3	4.8	6.4	6.8

Changes in catch



Changes by percentage of catch

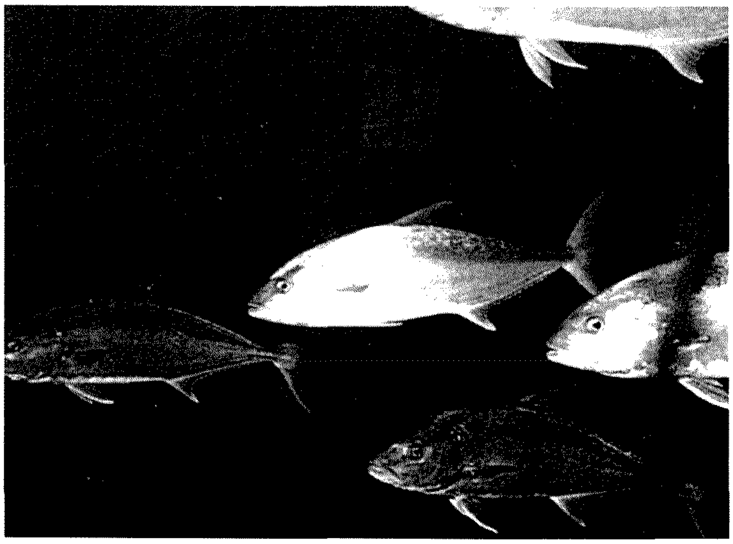


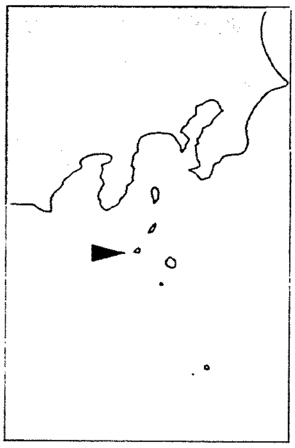


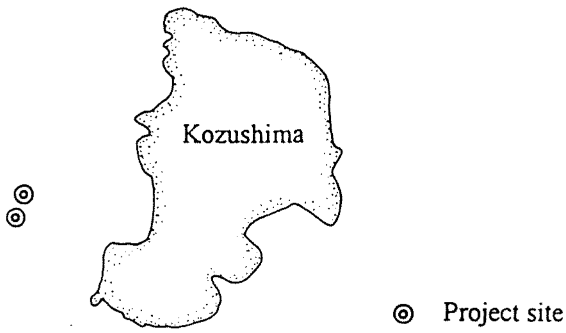
Angling

Figure 17-2

Name of district/ prefecture	Kozushima, Tokyo metropolitan area
Type of fish	Sea bream, yellowtail, striped jack, mackerel scad
Type of fishing	Angling







■ **Implementation of coastal development project (unit: in m²)**

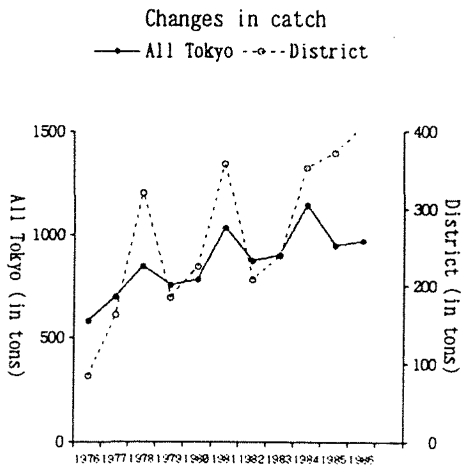
Project year	Project name	District name	Work volume
FY 1982	Large-scale fish reef	Kozushima	2,509
FY 1983	〃	〃	2,509

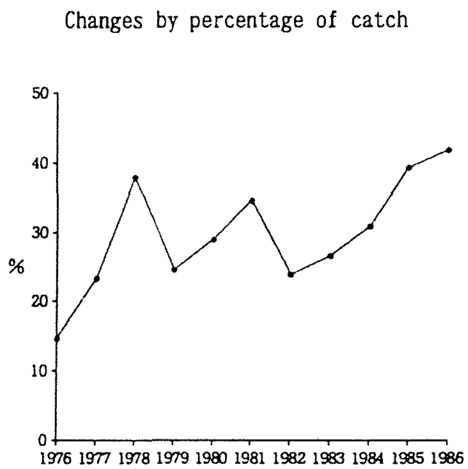
Figure 18−1

■ Changes in catch by angling

☐ : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Catch of all Tokyo	579	699	845	756	781	1,037	874	902	1,145	946	972
Catch by district	85	163	321	185	226	359	208	240	354	373	407
District's catch by percentage	14.7	23.3	38.0	24.5	28.9	34.6	23.8	26.6	30.9	39.4	41.9





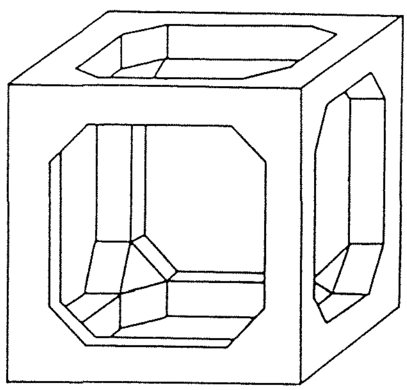
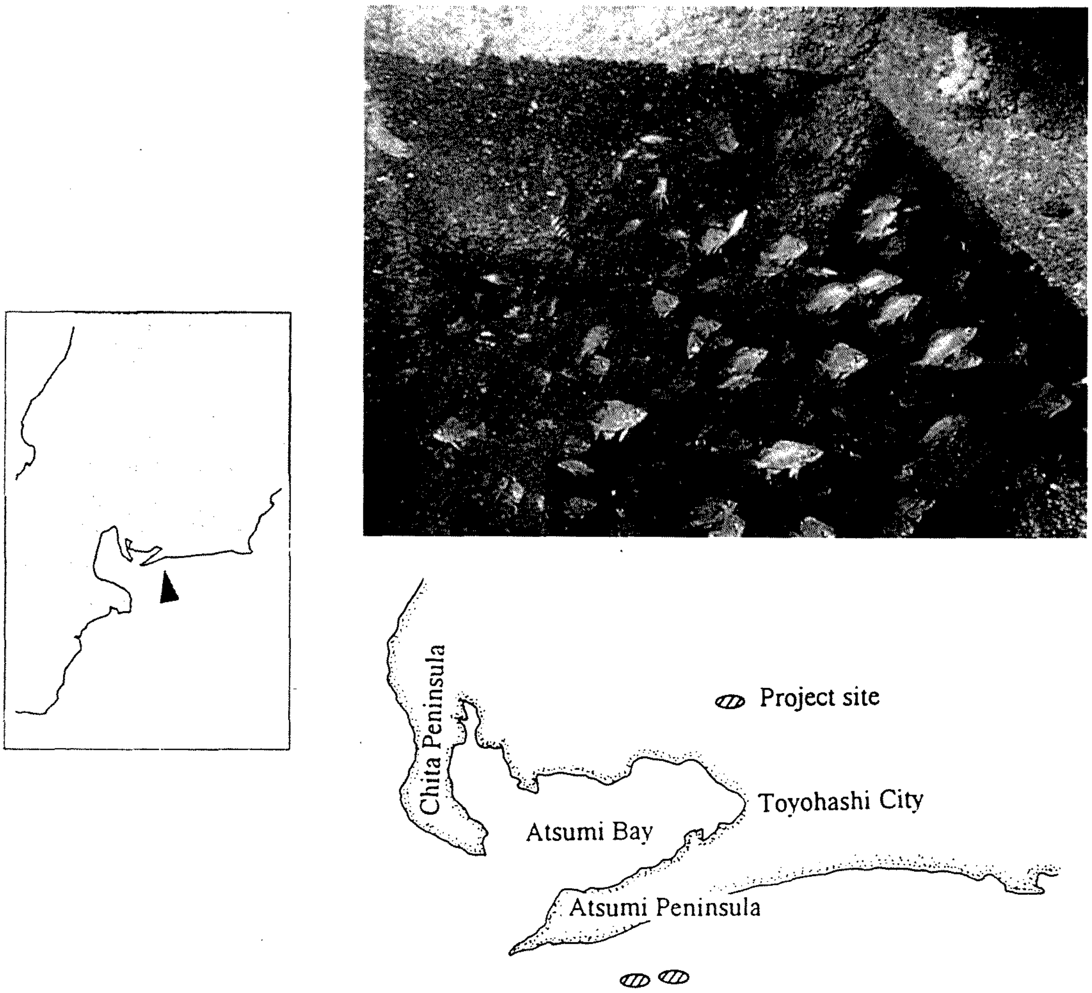


Figure 18-2

Name of district/ prefecture	Atsumi Gaikai District, Aichi Prefecture
Type of fish	horse mackerel, mackerel, three-lane grunt, Japanese stingfish
Type of fishing	Angling



■ Project summary

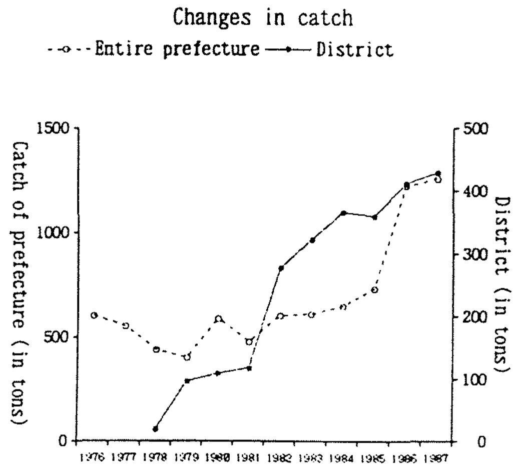
	Fish-reef-installation work
Project district	Atsumi Gaikai, Aichi Prefecture
Project period	FY 1977-1987
Total work volume	40,094 m³

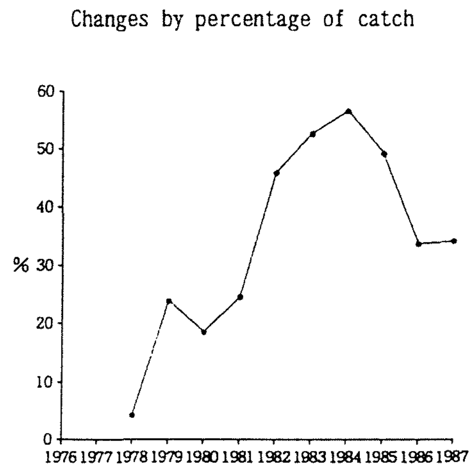
Figure 19-1

■ Changes in catch by angling

☐ : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	605	555	441	401	589	478	604	612	649	733	1,223	1,259
Catch by district	—	—	19	96	109	117	277	322	367	360	412	430
District's catch by percentage	—	—	4.3	23.9	18.5	24.5	45.9	52.6	56.5	49.1	33.7	34.2





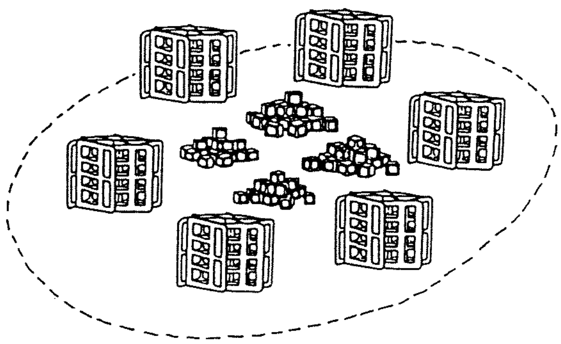
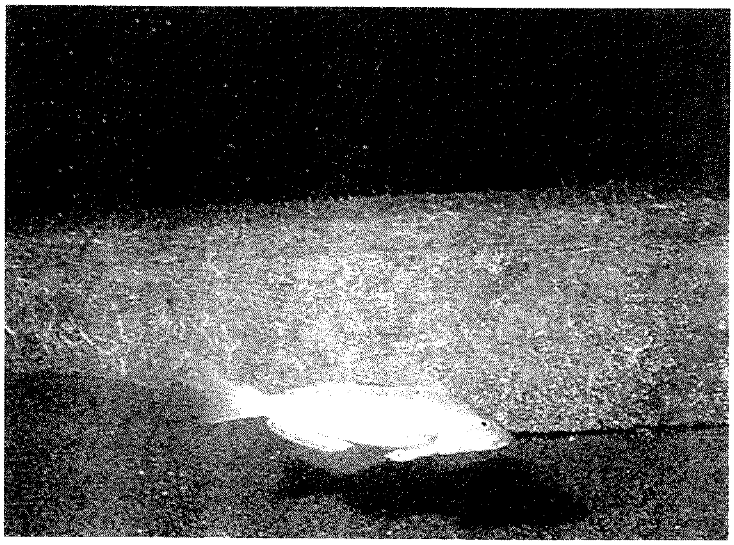
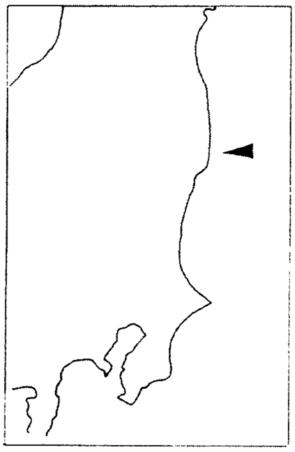
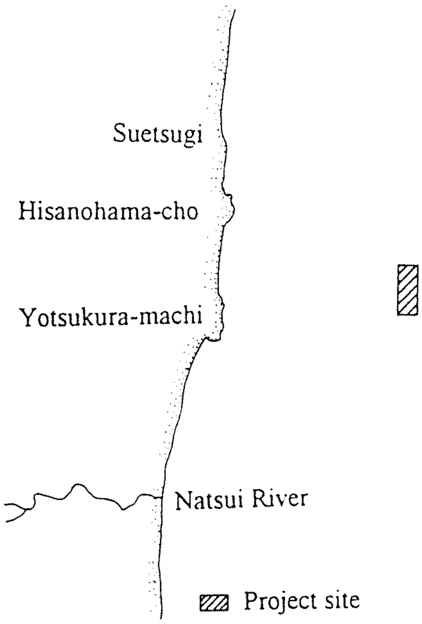


Figure 19-2

Name of district/ prefecture	Yotsukura District, Fukushima Prefecture
Type of fish	Flatfish, greenling, sea bass, Japanese stingfish, Japanese flounder, yellowtail
Type of fishing	Gill net, longline, angling







■ **Project summary**

	Artificial-reef-fishing-ground development project
Project district	Yotsukura District, Fukushima Prefecture
Project period	FY 1979-1983
Area of project	6.0 km^2
Major structure	1.5 m square-shaped reef, etc.

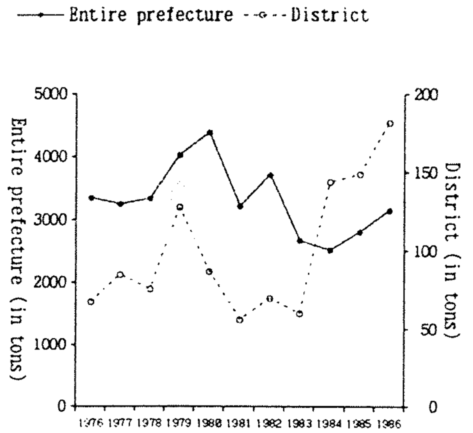
Figure 20−1

Changes in catch by prefecture and district

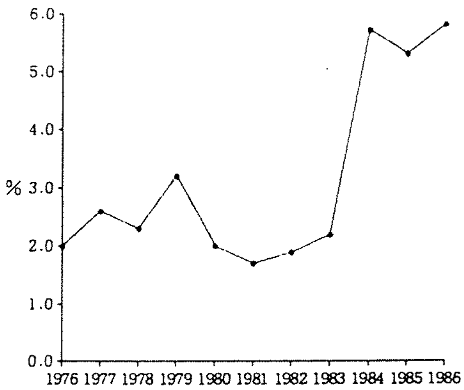
□ : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Catch by entire prefecture	3,353	3,249	3,339	4,029	4,390	3,212	3,714	2,670	2,513	2,807	3,149
Catch by district	68	85	76	128	87	56	70	60	144	149	182
District's catch by percentage	2.0	2.6	2.3	3.2	2.0	1.7	1.9	2.2	5.7	5.3	5.8

Changes in catch



Changes by percentage of catch



Rough arrangement plan

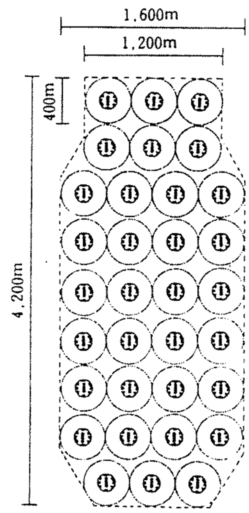
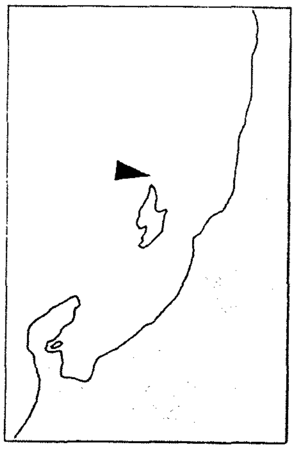
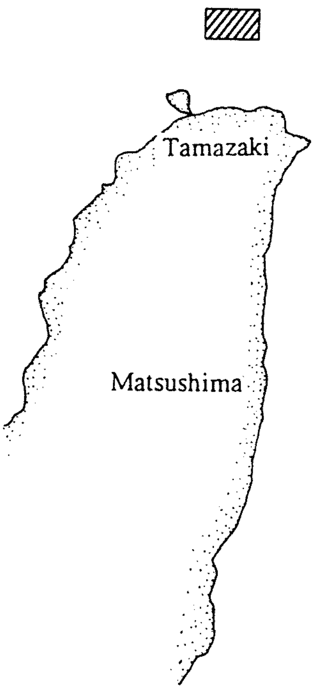


Figure 20-2

Name of district/ prefecture	Northern Sado, Niigata Prefecture
Type of fish	Sea bream, yellowtail, flatfish, Japanese flounder
Type of fishing	Gill net





Project site

■ **Project summary**

	Artificial-reef-fishing-ground development project
Project district	Sado, Niigata Prefecture
Project period	FY 1979-1983
Project area	8.8 km²
Major structure	1.8 m circular, cylinder-shaped fish reef, etc.

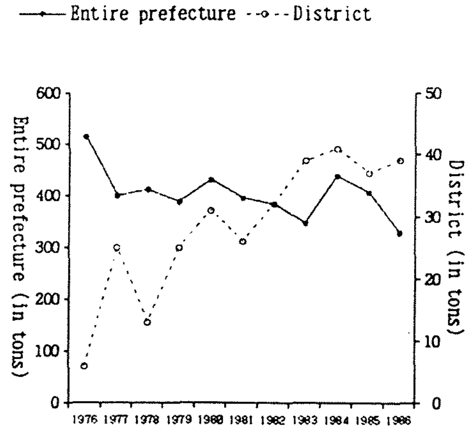
Figure 21-1

■ Changes in catch of sea breams by gill-net fishing

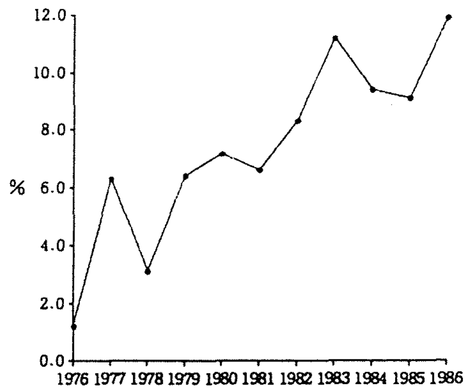
☐ : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Catch by entire prefecture	515	400	413	389	430	396	384	348	438	407	329
Catch by district	6	25	13	25	31	26	32	39	41	37	39
District's catch by percentage	1.2	6.3	3.1	6.4	7.2	6.6	8.3	11.2	9.4	9.1	11.9

Changes in catch



Changes by percentage of catch



Rough arrangement plan

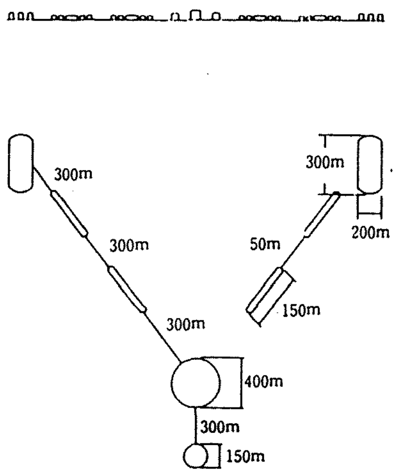
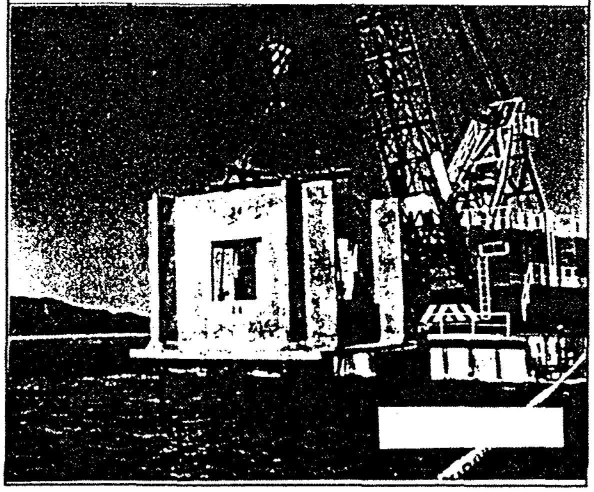


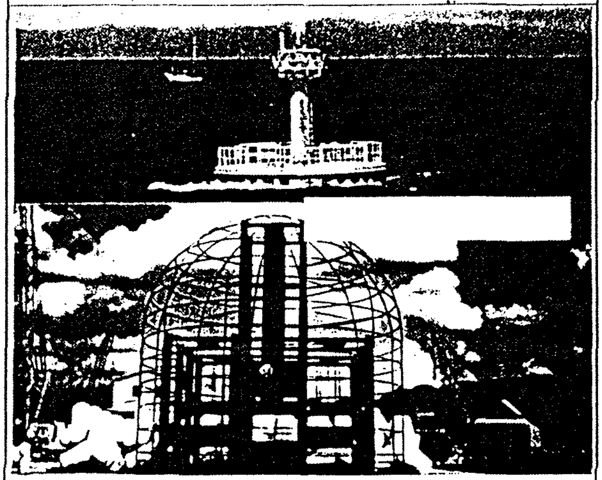
Figure 21-2

Fig. 22-1: Fish Reef

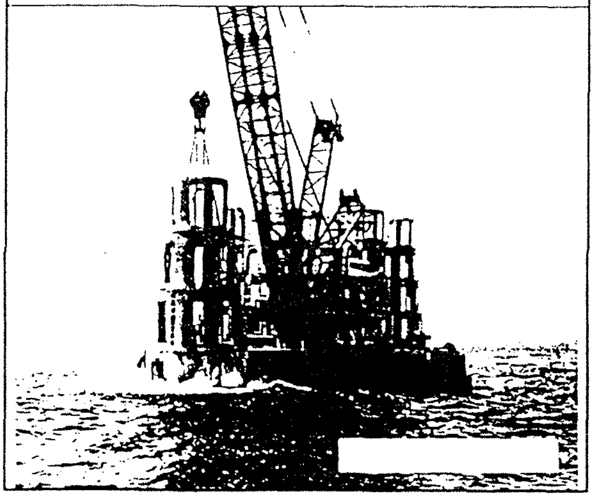
Concrete-made



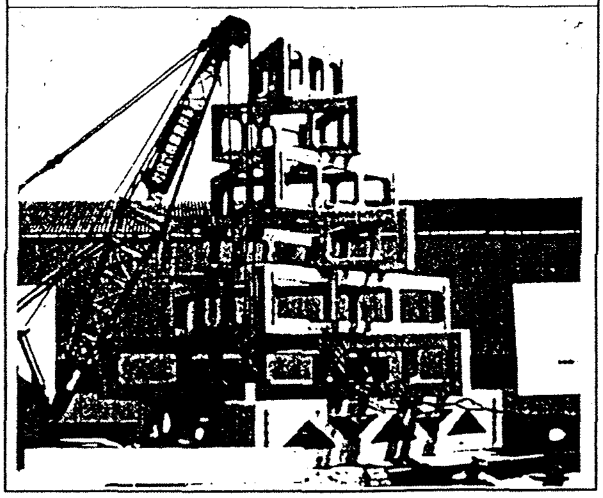
Steel-made



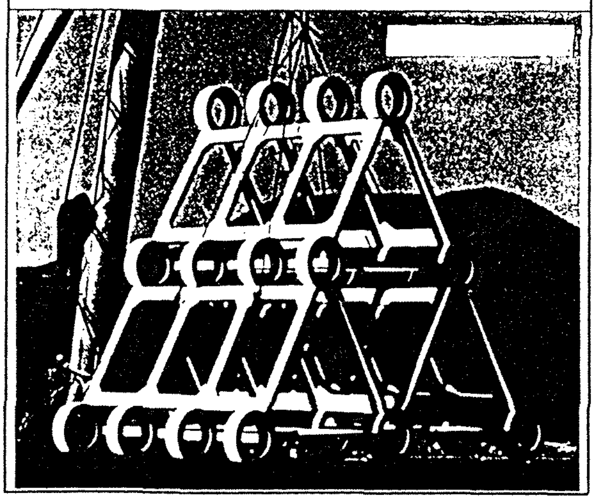
Concrete-made



Concrete-made



Concrete-made



Concrete-made

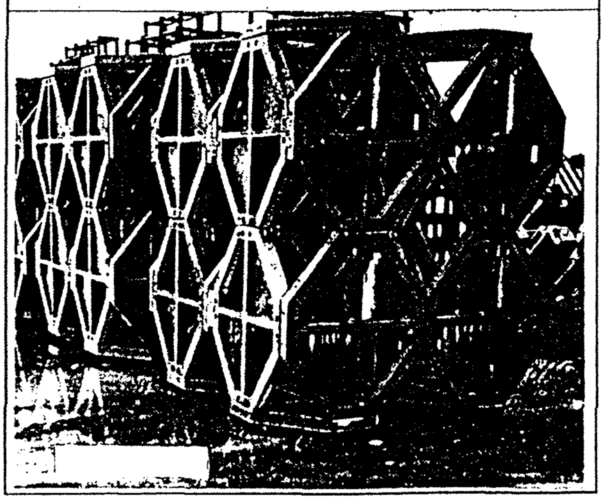


Fig. 22-2: Concrete Fish Reef

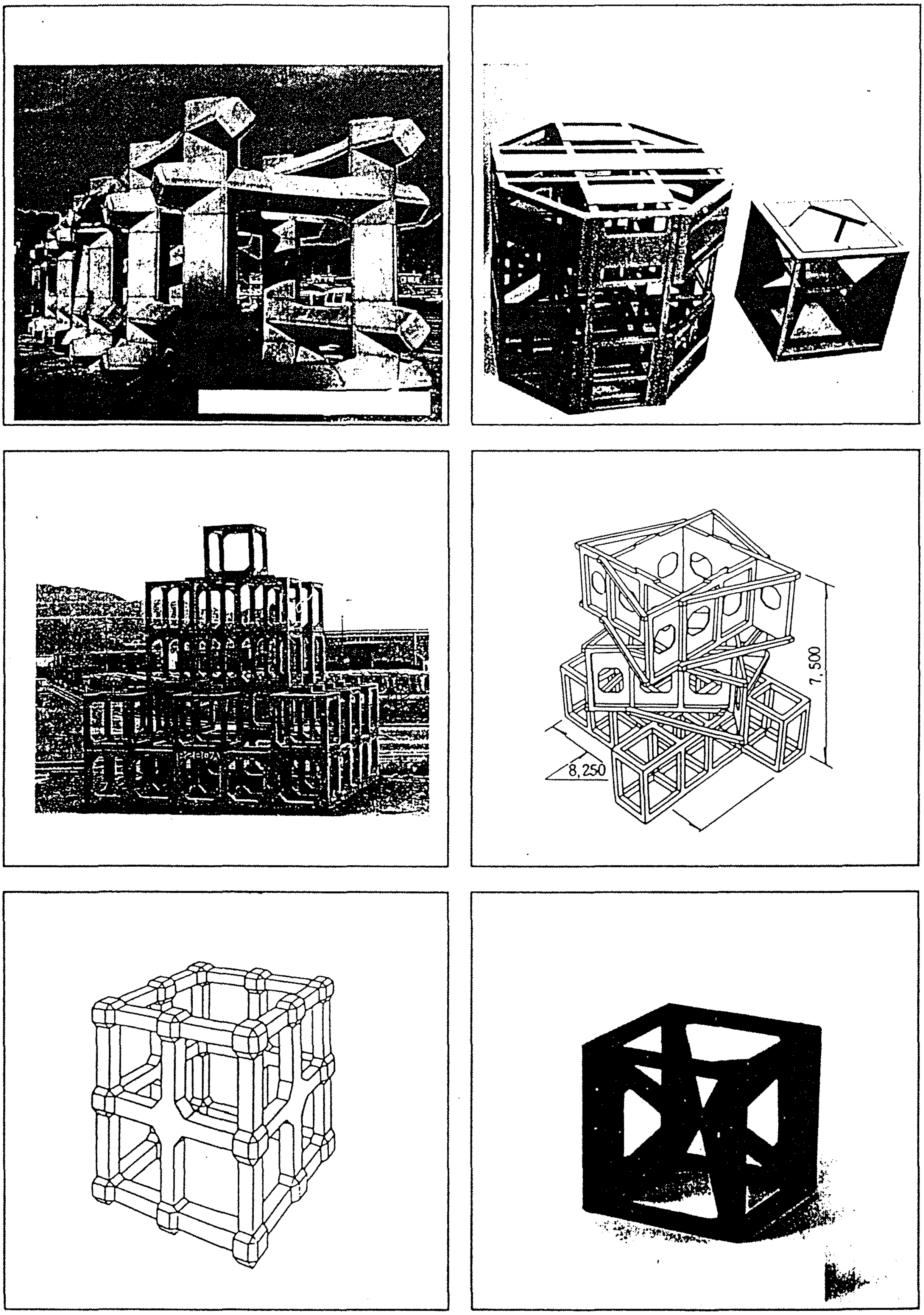
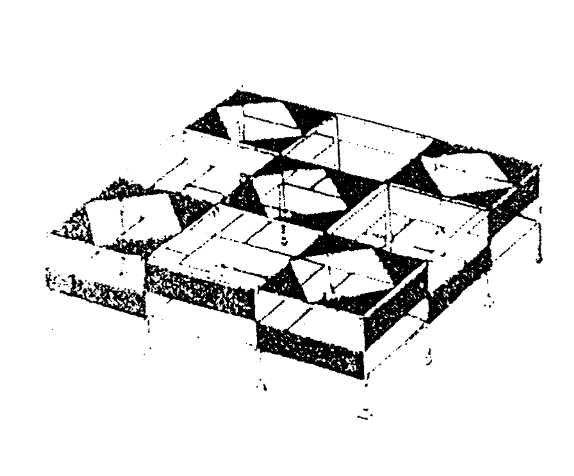
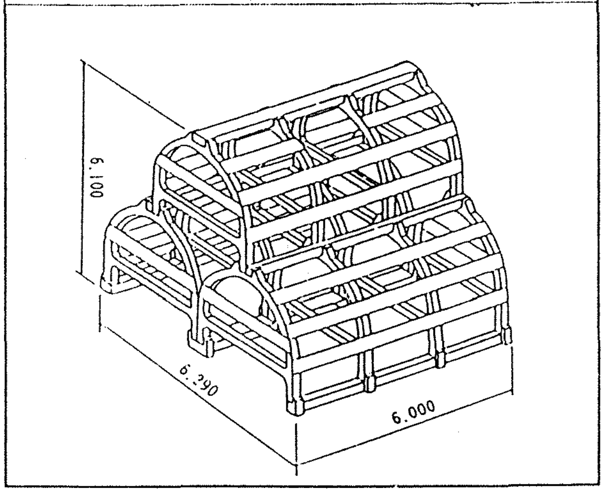


Fig.22-3:Fish Reef

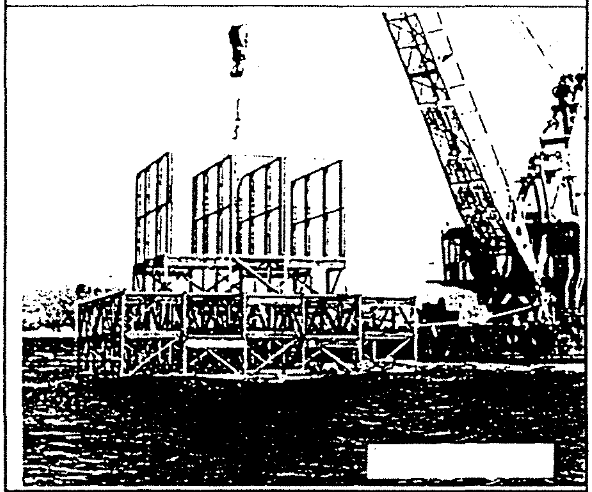
Steel-made



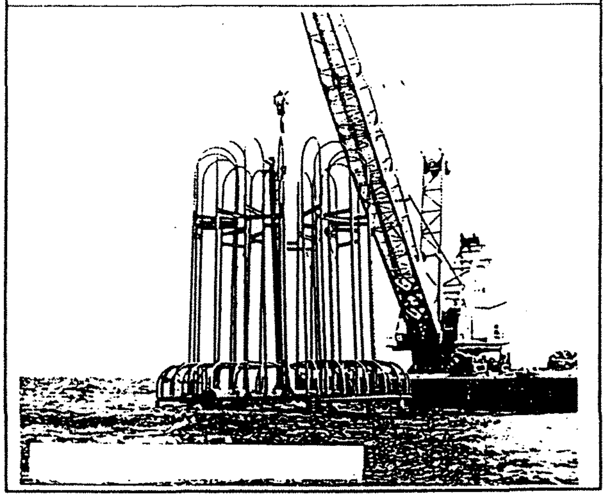
Concrete-made



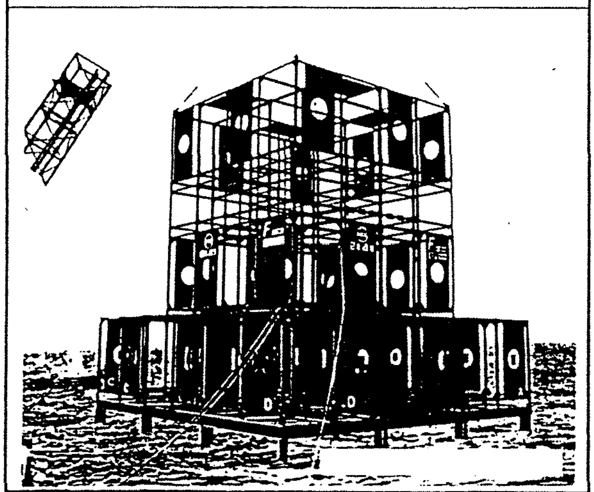
Steel-made



Steel-made



Steel-made



Steel-made

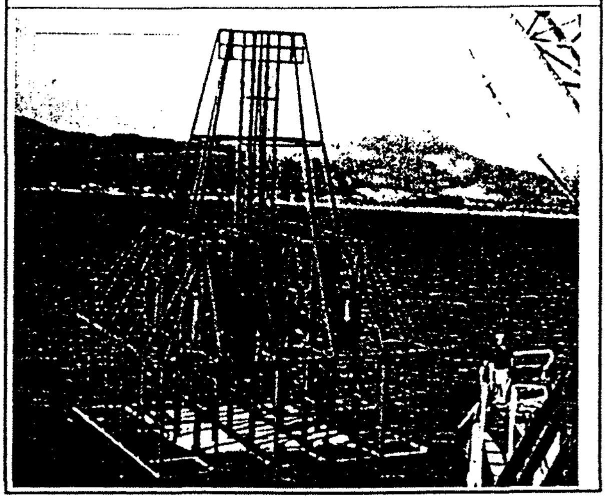
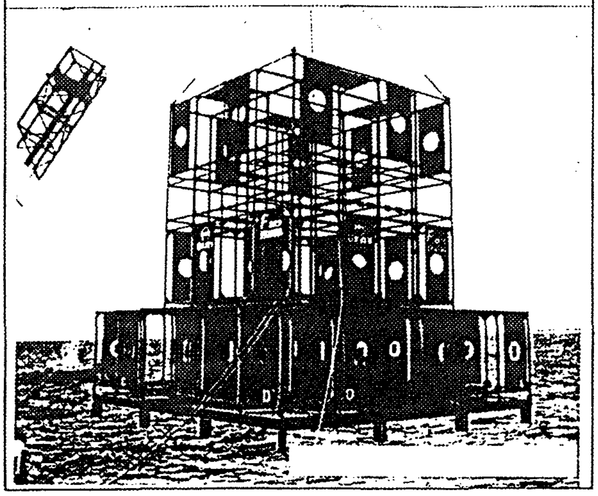
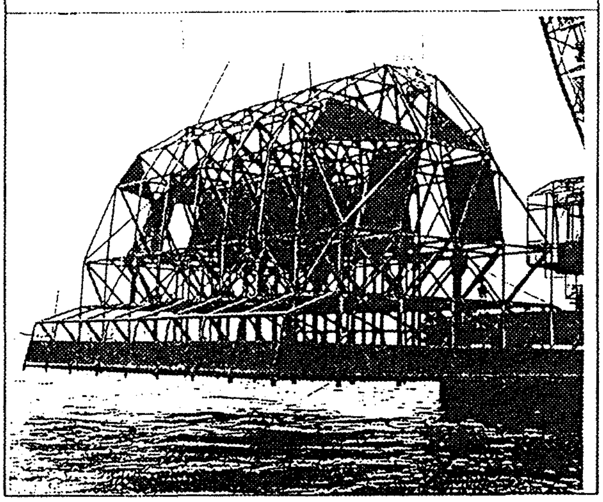


Fig. 22-4:Fish Reef

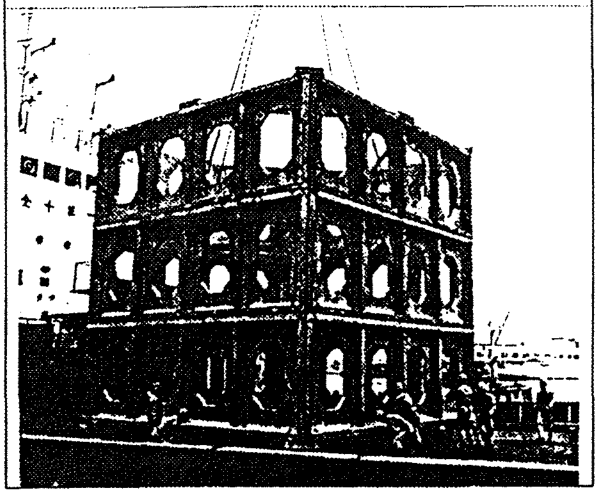
Steel-made



Steel-made



Concrete-made



Floating fish shellter (surface and middle layer)

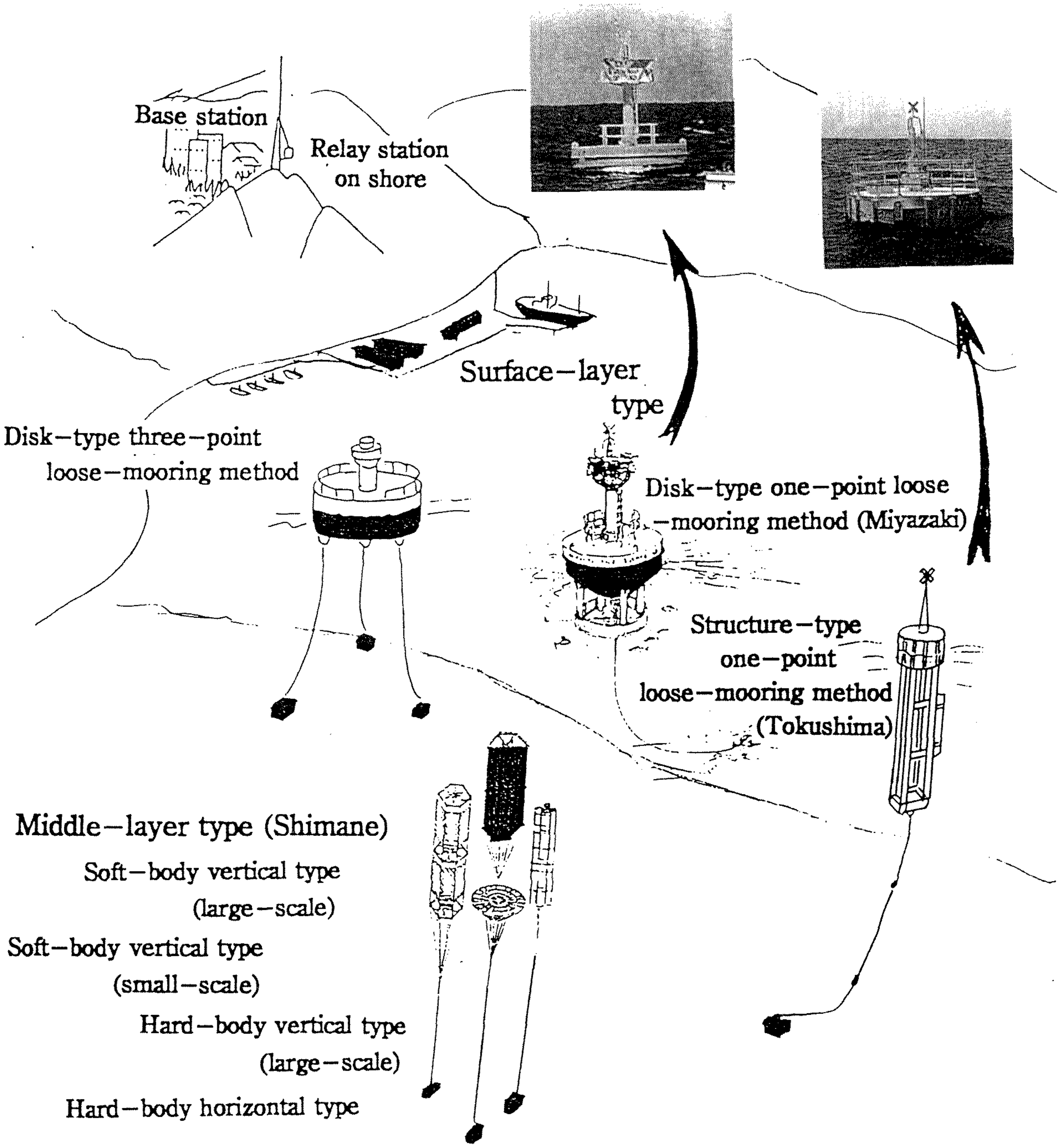


Figure 23

システム構成図

Radio Link Network System Configuration

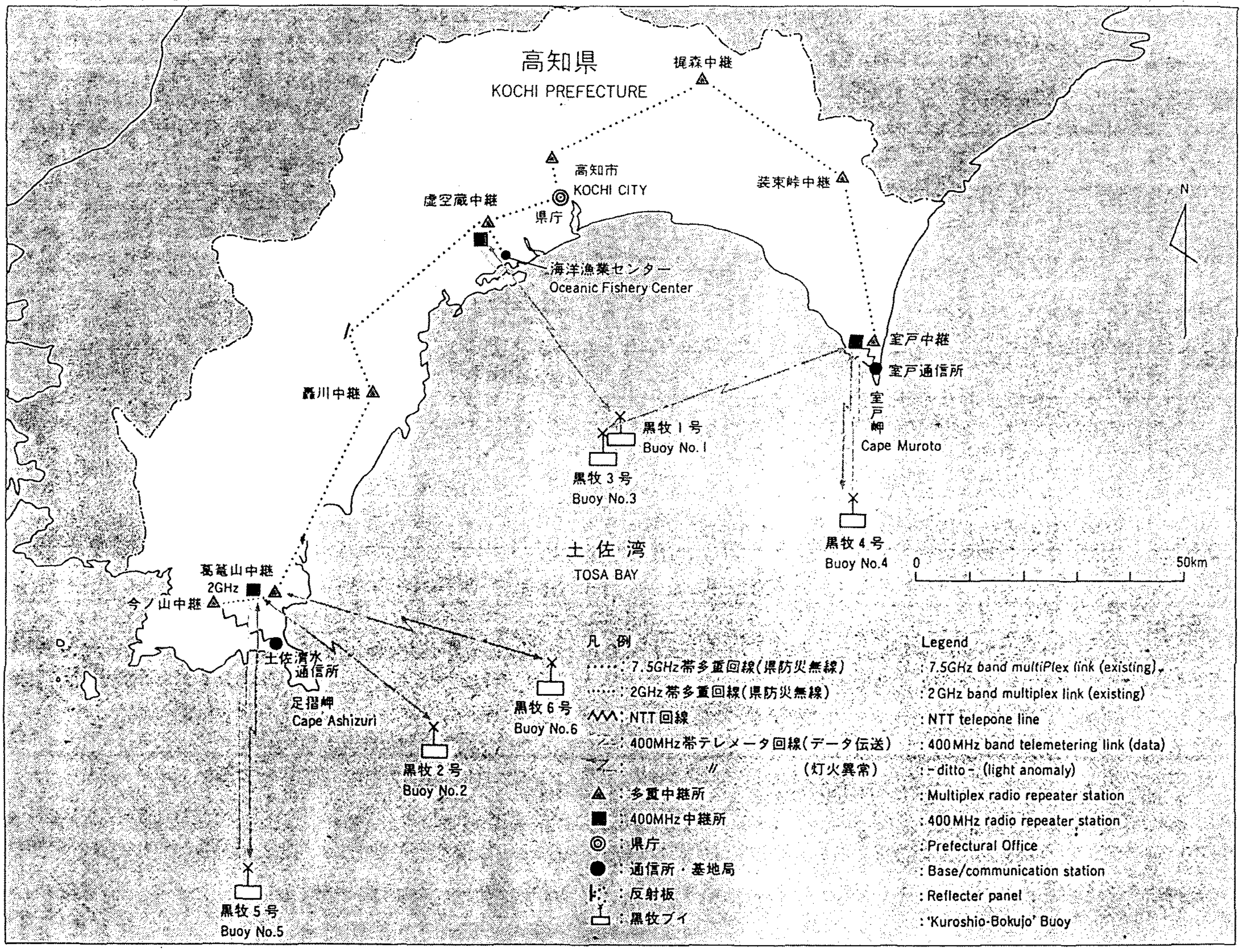
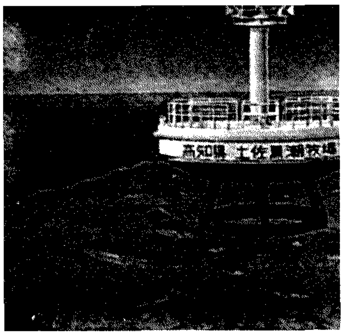


Figure 24



土佐黒潮牧場ブイ構成図(5号)

Structure of the Buoy and Mooring System

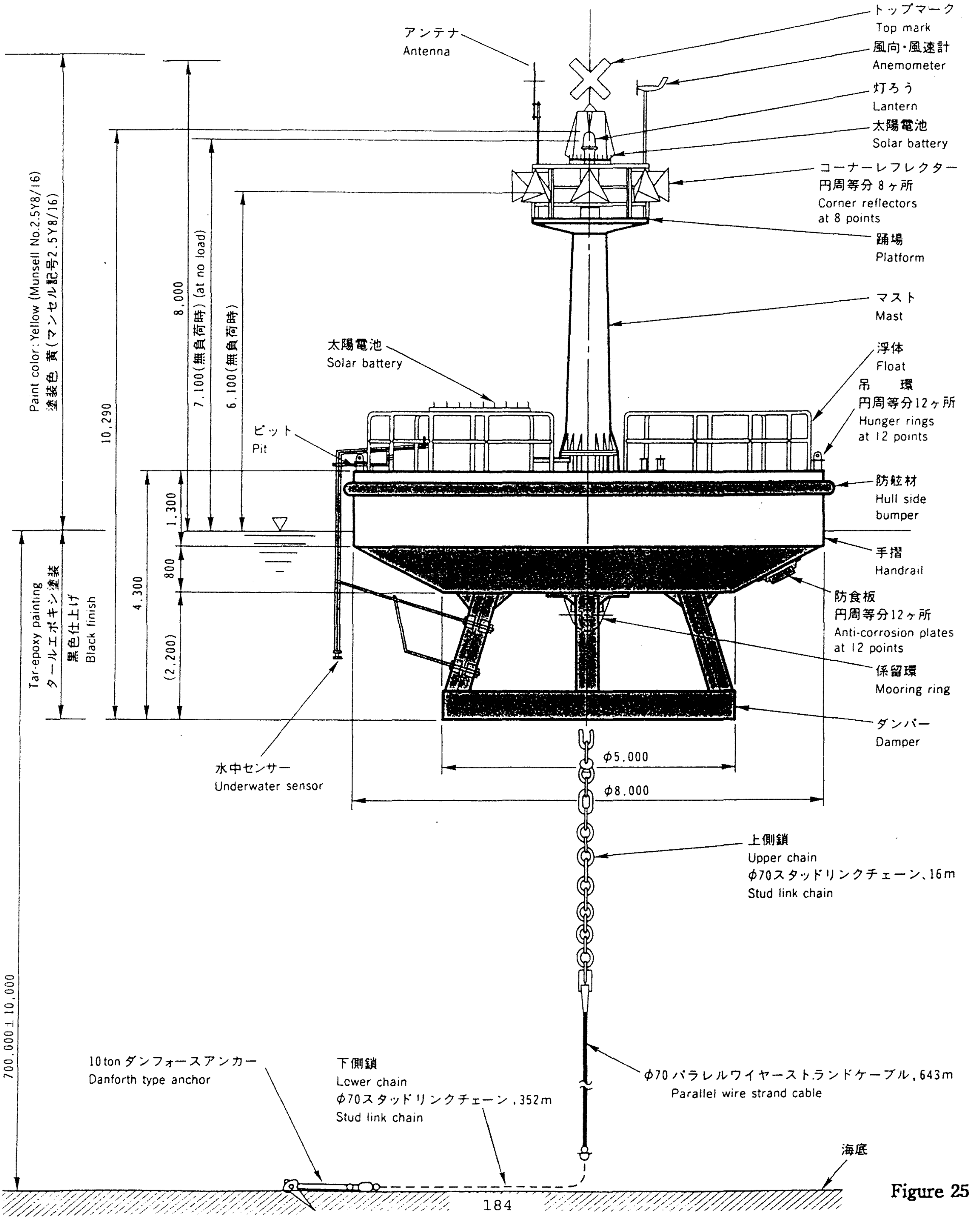
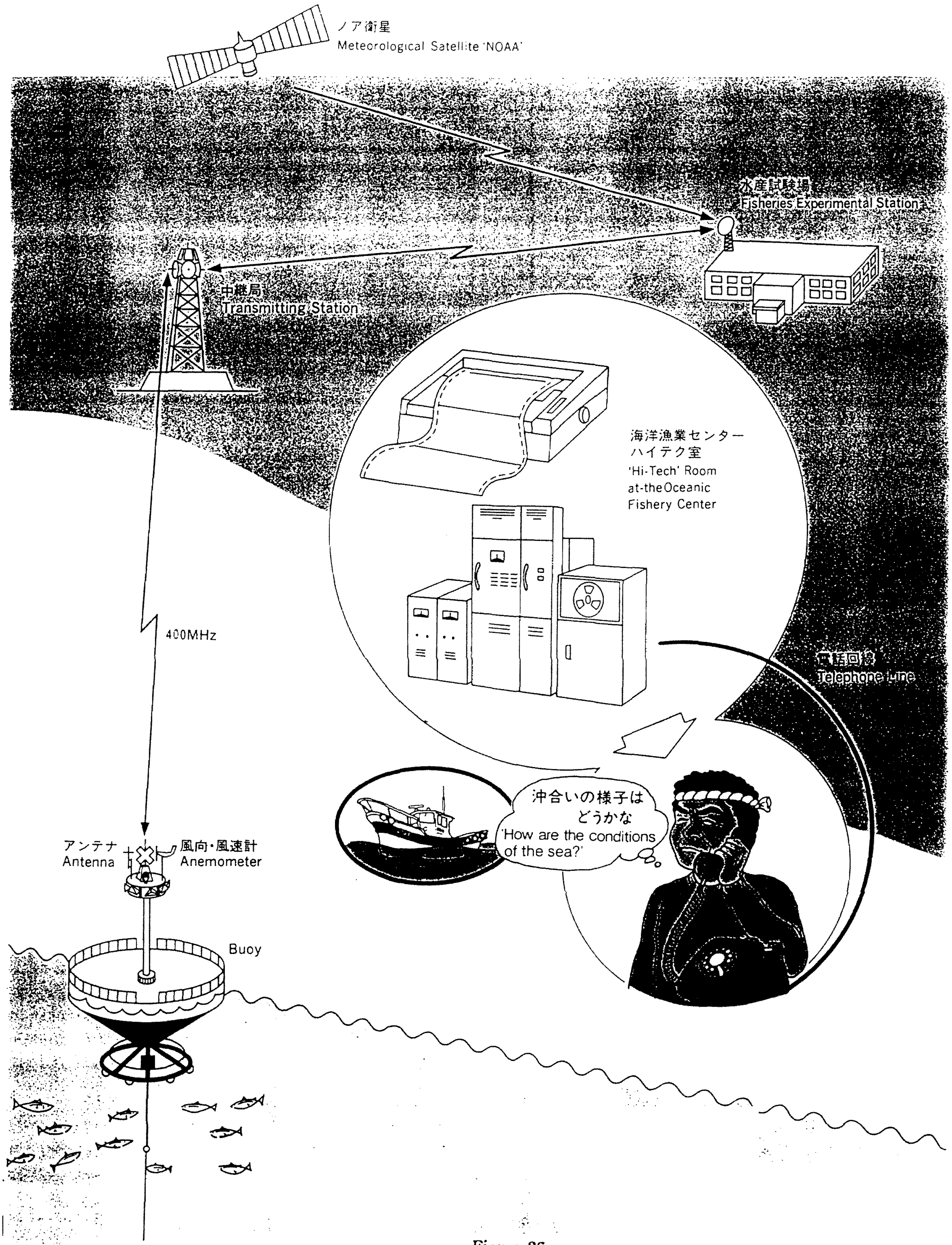
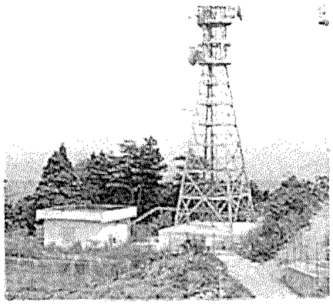


Figure 25

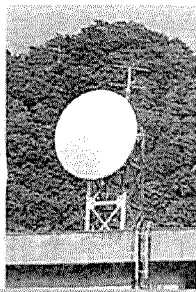


ノア衛星
Metecrological Satellite 'NOAA'
水産試験場
Fisheries Experimental Station
中継局
Transmitting Station
海洋漁業センター
ハイテク室
'Hi-Tech' Room
at-theOceanic
Fishery Center
Telephone Line
400MHz
沖合いの様子は
どうかな
'How are the conditions
of the sea?'
アンテナ
Antenna
風向・風速計
Anemometer
Buoy

Figure 26



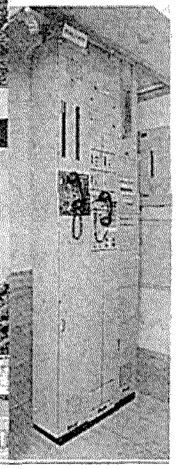
▲虚空蔵山中継局舎と空中線塔
Kokuzozan Transmitting Station Shelter and Antenna Tower



水産試験場 空中線▶
Antenna at the Fisheries Experimental Station

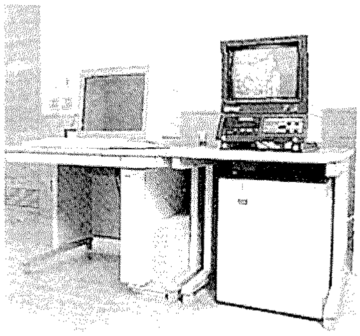
高知県水産試験場▶
Kochi Prefectural Fisheries Experimental Station

高知県海洋漁業センター
Kochi Prefectural Oceanic Fishery Center

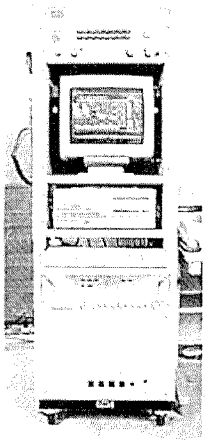


◀ハイテク室 虚空蔵山中継局向7.5GHz帯多重回線架
Hi-Tech Room Multiplex Radiotelephone Equipment for Kokuzozan Transmitting Station

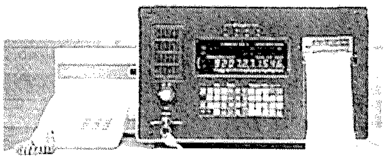
▲高知県海洋漁業センター ハイテク室全景 'Hi-Tech' Room at the Oceanic Fishery Center



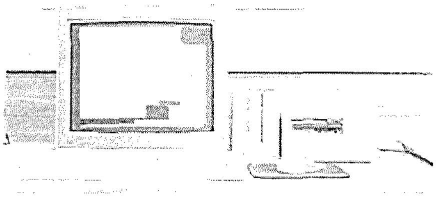
▲ノア衛星受画装置とワークステーション
NOAA Satellite Data Receiving Equipment and Workstation



▲制御監視信号処理装置
Control/Supervision Signal Processing Equipment



▲電話応答通報装置
Telephone Answering Equipment



▲ワークステーション
Workstation

ワークステーションシステム系統図
Workstation System Diagram

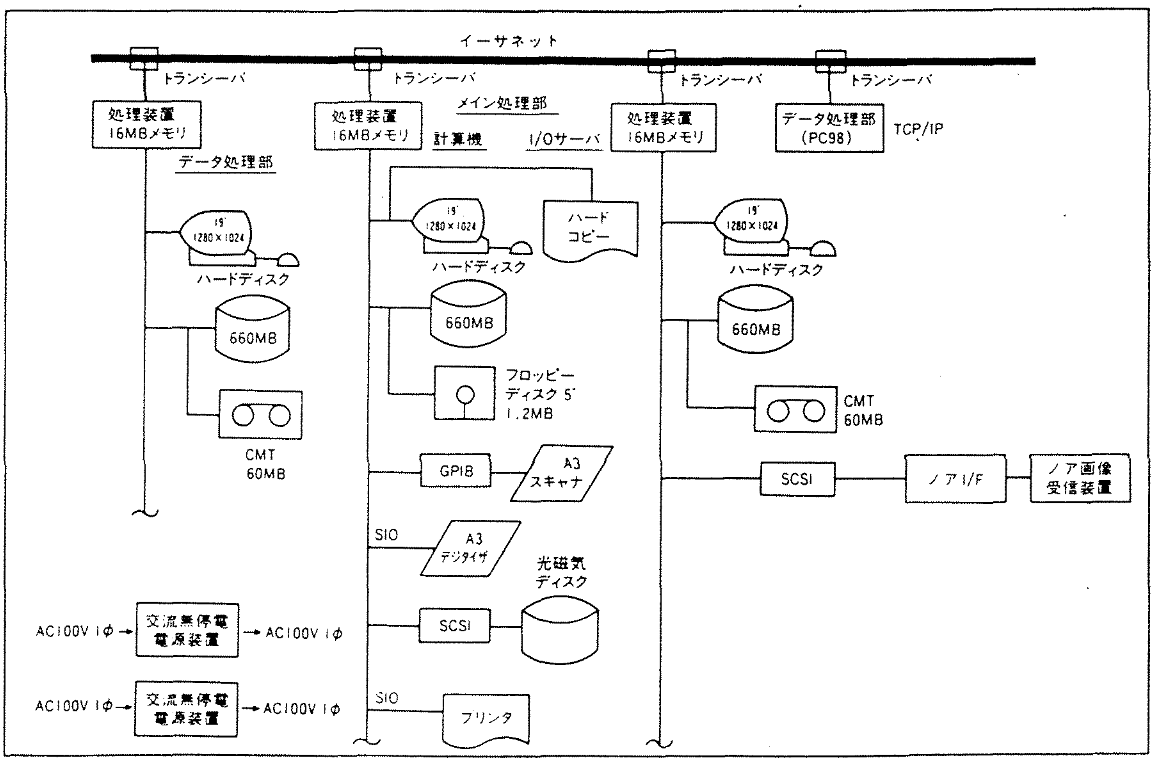
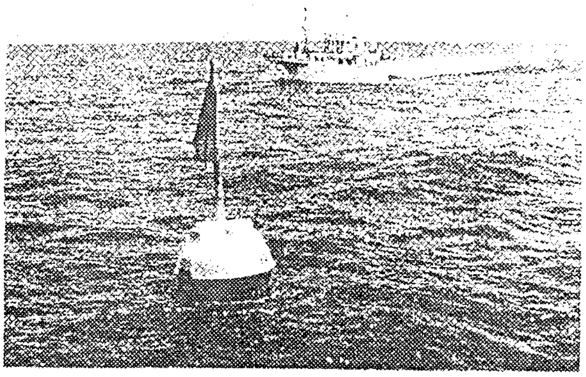
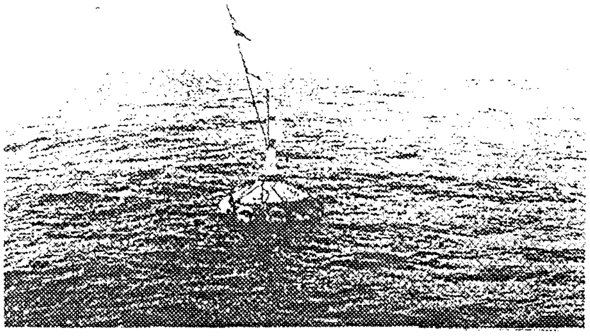


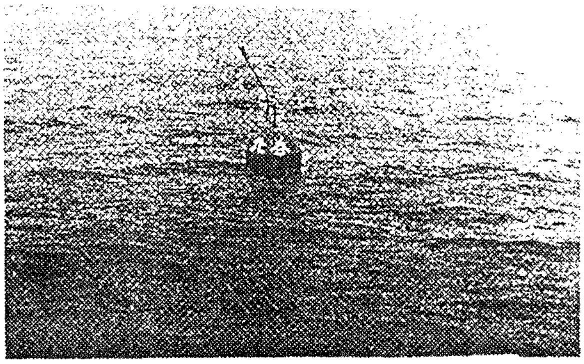
Figure 27



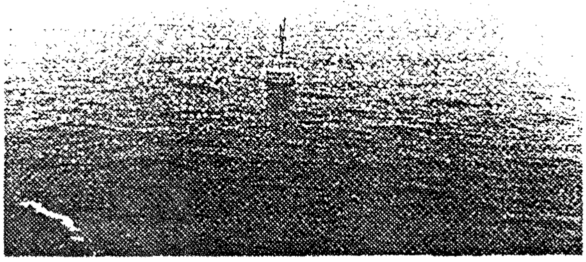
A. homemade(using water tank)



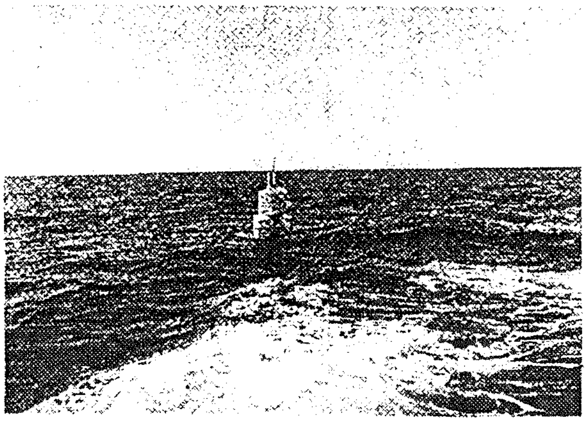
E. ready-made fish reef



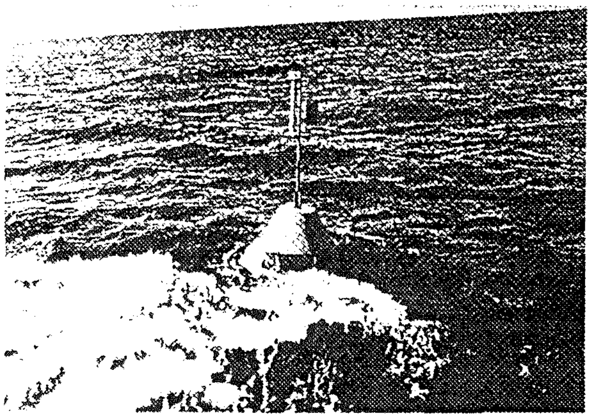
B. homemade(using water tank)



F. ready-made fish reef

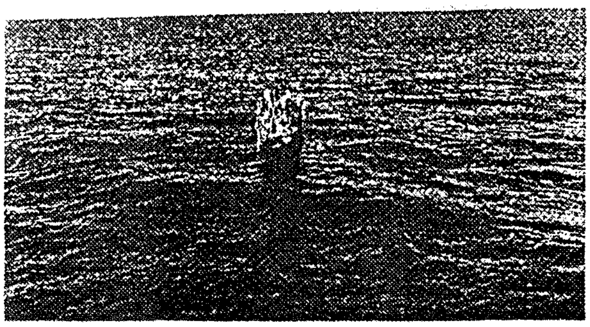


C. homemade(using pole and float)



G. ready-made fish reef

D. homemade(buoy-connecting type)



H. ready-made fish reef

Fig. 28:Floating fish shelter types

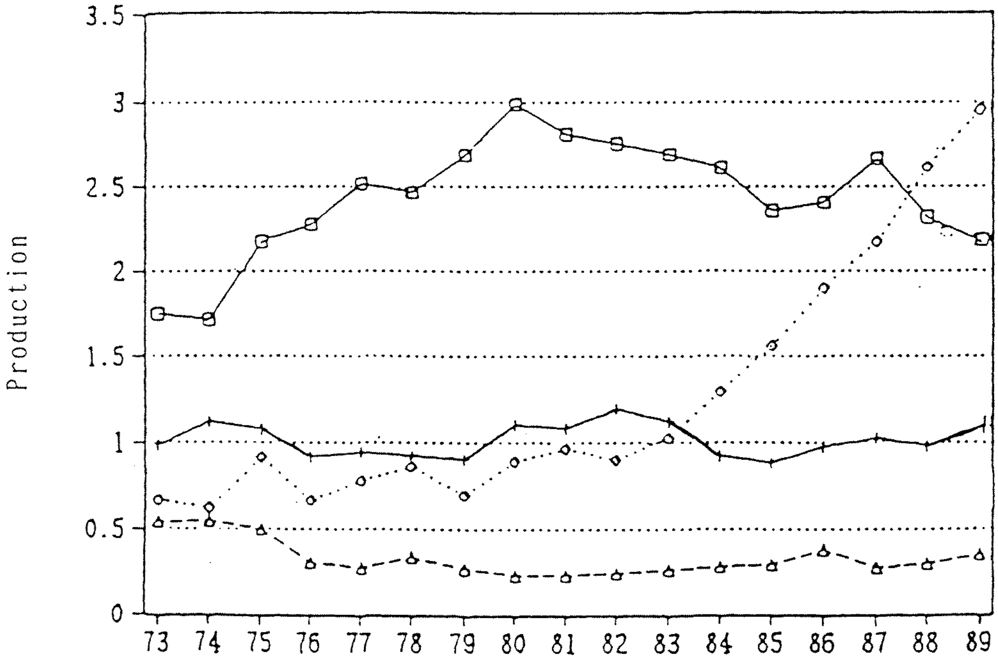


Fig. 29:Production of coastal fisheries by type

(Source:Statistics of Agriculture and Fisheries Ministry)

□angling, +bottom longline, ◇trolling line, △squid fishing

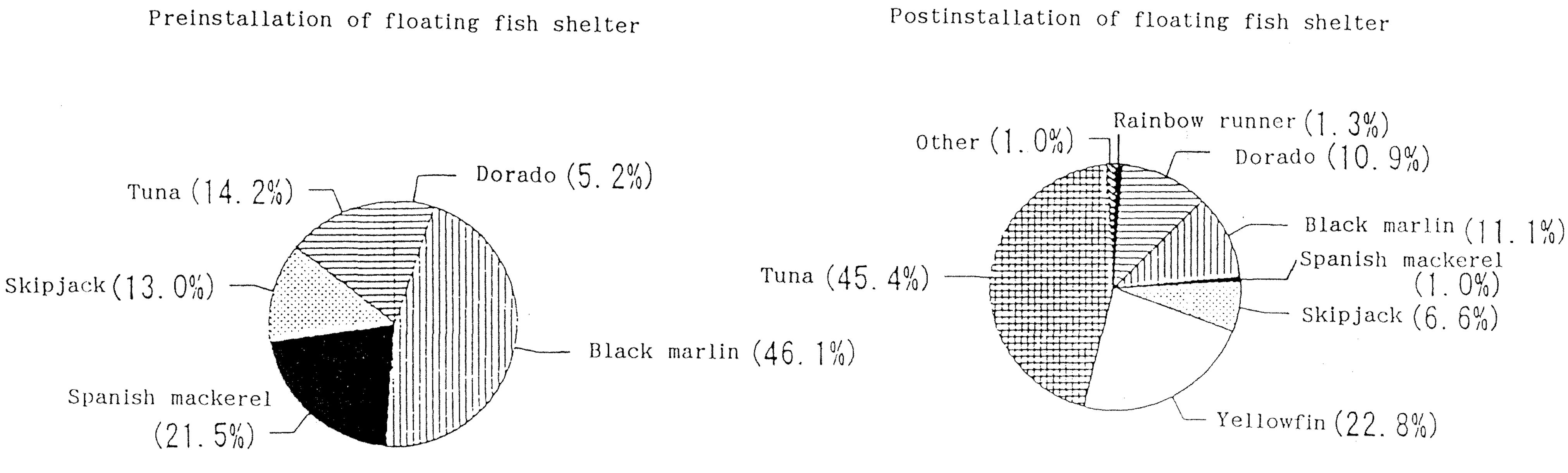


Fig.30: Comparison of catch composition before and after use of floating fish shelter

Preinstallation of floating fish shelter: average from 1980 to 1984

Postinstallation of floating fish shelter: average from 1985 to 1989

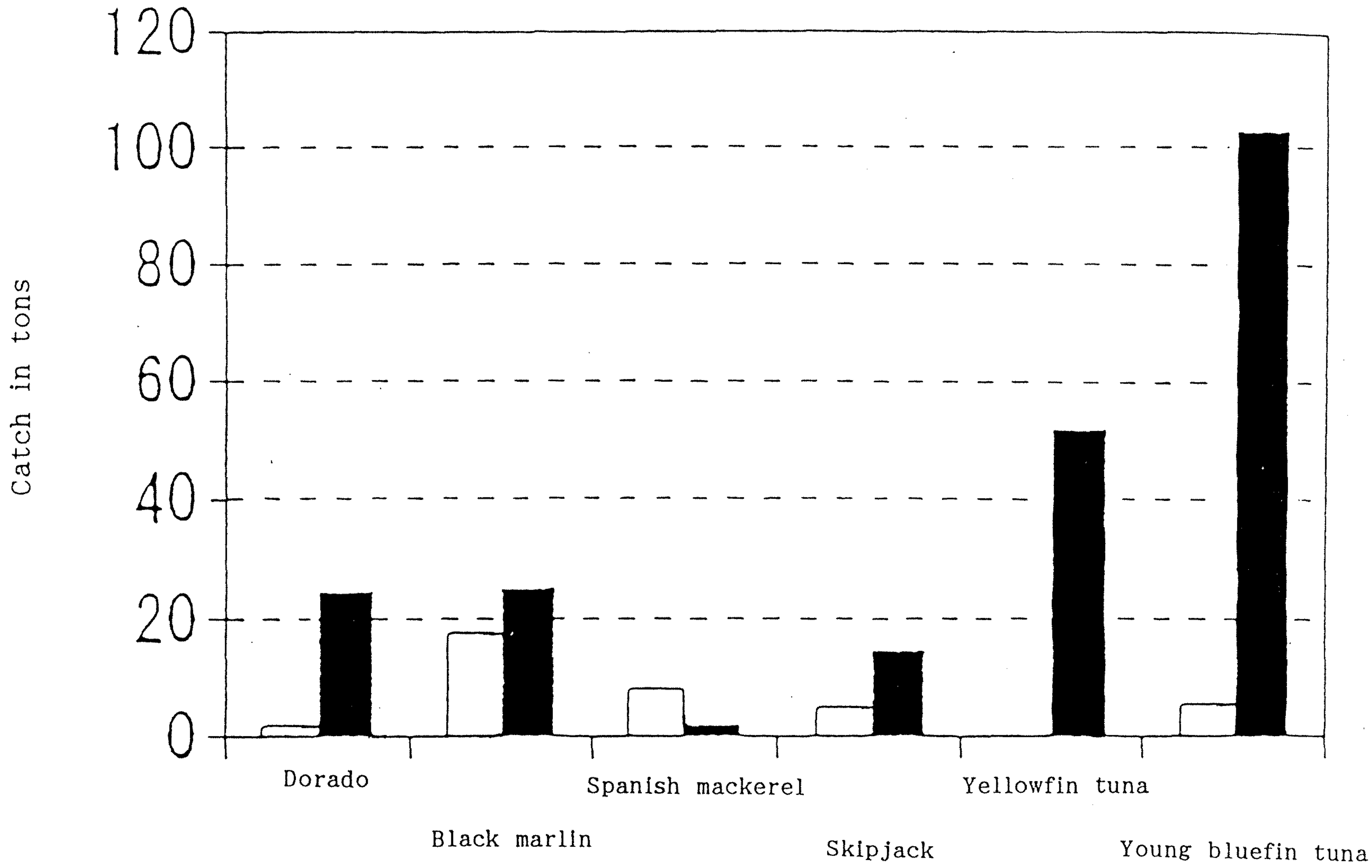


Fig. 31: Comparison of catch pre- and postinstallation of floating fish reef

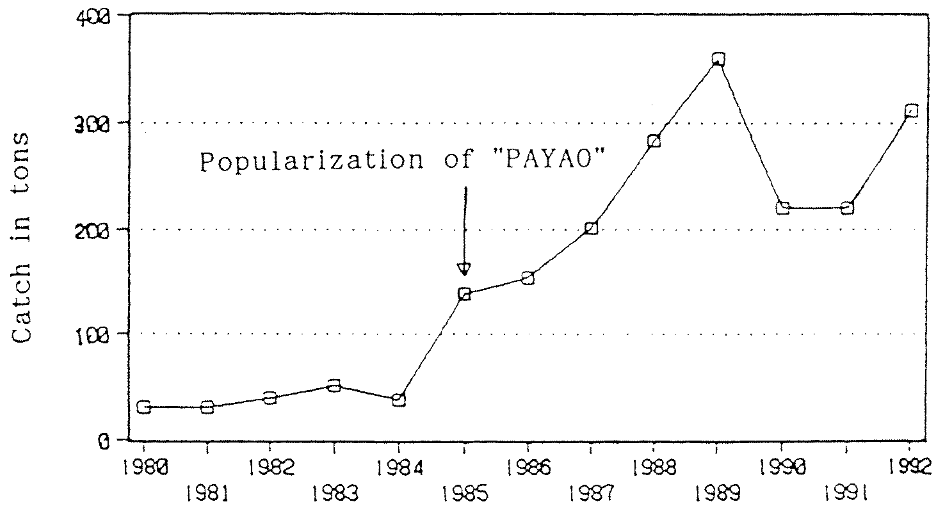


Fig. 32: Chronological changes in catch by troll-line fishing (Itoman Fishermen's Cooperative Association)

Fig.33:Difference in Catch Pre- and Postinstallation of Floating Fish Shelter by Small Troll-Line Fishing Vessel

	Kind of fish	Type of fishing	Fishing ground	Method for choosing fishing ground
Preinstallation	Black marlins Wahoos Small yellowfins Skipjacks	Marlin troll-line fishing Spanish-mackerel troll-line fishing	Around natural sone and islands. Targeting resources attached to sone and islands.	Choosing fishing ground based on past experience.
Postinstallation	Yellowfins Black marlins Dorados	Troll line Drift angling Marlin troll-line fishing Isimaki, etc.	Using multiple floating fish shelters, types of fish congregating around the shelters are targeted.	Based information obtainedfrom fishing vessels, choosing floating fish shelters good at attracting fish.

Excluding shelter for dorados

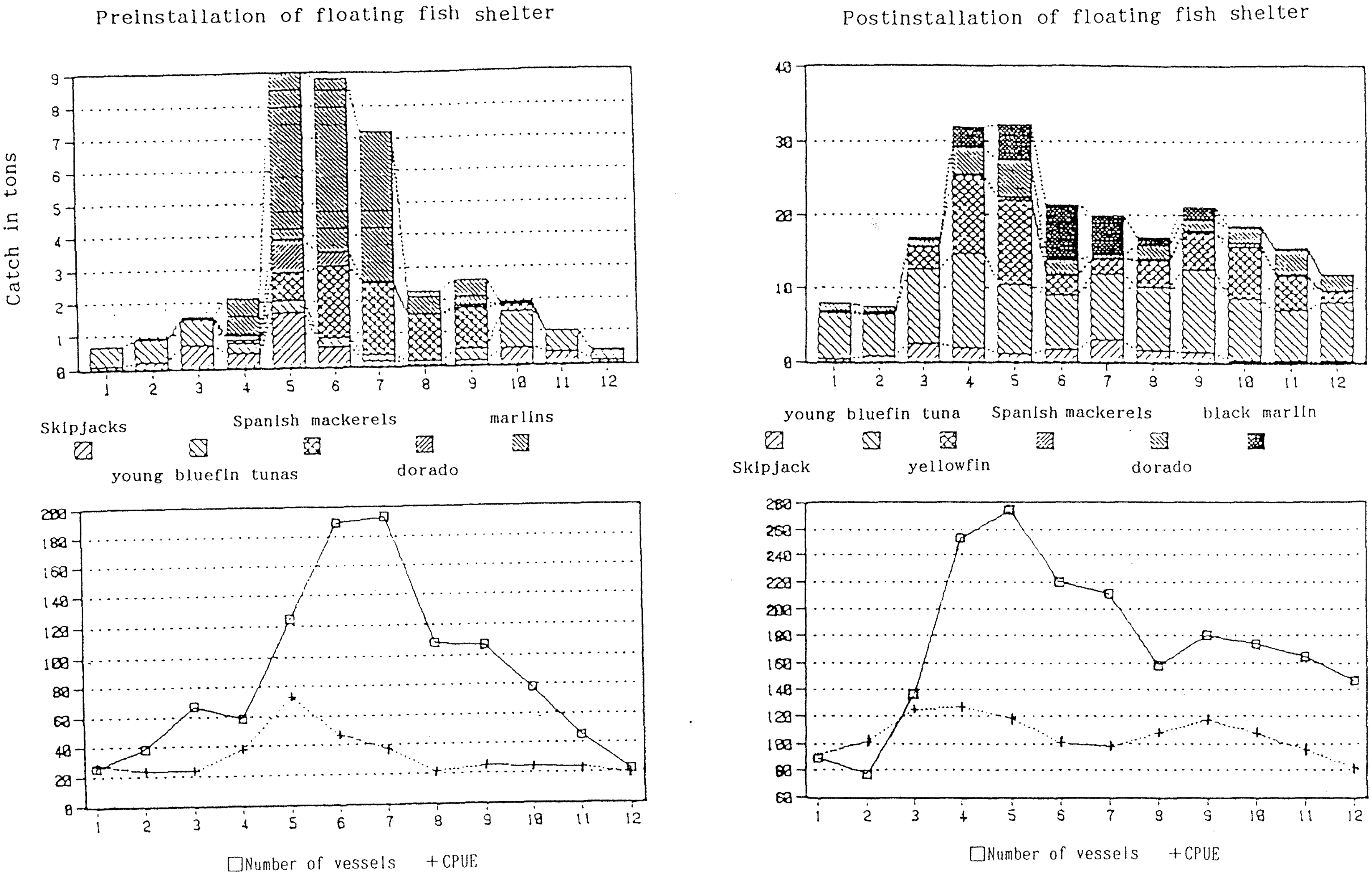
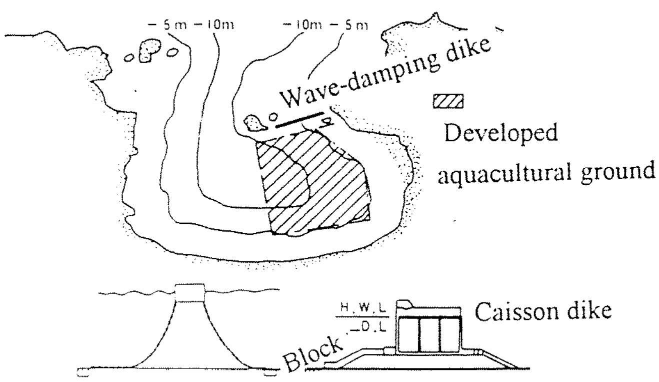
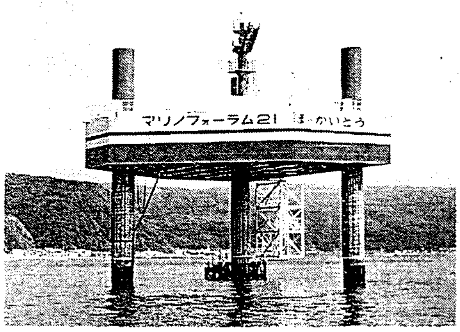


Fig. 34: Seasonal changes in catch, number of vessels, and CPUE (kg)

Aquacultural – ground – development project

Aquacultural-ground development project





Pilot farm of offshore culture
(Okushiri Island, Hokkaido)

Figure 35

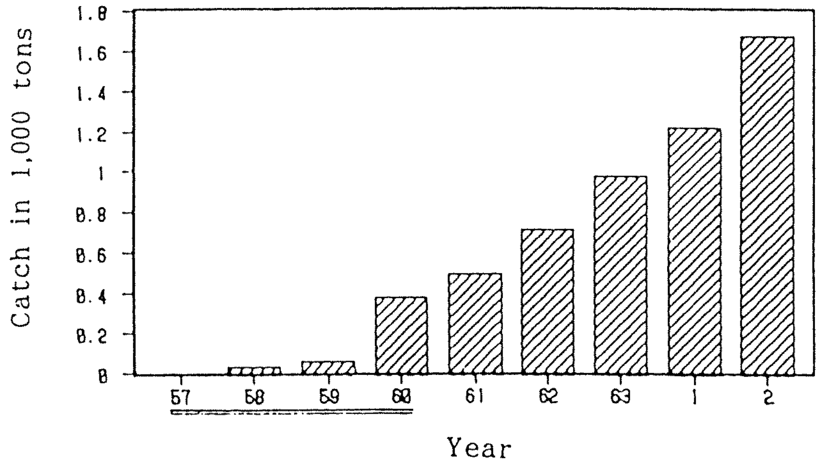
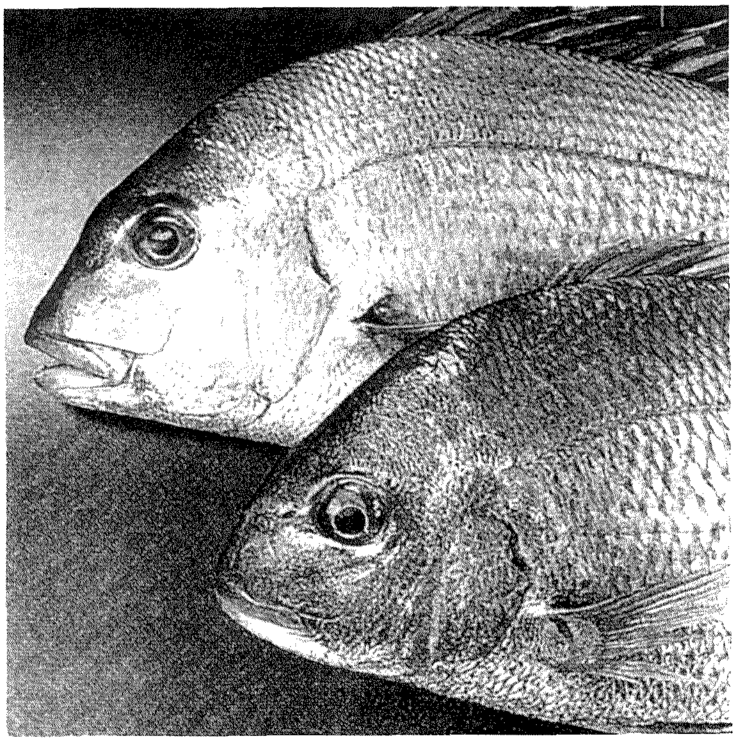
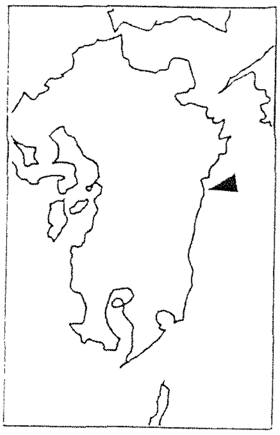
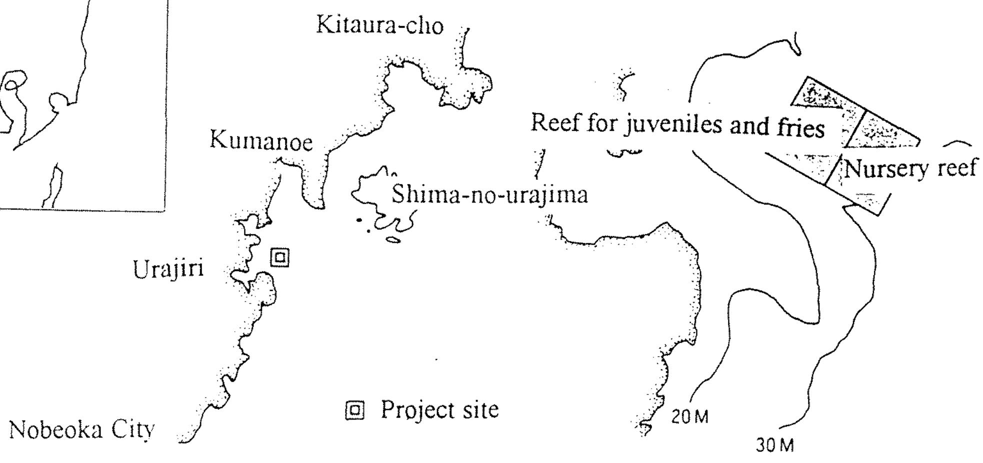


Fig. 36: Changes in catch of Japanese short neck clam in propagation ground

Name of district/ prefecture	Northern Nobeoka District, Miyazaki Prefecture
Type of fish	Red sea bream







■ **Project summary**

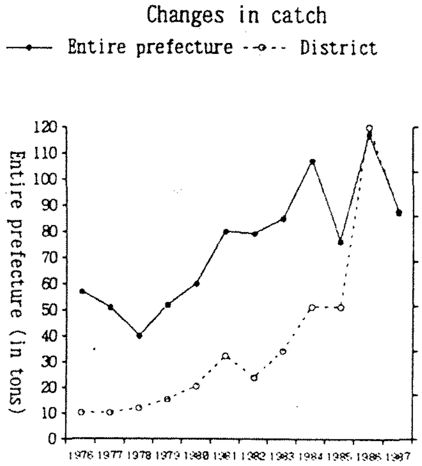
Project name	Project year	Work volume	Major structure
Propagation-ground-development project	FY 1982-1985	22.7 ha	312 reefs for juveniles and fries 312 nursery reefs

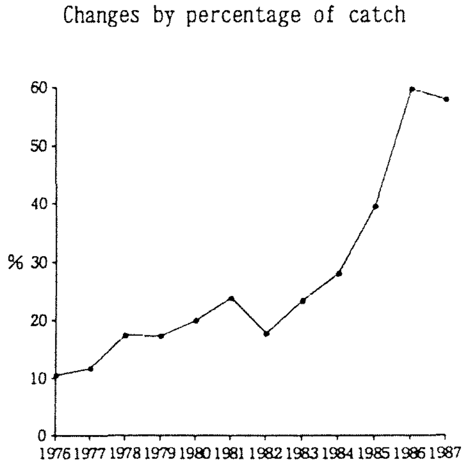
Figure 37-1

■ Changes in catch of red sea bream

[ ] : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Entire prefecture	57	51	40	52	60	80	79	85	107	76	117	88
Nobeoka District	6	6	7	9	12	19	14	20	30	30	70	51
Percentage of catch	10.5	11.8	17.5	17.3	20.0	23.8	17.7	23.5	28.0	39.5	59.8	58.0





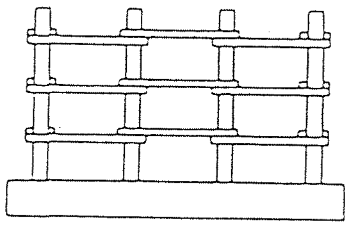
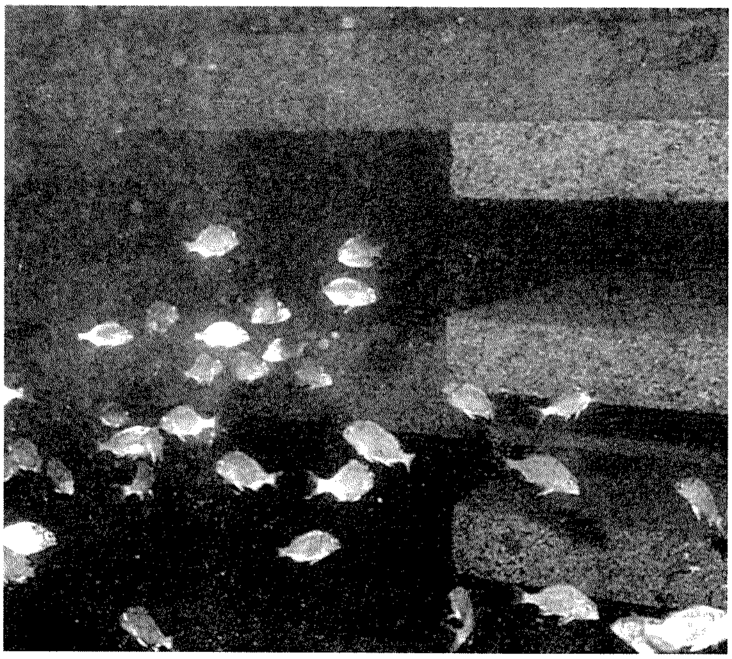
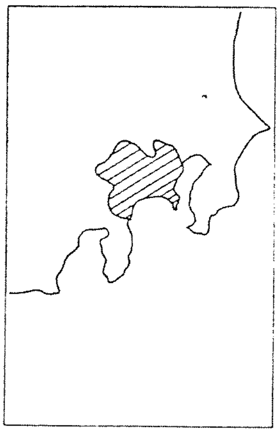
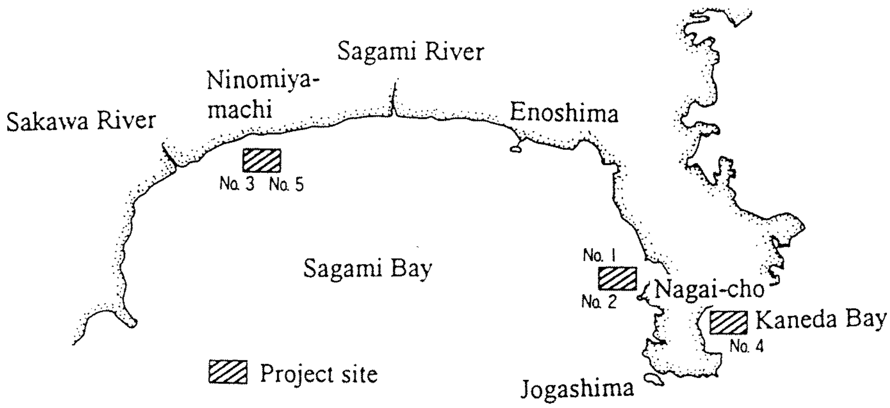


Figure 37-2

Name of district/ prefecture	Whole of Kanagawa Prefecture
Type of fish	Red sea bream







■ Project summary

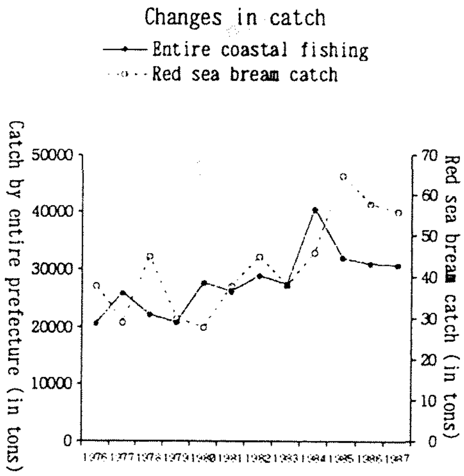
No.	Project name	FY	Work volume	Major structure
1	Propagation-ground-development project	1979	4.0 ha	Nursery ground of juveniles and fries (juvenile-and-fry-nursery reef)
2	〃	1980	1.0 ha	Nursery ground of juveniles and fries (juvenile-and-fry-nursery reef)
3	〃	1982	2.8 ha	Small-scale propagation ground (juvenile-and-fry-nursery reef)
4	〃	1985	2.5 ha	Small-scale propagation ground (juvenile-and-fry-nursery reef)
5	〃	1986	2.0 ha	Small-scale propagation ground (juvenile-and-fry-nursery reef)
Total			12.3 ha	

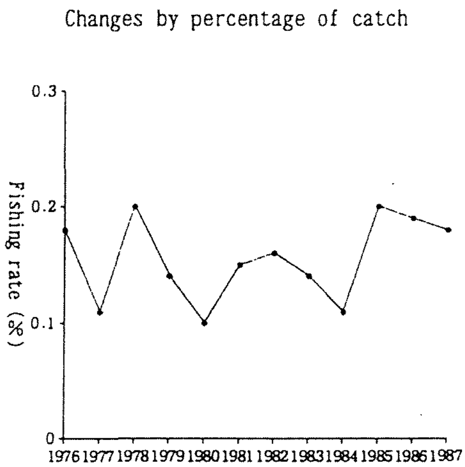
Figure 38-1

■ Prefectural Changes in Red Sea Bream Catch

☐ : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	20,591	25,827	22,169	20,790	27,616	26,115	28,915	27,362	40,485	31,957	30,934	30,748
Red sea bream catch	38	29	45	30	28	38	45	38	46	65	58	56
Red sea bream fishing rate	0.18	0.11	0.20	0.14	0.10	0.15	0.16	0.14	0.11	0.20	0.19	0.18





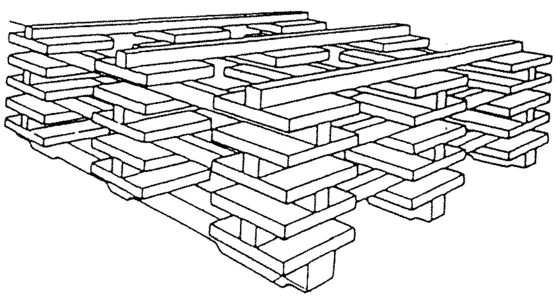
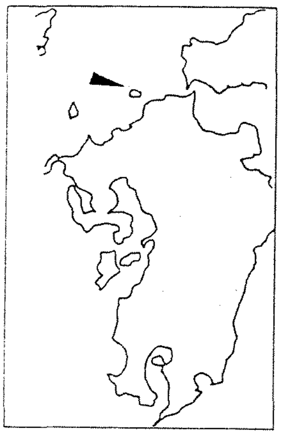
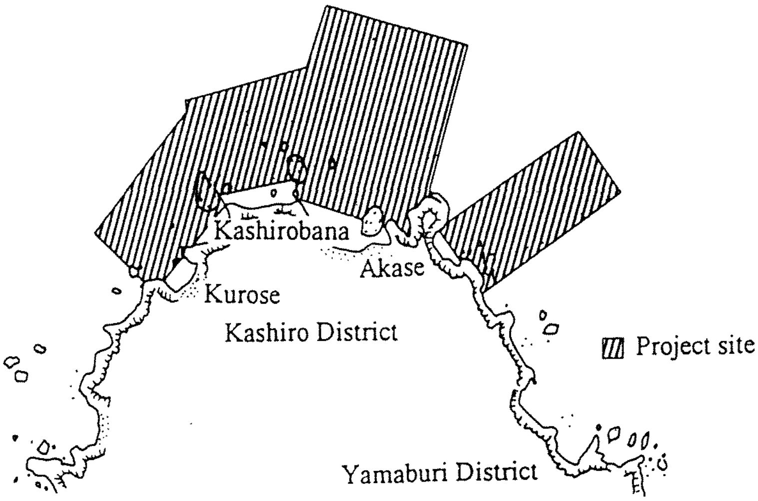


Figure 38-2

Name of district/ prefecture	Oshima, Fukuoka Prefecture
Type of fish	Abalone





■ Project summary

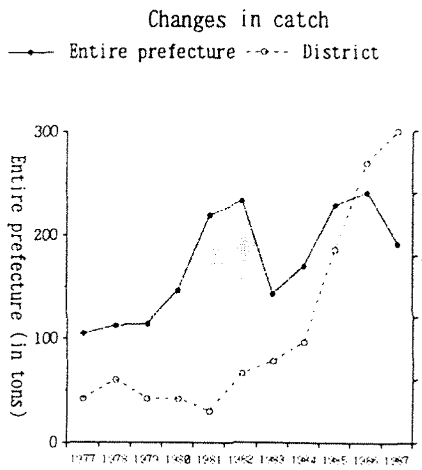
Project name	Project year	Work volume	Major structure
Propagation-ground-development project	FY 1981-1984	115,540 m²	Natural stone

Figure 39-1

■ Changes in Abalone Production

☐ : Project year (unit: tons)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	105	112	114	146	219	233	143	170	229	241	192
Catch by district	7	10	7	7	5	11	13	16	31	45	50
District's catch by percentage	6.7	8.9	6.1	4.8	2.3	4.7	9.1	9.4	13.5	18.7	26.0



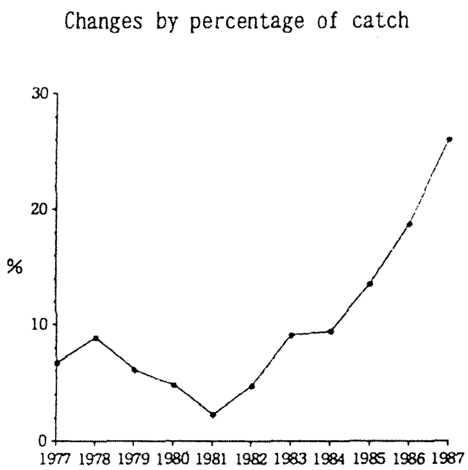
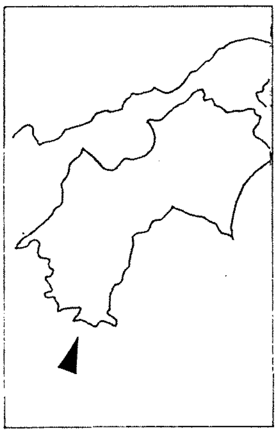
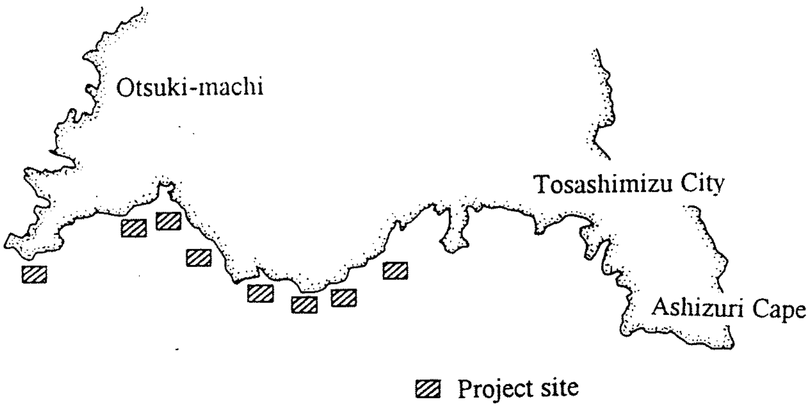


Figure 39-2

Name of district/ prefecture	Tsukinada District, Kochi Prefecture
Type of fish	Spiny lobster





■ **Project summary**

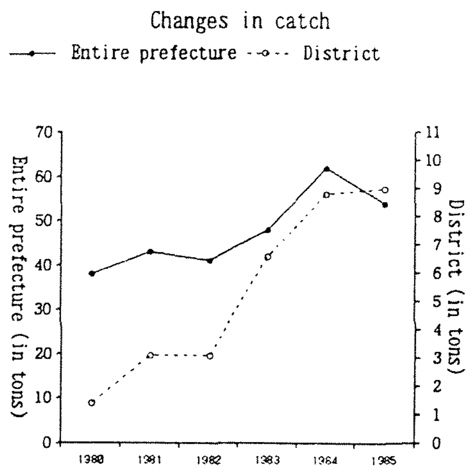
Project name	Project year	Work volume	Major structure
Propagation-ground-development project	FY 1981-1984	250 ha	Propagation block

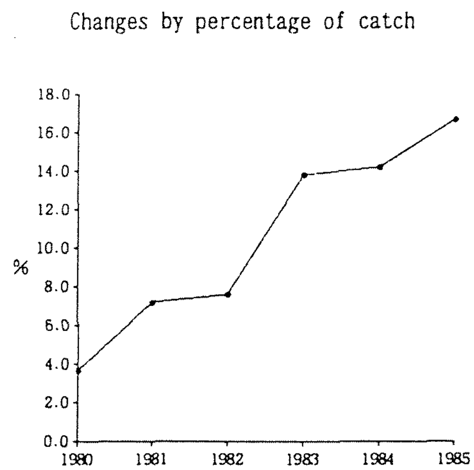
Figure 40-1

■ Changes in Spiny Lobster Catch ░ : Project year (unit: tons)

	1980	1981	1982	1983	1984	1985
Catch by entire prefecture	38	43	41	48	62	54
Catch by district	1.4	3.1	3.1	6.6	8.8	9.0
District's catch by percentage	3.7	7.2	7.6	13.8	14.2	16.7

* Catch by district/catch of entire prefecture × 100 = fishing rate of district





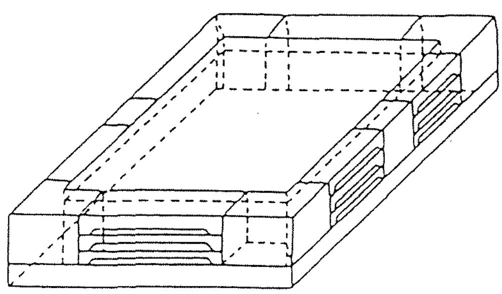
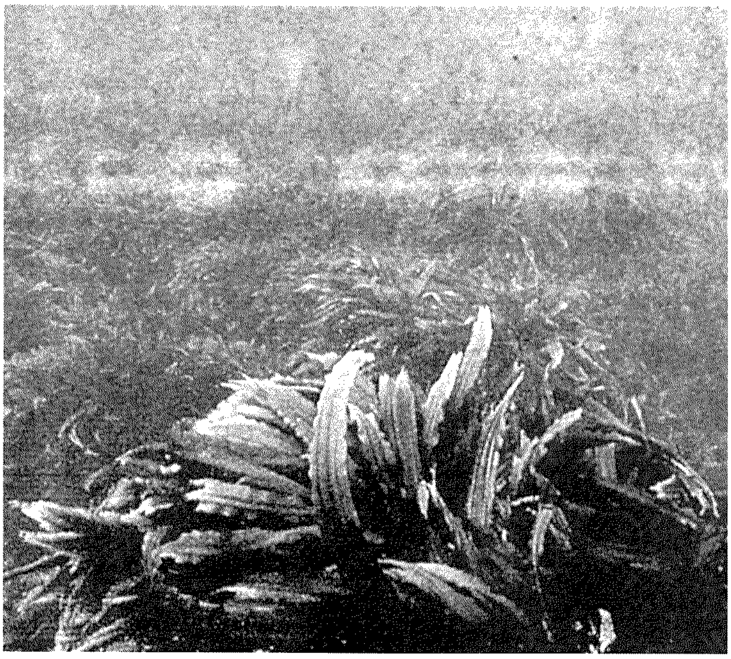
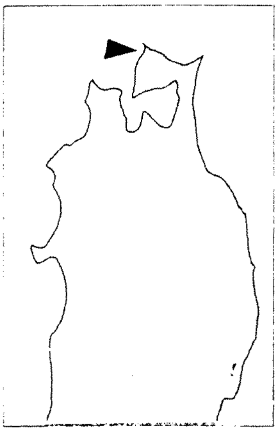
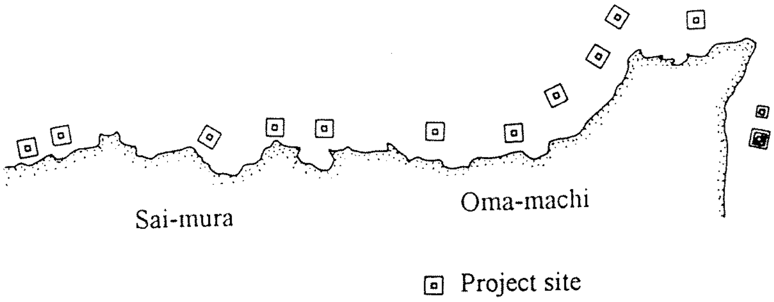


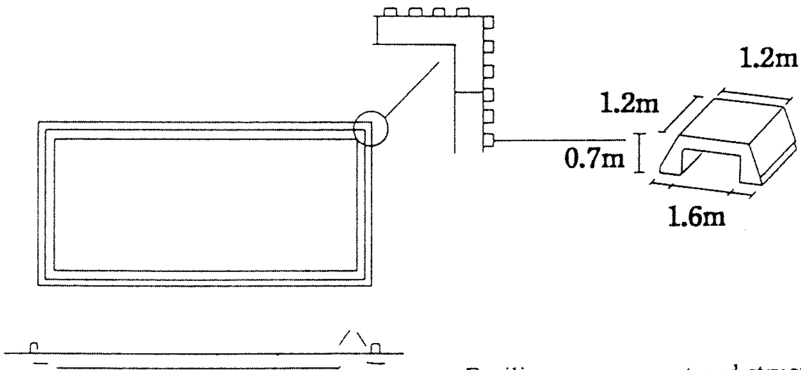
Figure 40-2

Name of district/ prefecture	Oma District, Aomori Prefecture
Type of fish	Kelp









Facility arrangement and structural plan

■ Project summary

Project name	Project year	Work volume	Major structure
Propagation-ground-development project	FY 1978-1981	220 ha	Natural stone/propagation block

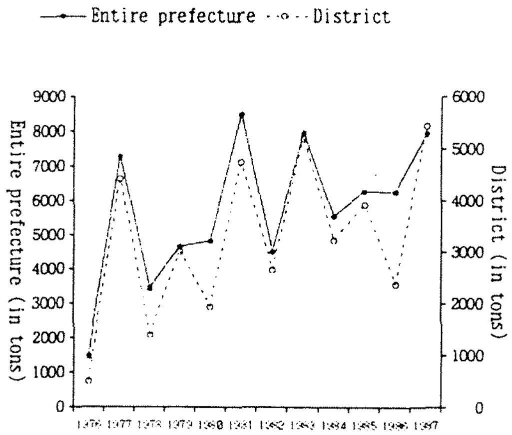
Figure 41-1

■ Changes in Kelp Production

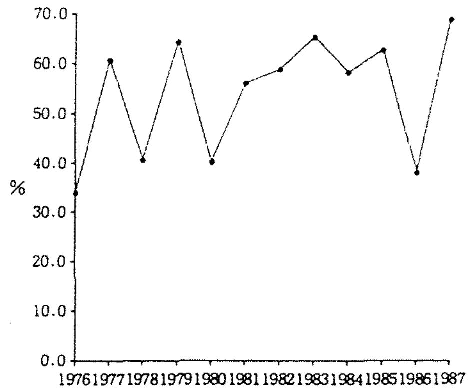
☐ : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	1,487	7,281	3,439	4,672	4,827	8,476	4,516	7,971	5,555	6,277	6,250	7,930
Catch by district	506	4,422	1,401	3,007	1,939	4,752	2,652	5,198	3,233	3,931	2,375	5,449
District's catch by percentage	34.0	60.7	40.7	64.4	40.2	56.1	58.7	65.2	58.2	62.6	38.0	68.7
Sea-urchin catch	262	206	297	288	237	262	162	272	165	659	492	491

Changes in kelp catch



Changes by percentage of kelp catch



District's sea-urchin catch

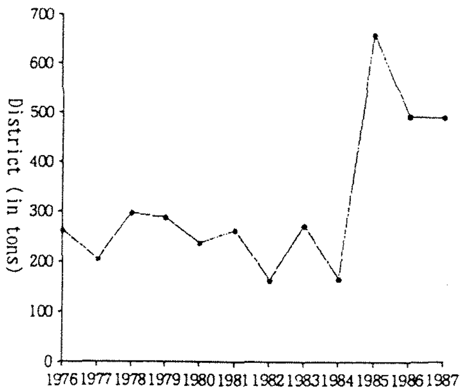
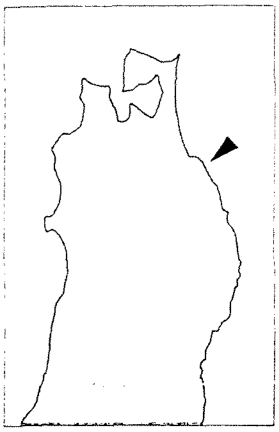
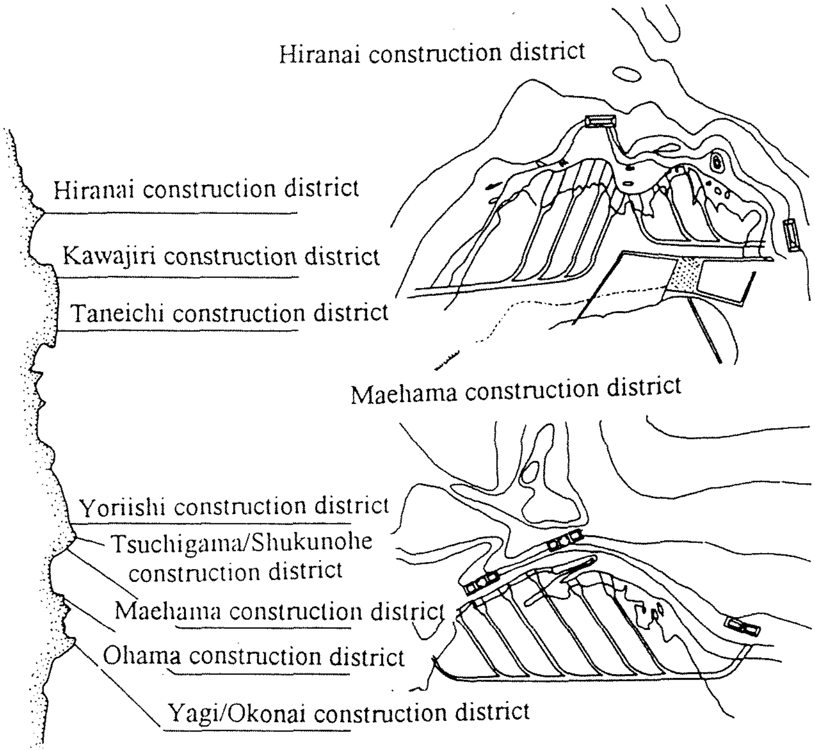


Figure 41-2

Name of district/ prefecture	Taneichi District, Iwate Prefecture
Type of fish	Sea urchin, abalone





■ **Project summary**

Project name	Project year	Work volume	Major structure
Propagation-ground-development project	FY 1975-1980	51.9 ha	Propagation ditch/ propagation block

Figure 42-1

■ Changes in Sea-Urchin Production (Shelled)

☐ : Project year (1975-1980)

(unit: tons)

	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	299	196	170	237	230	64	192	170	242
Catch by district	6.6	12.1	18.5	20.5	15.7	7.6	5.7	7.0	9.7
District's catch by percentage	2.0	6.2	10.9	8.6	6.8	11.9	3.0	4.1	4.0

■ Changes in abalone catch

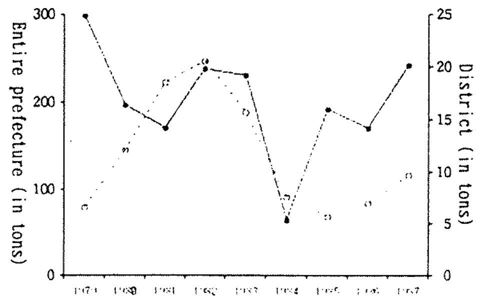
☐ : Project year (1975-1980)

(unit: tons)

	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	779	819	614	596	414	175	412	466	419
Catch by district	3.3	5.6	6.0	8.2	4.1	0.6	2.0	7.2	7.6
District's catch by percentage	0.4	0.7	1.0	1.4	1.0	0.3	0.5	1.5	1.8

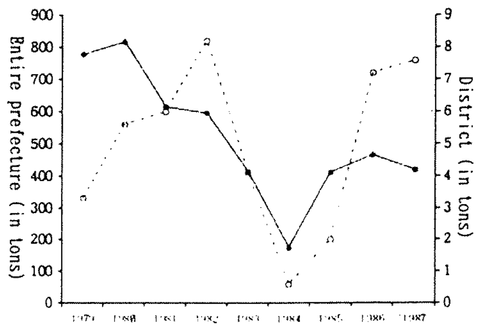
Changes in sea-urchin production (shelled)

Entire prefecture - - o - - District



Changes in abalone catch

Entire prefecture - - o - - District



Sea-urchin and abalone catch changes by percentage

Sea urchin - - o - - Abalone

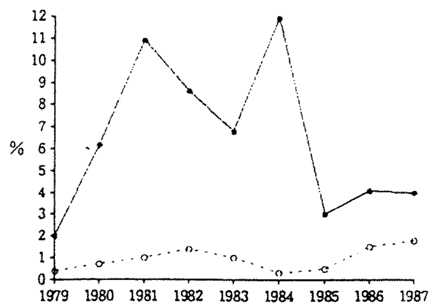


Figure 42-2

Changes in Aquacultural Production

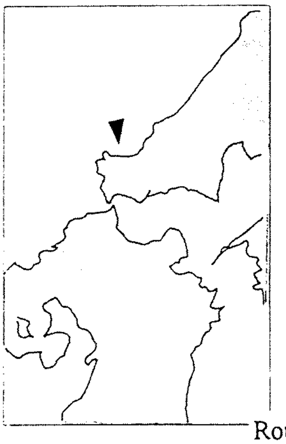
(unit: tons, ¥1 million)

Classification	1983	1984-1985	1986-1987	1988-1989	1990-1991
Yellowtail	390	390	546	624	1,224
Globefish	0	5	5	5	4
Japanese flounder	0	0	0	0	3
Striped jack	0	0	0	0	1
Total	390	395	551	629	1,232
Production volume	299	336	388.5	502.5	839

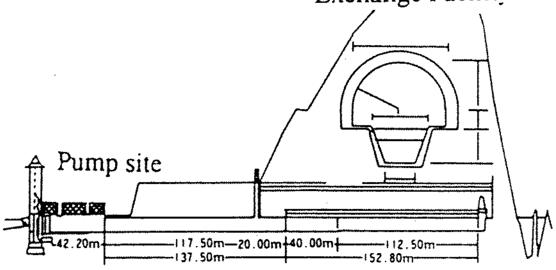
Note: 2-3: Average value of two to three years.
Same with others.

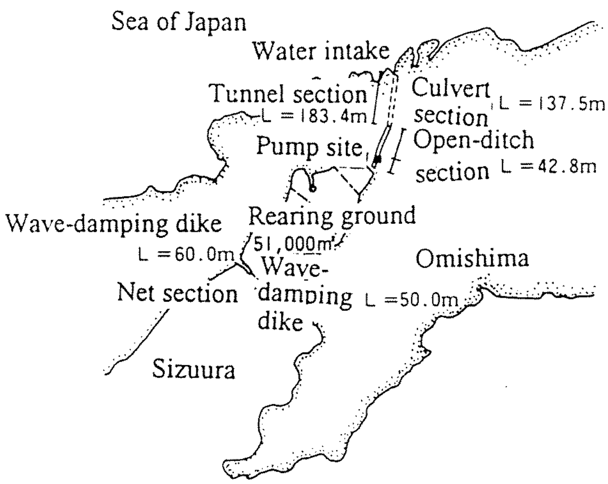
Table 43

Name of district/ prefecture	Senzaki District, Yamaguchi Prefecture
Type of fish	Yellowtail, sea bream, globefish, Japanese flounder, flatfish



Rough plan of Sea Water Exchange Facility





■ **Project summary**

Seawater–exchange facility	**Tunnel**	**(culvert section)**	**l = 183.4 m**
	Canal	**(open ditch section)**	**l = 180.3 m**
Wave–damping facility	**Wave–damping dike (two dikes)**		**l = 110.0 m**

Project name	Project year	Work volume
Aquacultural-ground-development project	FY 1978-1980	51,000 m²

Figure 44-1

■ Changes in Production

(unit: 1,000)

	1976 (preinstallation)	1981	1982	1983	1984	1985	1986	1987	1988
Red sea bream	327	467	408	369	454	305	395	362	304
Yellowtail	190	215	224	222	220	209	232	234	237
Globefish	25	53	47	42	50	12	11	12	11
Japanese flounder	10	147	232	341	378	353	378	388	484
Total	552	882	911	974	1,102	879	1,016	996	1,036

Changes in number of fish produced
at aquacultural ground

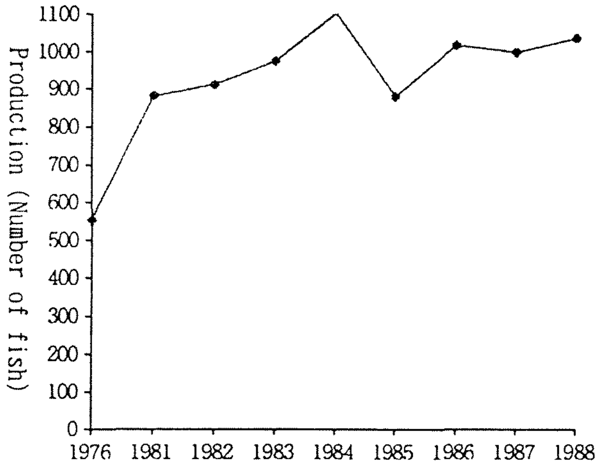
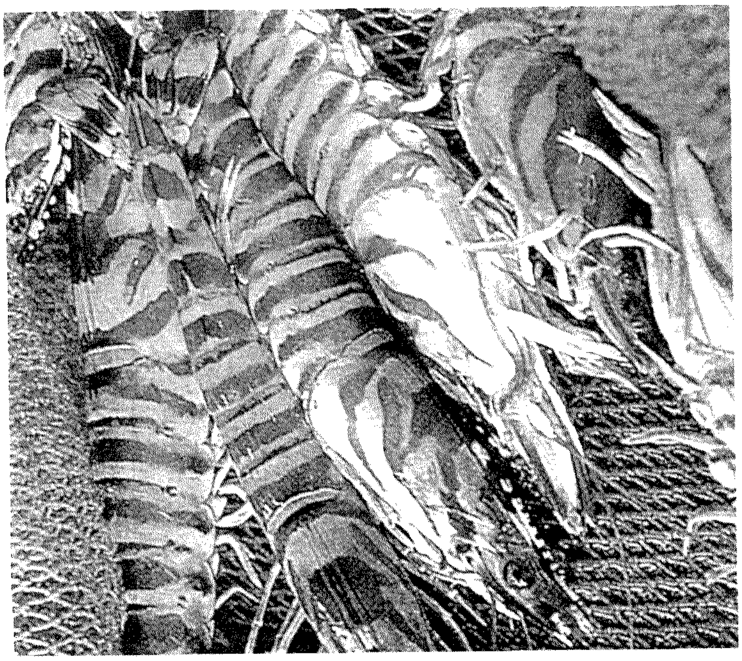
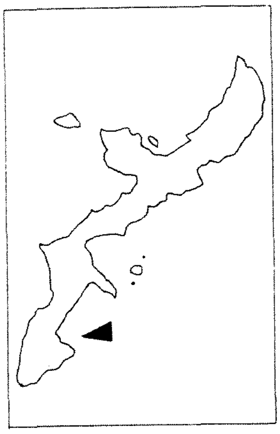
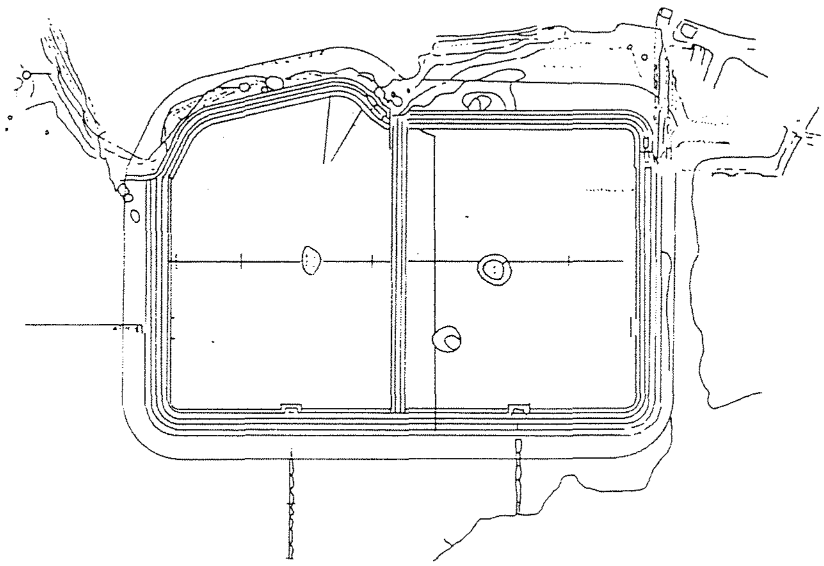


Figure 44-2

Name of district/ prefecture	Itanma District, Okinawa Prefecture
Type of fish	Kuruma prawn







■ **Project summary**

Project name	Project year	Project expenses
Aquacultural-ground-development project	FY 1979-1982	¥634 million

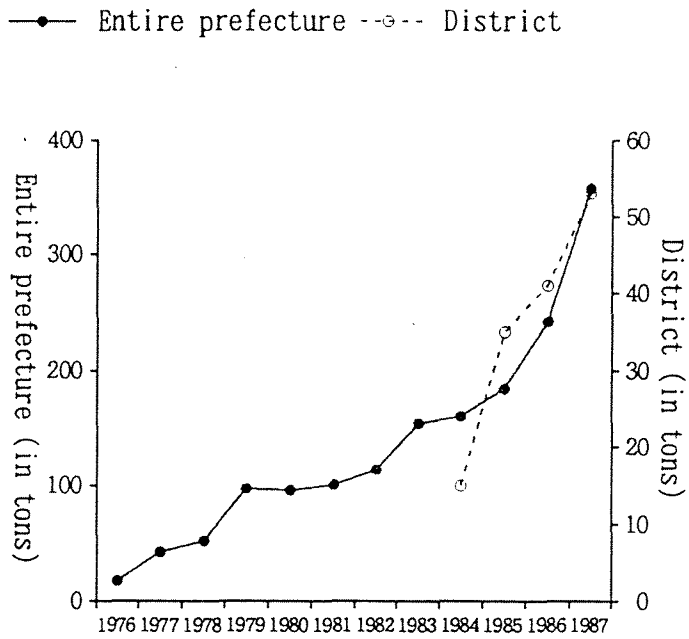
Figure 45-1

■ Changes in Kuruma Prawn Production

☐ : Project year (unit: tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Production of entire prefecture	18	43	52	97	96	101	114	154	160	184	242	358
Production of facility	—	—	—	—	—	—	—	—	15	35	41	53
Facility's percentage in production	—	—	—	—	—	—	—	—	9.4	19.0	16.9	14.8

Changes in production



Changes by percentage of catch

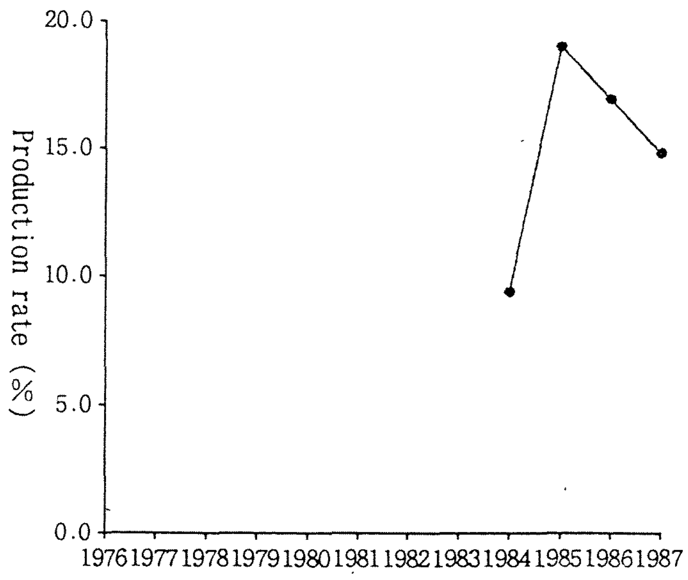
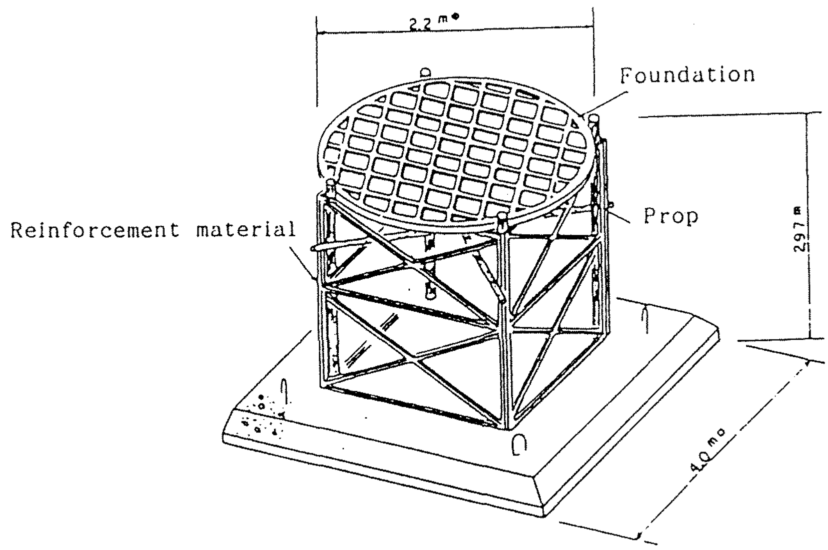
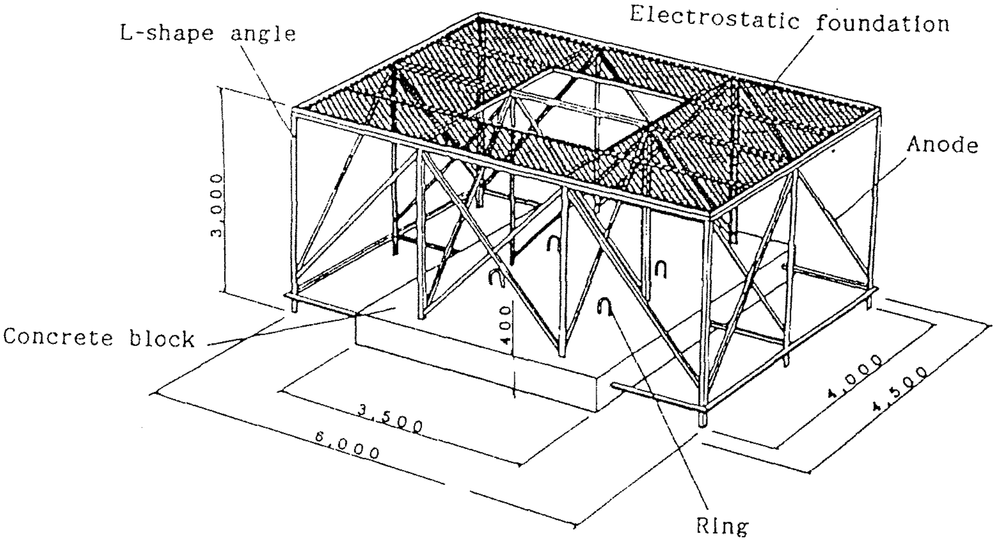


Figure 45-2



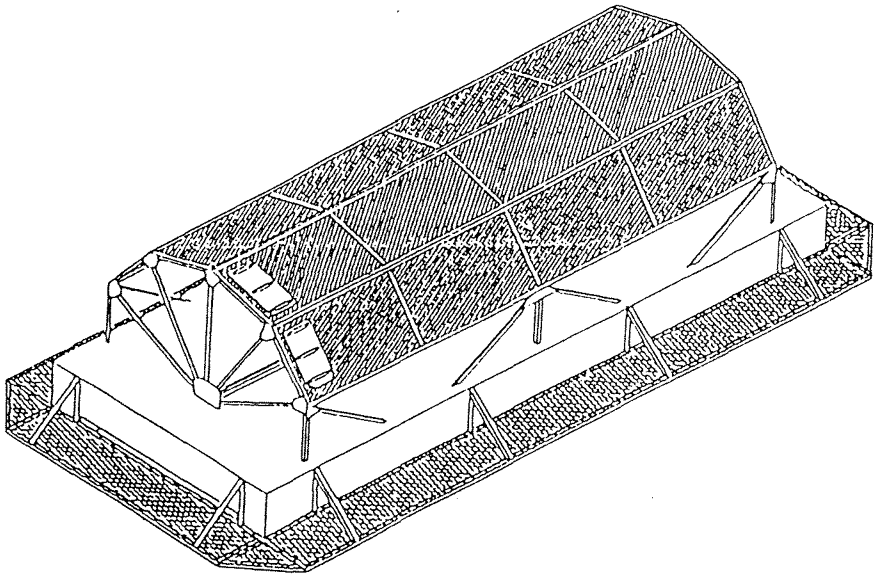
Structure with FRP lattice Table as matrix

Fig. 46: MF21 Lattice Table Matrix



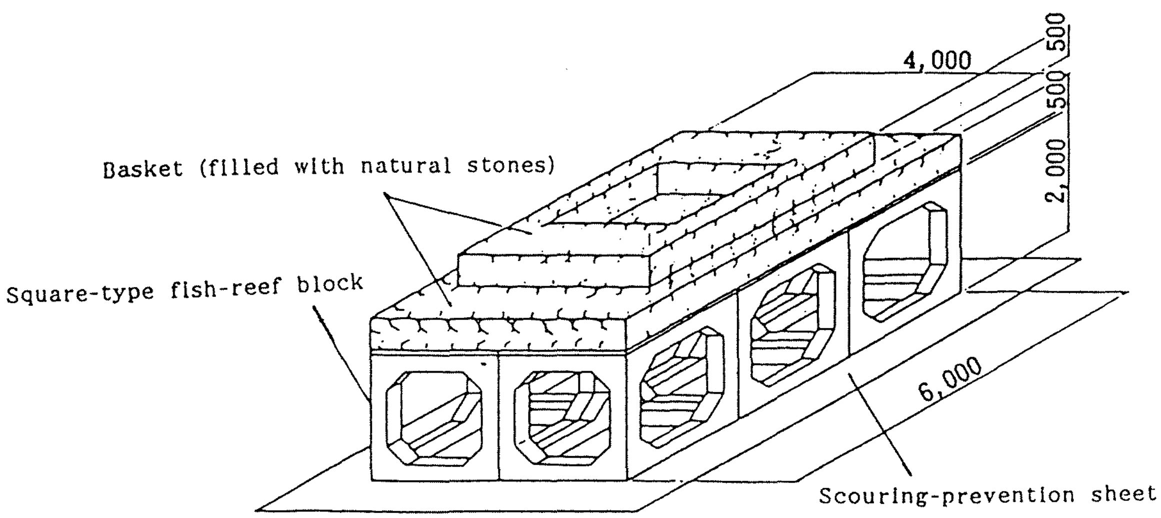
Structure depositing Ca ions and Mg ions in seawater as electrostatics to a wire-netting surface that comprises the electrolytic cathode

Fig. 47-1: MF21 electrostatic matrix



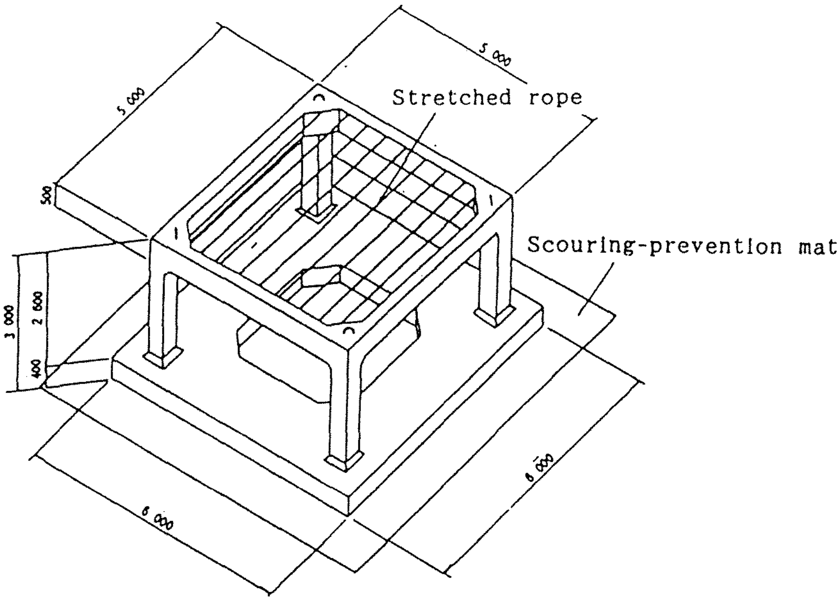
This is a style that installs an electrostatic foundation of a multiangular roof-type mesh structure on the basic concrete with scouring-prevention material.

Fig. 47-2: Electrostatic seaweed-reef style (scouring-prevention type)



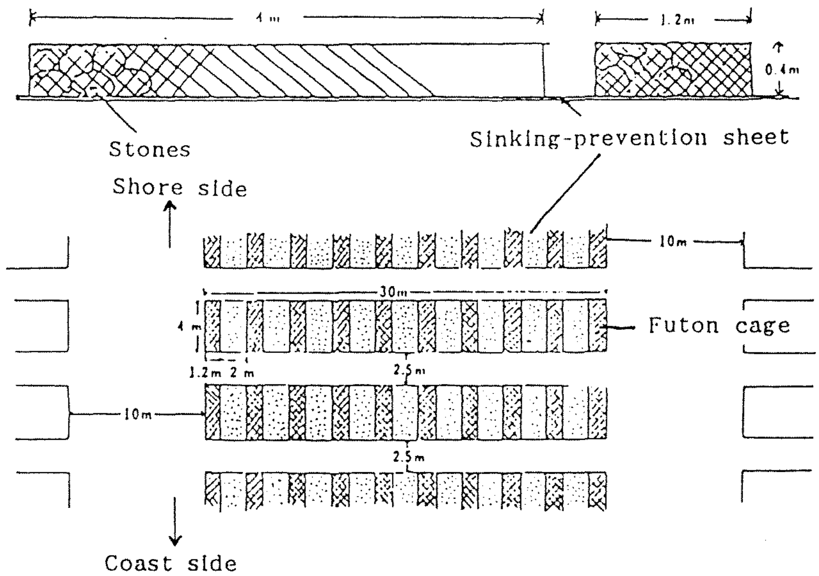
Using a normal square fish reef as the basis, baskets full of natural stones comprise the foundation.

Fig. 48: MF21 masonry matrix



Structure is of reinforced concrete used as a foundation, comprised of the bottom base, pier stud, and foundation frame as the basic structure. Ropes are stretched in the hollow part.

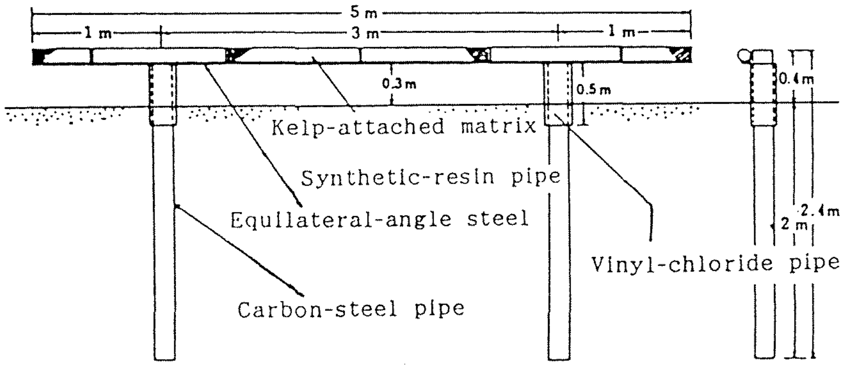
Fig. 49: MF21 hollow matrix



Ground plan of futon-cage-facility arrangement

A method to cast several tens of stones wrapped by wire in futon style

Fig. 50: Futon-cage method



Two steel-pipe piles are used as props by insertion into sand. On the two props, netolon-net-wrapped L-shaped steel is attached.

Fig. 51: Steel-pipe-pile method

Stones are filled into a barrel-shaped FRP lattice, which is arranged vertically.

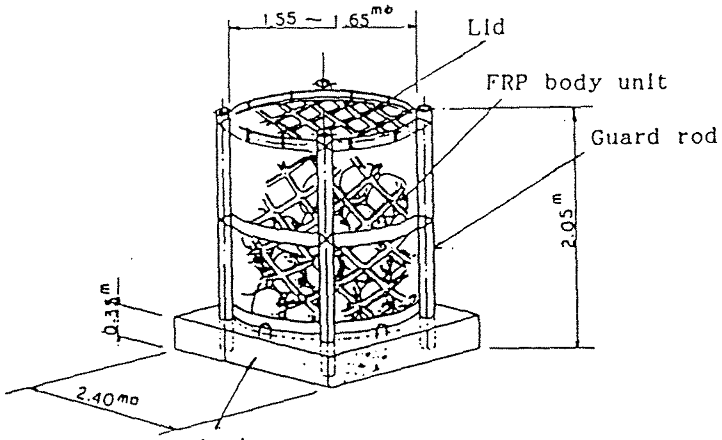
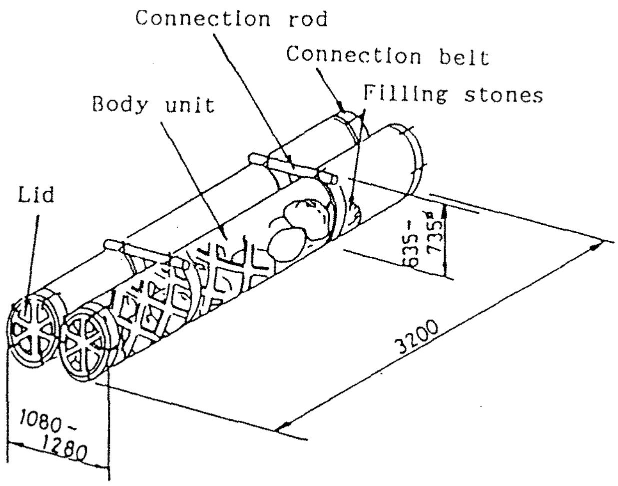
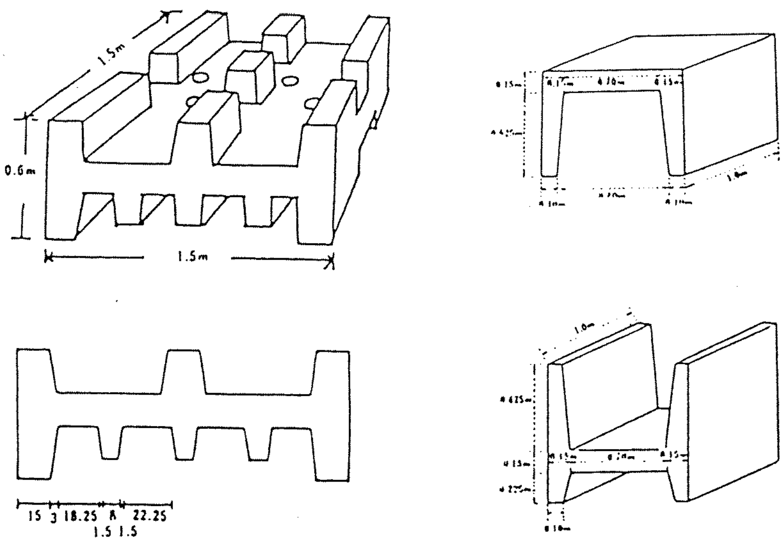


Fig. 52: FRP-cage method (vertical type)



Stones are inserted into barrel-shaped FRP lattices, which are installed horizontally.

Fig. 53: FRP-cage method (laying type)



Used are blocks in a shape suitable for burying in sand, and that can resist drifting sand.

Fig. 54-1: Concrete-block method (mainly for kelp)

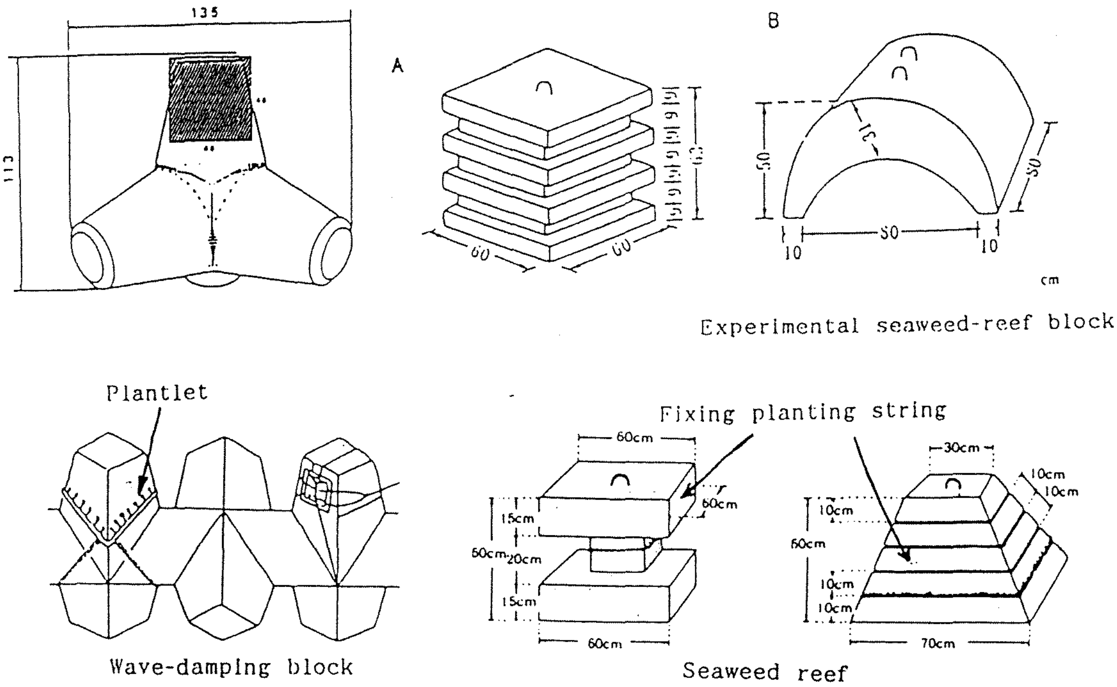
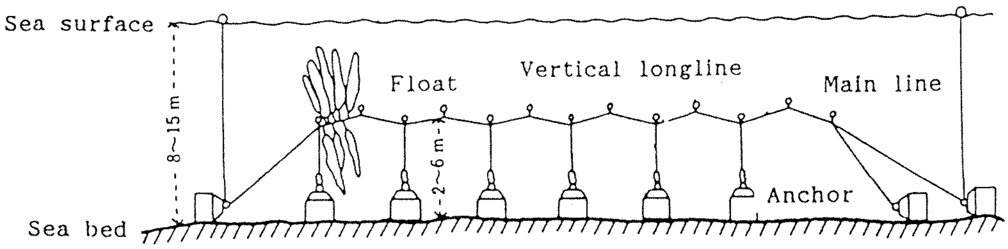
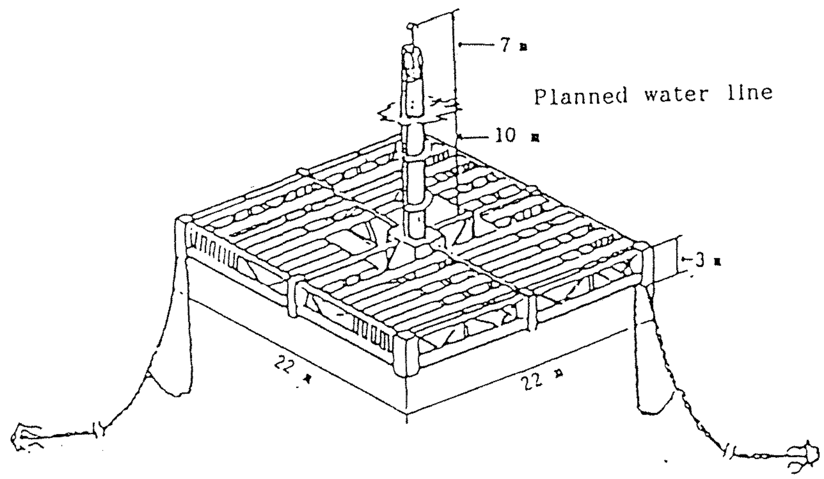


Fig. 54-2: Concrete-block method (mainly for Eisenia bicyclis and sea trumpet)



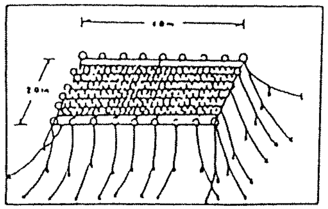
Method that stretches longlines between anchors and floats-connecting rope

Fig. 55: Vertical-longline method

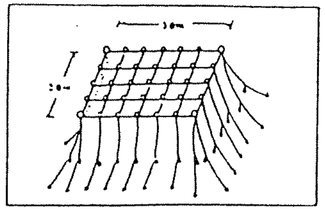


In this method a steel shelf is moored at a sea depth accessible by light.

<u>Fig. 56: Steel-made floating-shelf method</u>



Culturing structure with spore planting net



Culturing structure with spore planting string/parent rope

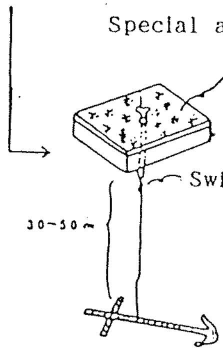
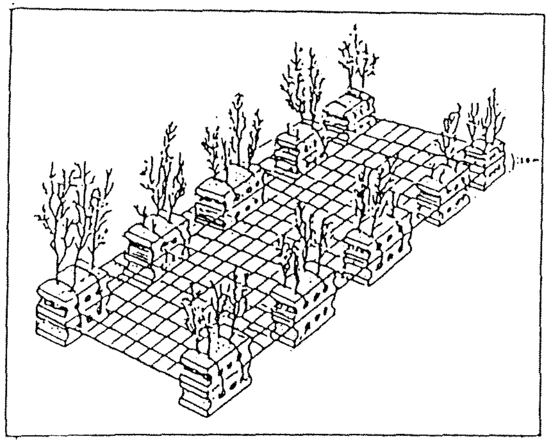


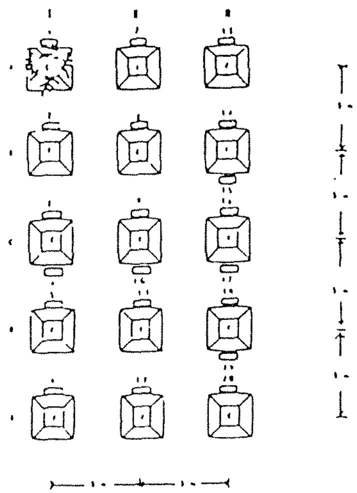
Diagram showing how to set special attachment plate

This method employs a floating body such as a styrene-foam structure, to which Cremona or nylon is attached.

Fig. 57: Floating-rack culturing method

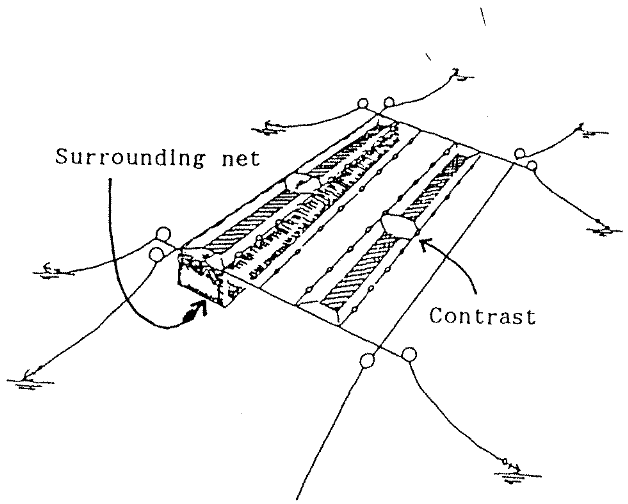


Sketch of wire-mesh-setting method



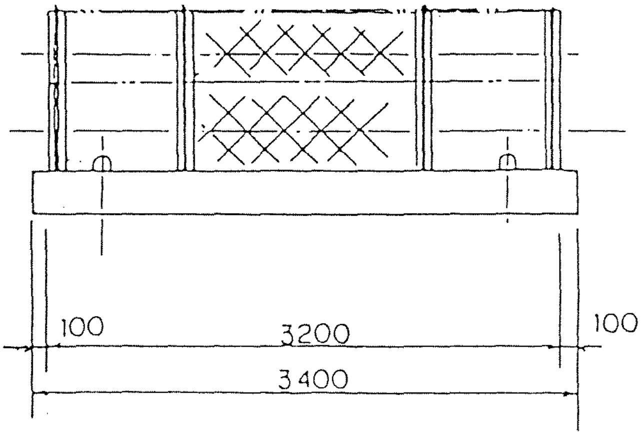
Using blocks with transplanted mother-seaweed as fulcrum, wire ropes are stretched all around.

Fig. 58: Concrete-block method



Seaweed spore-planted nets are set in raft manner and suspended downward.

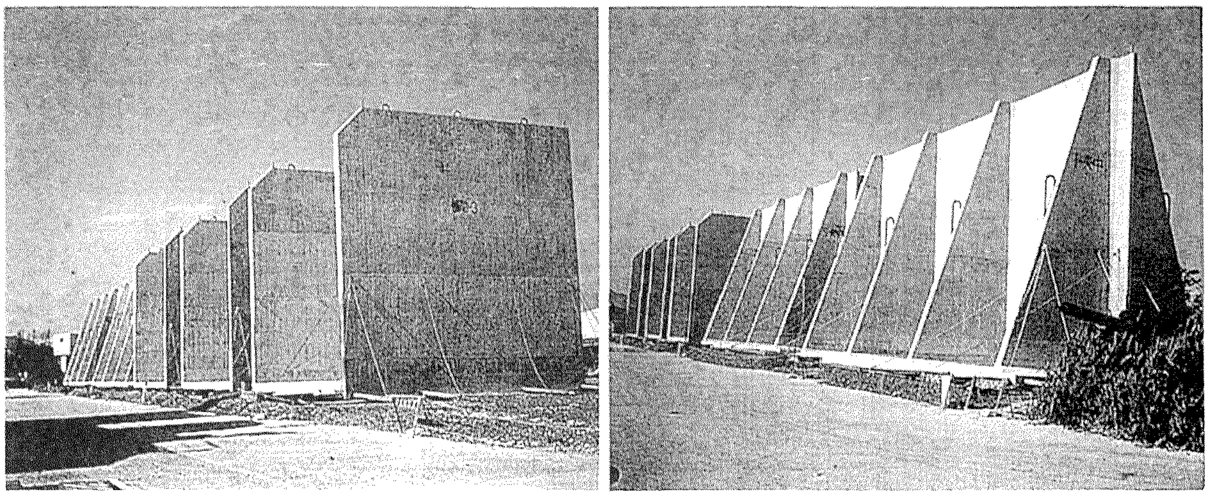
Fig. 59: Net-raft method



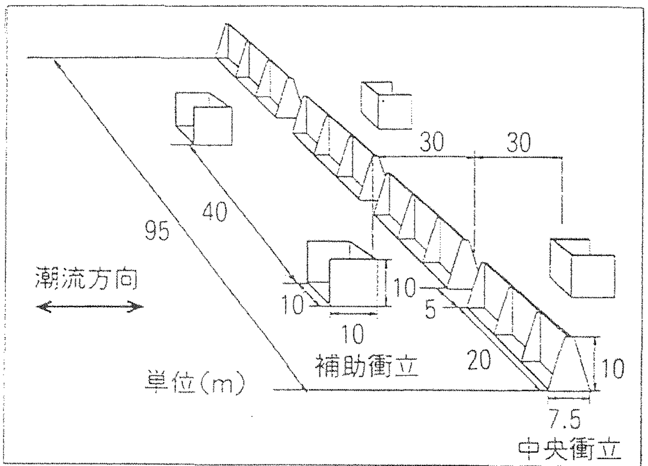
Barrel-shaped FRP lattices are piled up after the fashion of straw bags in multilayers. These are fixed transversely to a concrete base.

Fig. 60: FRP-cage method

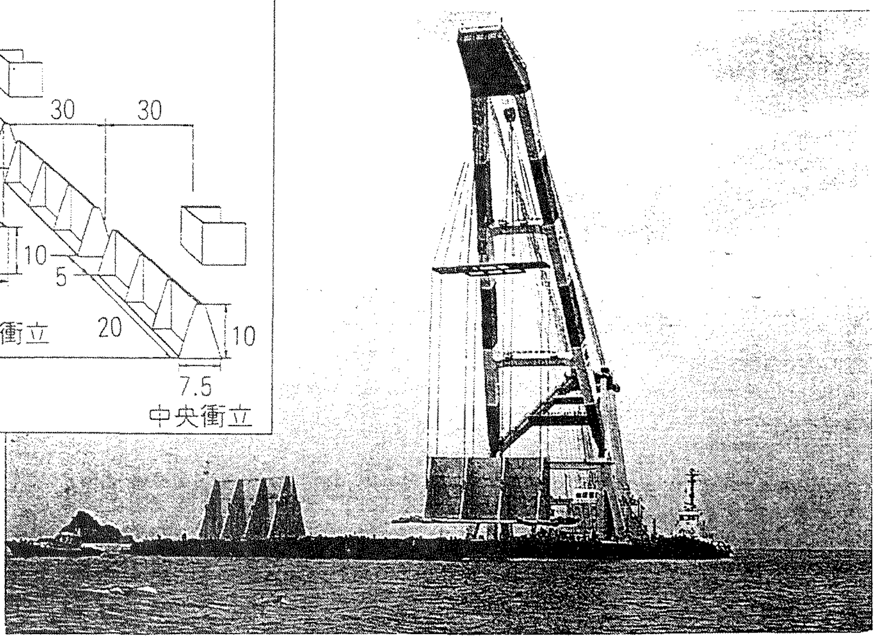
Artificial-upwelling-flow-generation structure



Artificial-upwelling-flow-generation structure



Scale and arrangement



State of installation

Figure 61

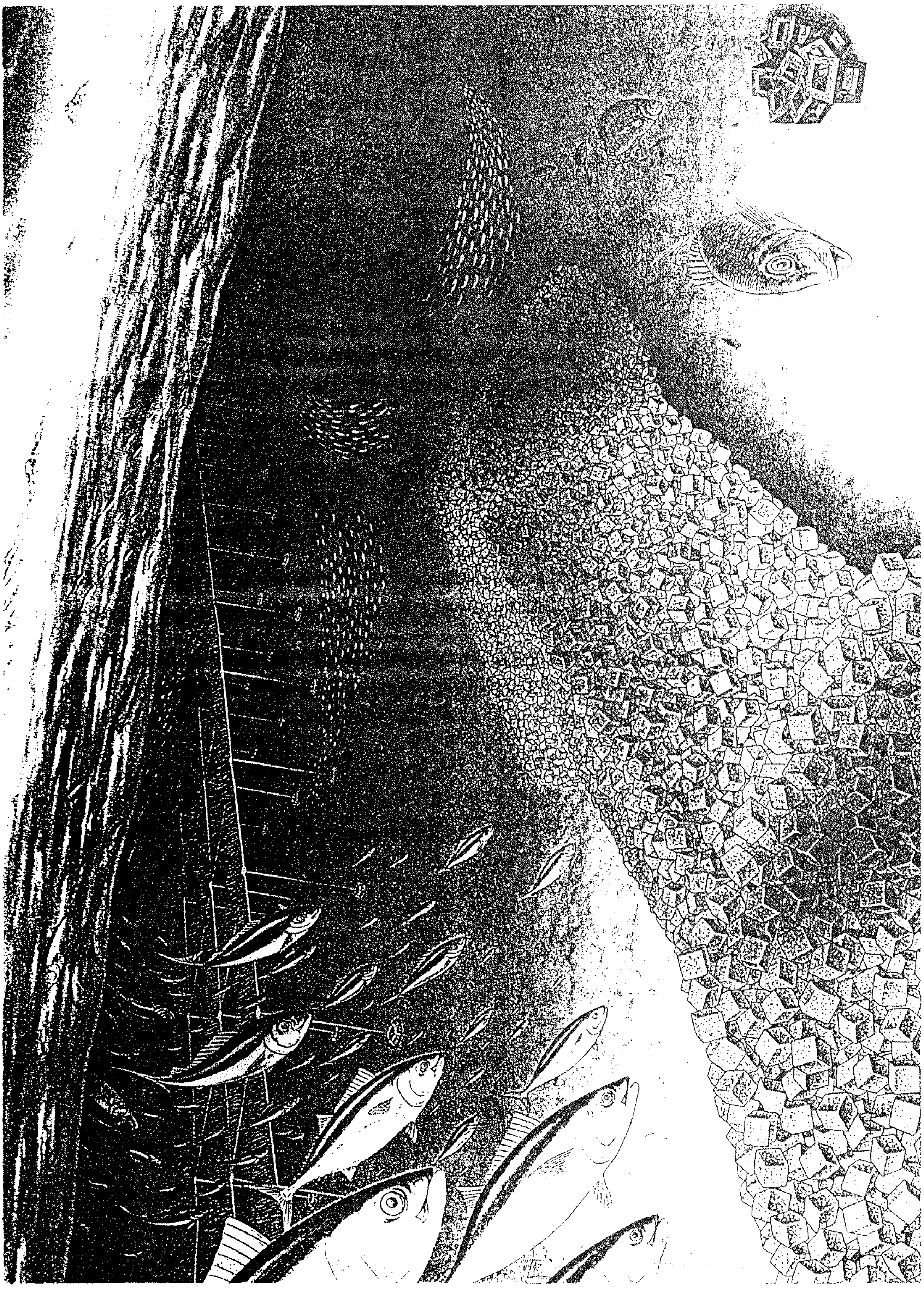


Figure 62

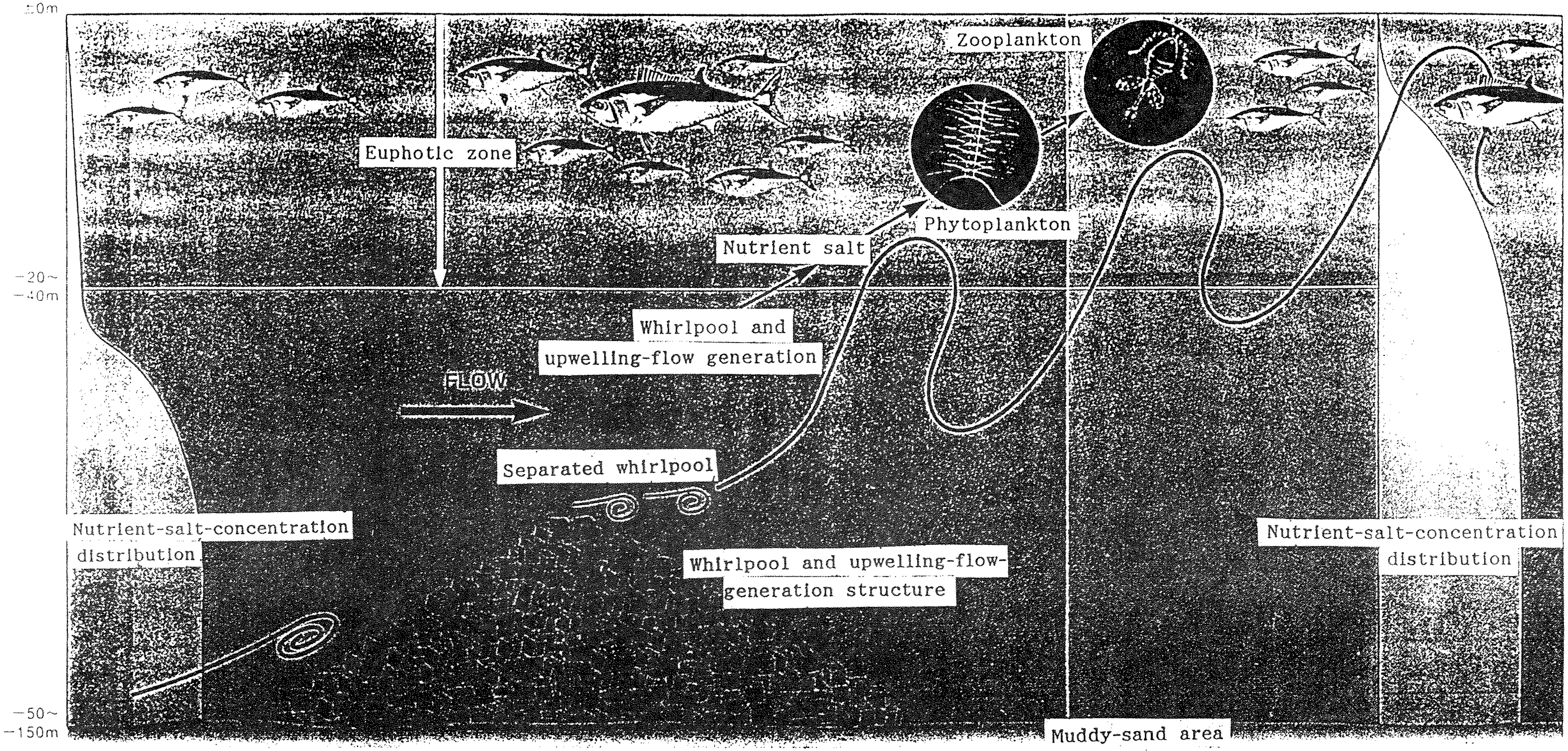
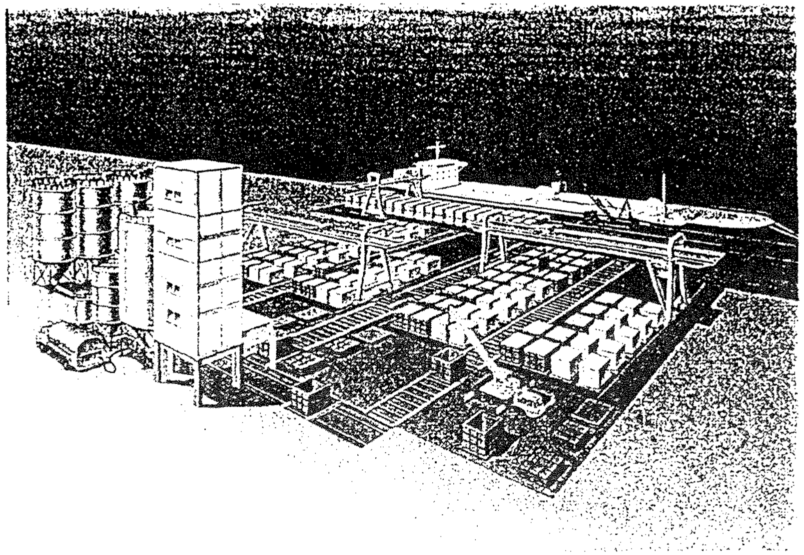
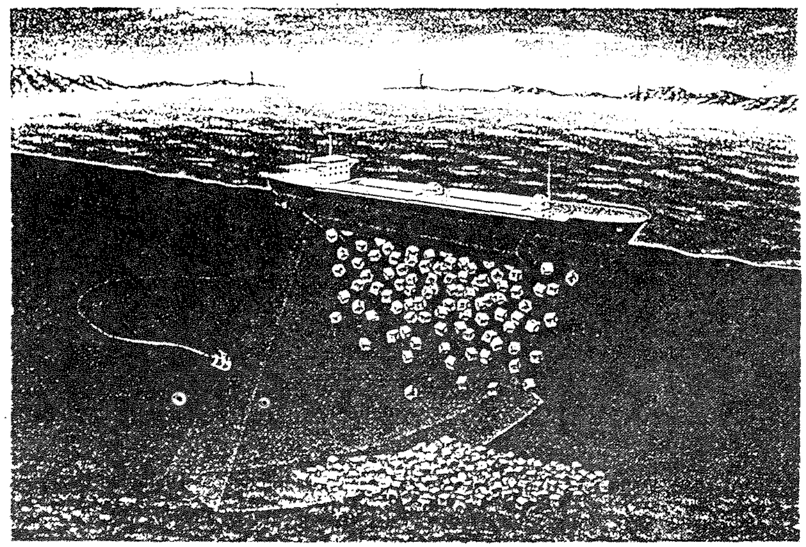


Fig. 63: Upwelling generation and food chain



o Hardened-block manufacturing

A plant is established in a yard close to a power station. Blocks are manufactured by sequential material mixing, striking of material form, and compaction by pressing and excitation. The amount of coal ash generated from a 1-million-KW power station is about 300,000 tons a year. Using 30 percent of the ash, about 9,000 cubic blocks are manufactured, measuring 2 meters on each side.

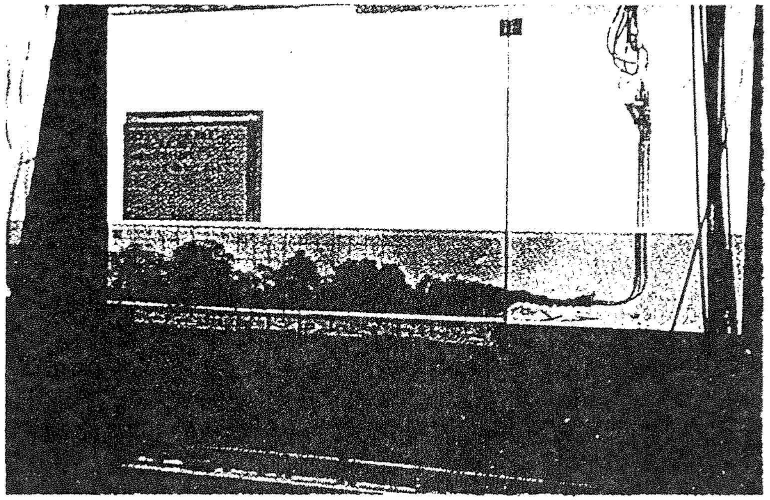


o Sinking of hardened blocks

Maintaining barge position by means of the automatic positioning control system (DPS), and estimating the position for dropping, blocks are released through an opening in the barge bottom. A mound of 23 m (H) and 230 m (L) (280,000 m^3) can be constructed in one year.

Hydraulic Model Experiments and Numerical Simulations

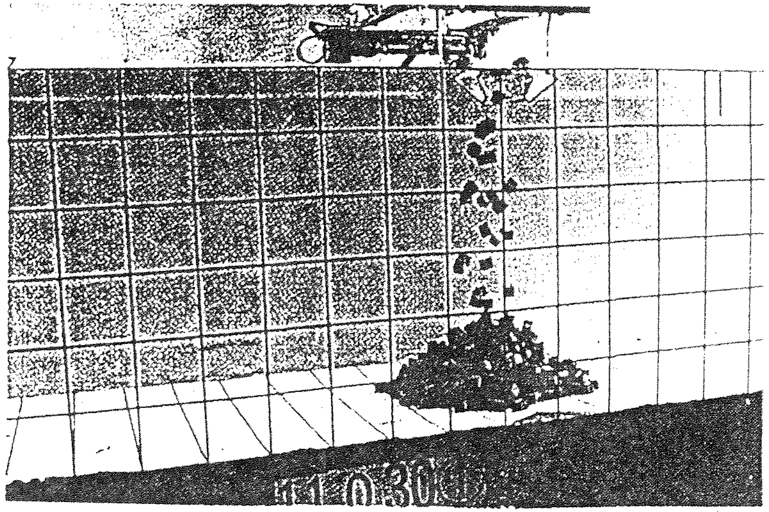
Fig. 64-1: Artificial Ridge Development



Hydraulic-model experiment concerning upwelling-flow volume

o Upwelling-flow generated by artificial ridge

How a quantity of upwelling-flow changes by the form of a mound, flow conditions, and difference in density between the surface and bottom layers is clarified by hydraulic experiments. Based on the ascertained data, numerical simulations enable estimates of the quantity of added nutrient salts and ecosystem changes through the food chain in actual seawater.



Block-casting hydraulic-model experiment

o Underwater-mound construction

Hydraulic-model experiments elucidate the state of mound accumulation incurred from differences in casting conditions (such as casting time) of hardened blocks and local conditions (flow velocity).

Fig. 64-2: Artificial Ridge Development

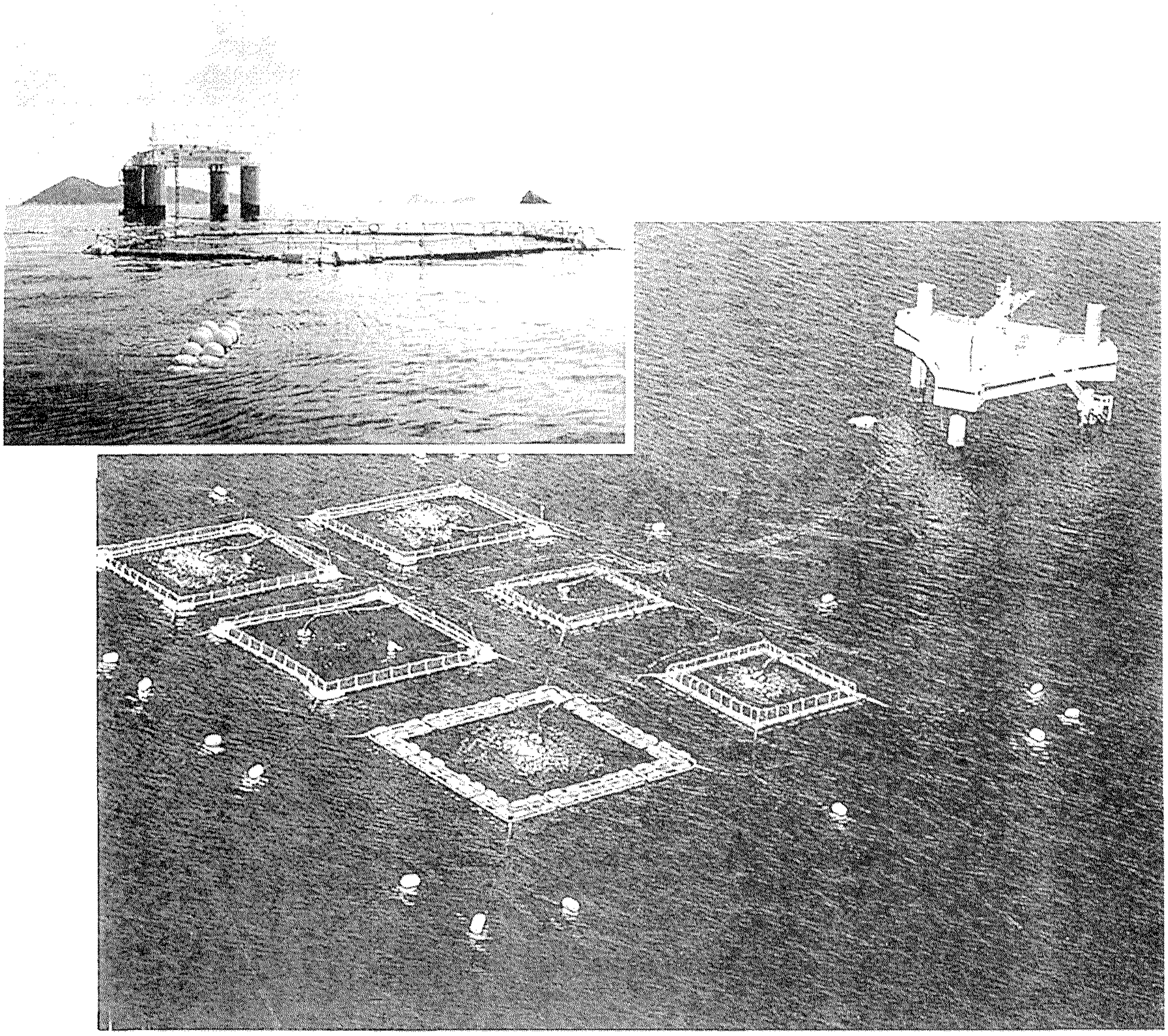
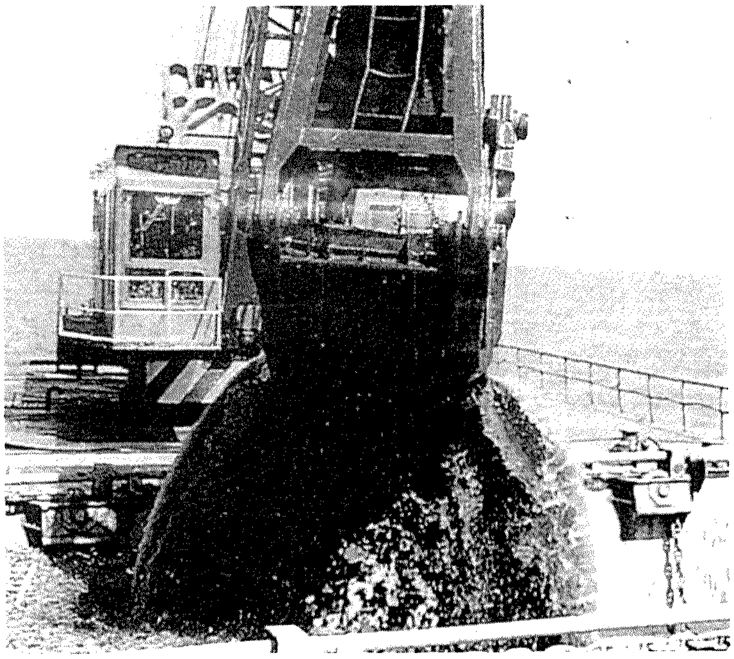
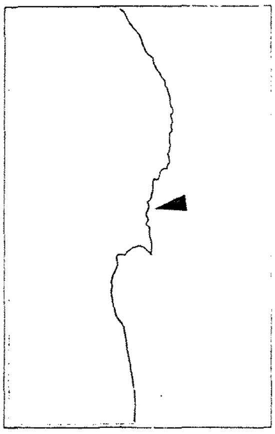
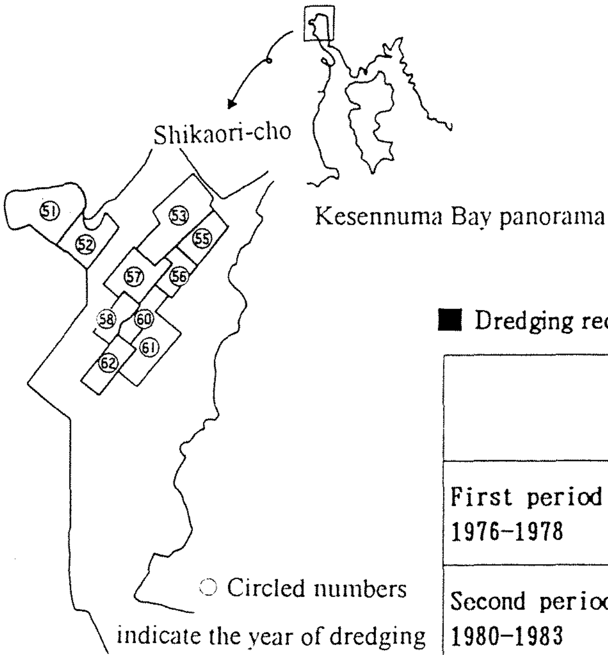


Figure 65: Offshore–aquacultural system

Name of district/ prefecture	Kesennuma District, Miyagi Prefecture
Purpose	Restoration of fishery environment







■ Dredging record

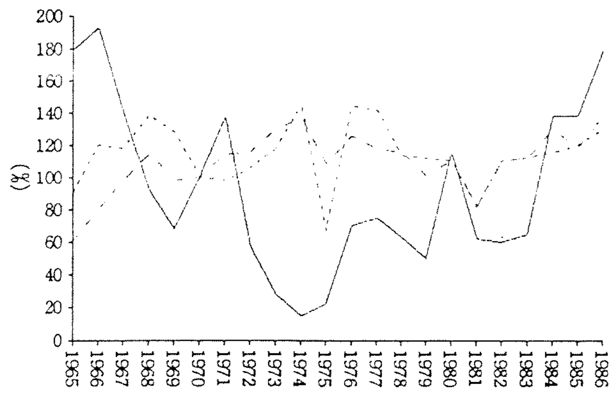
	Dredged area	Dredged-mud volume
First period 1976-1978	m² 141,435	m³ 102,420
Second period 1980-1983	101,660	53,100
Third period 1985-1987	82,700	35,420
Total	325,795	190,940

■ Project summary

Project name	Project year	Work volume	Note
Large-Scale Fishing-Ground Preservation Project	First period 1976-1978 Second period 1980-1983 Third period 1985-1987	Dredged area 32.6 ha Dredged-mud volume 191 thousand m³	Dredging up sludge

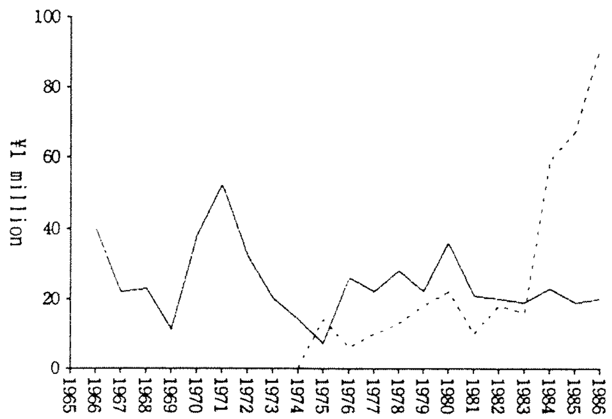
Figure 66-1

—— Shikaori District - - - Entire prefecture
----- Kesennuma Bay District



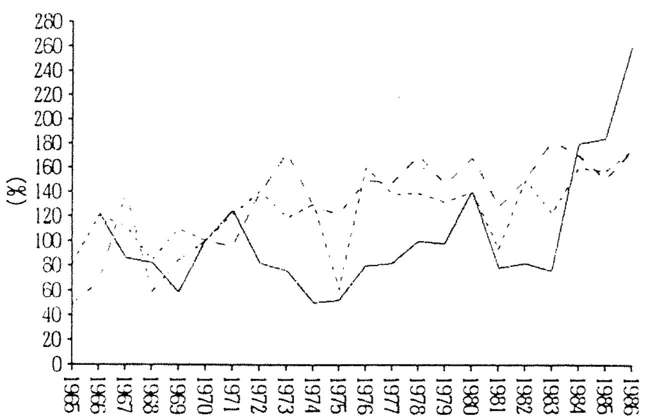
Changes in aquacultural-production volume
(excluding fish aquaculture 1970 as 100)

—— Oyster aquaculture ----- Kelp aquaculture



Changes in production volume of major aquacultural
products in the Shikaori District

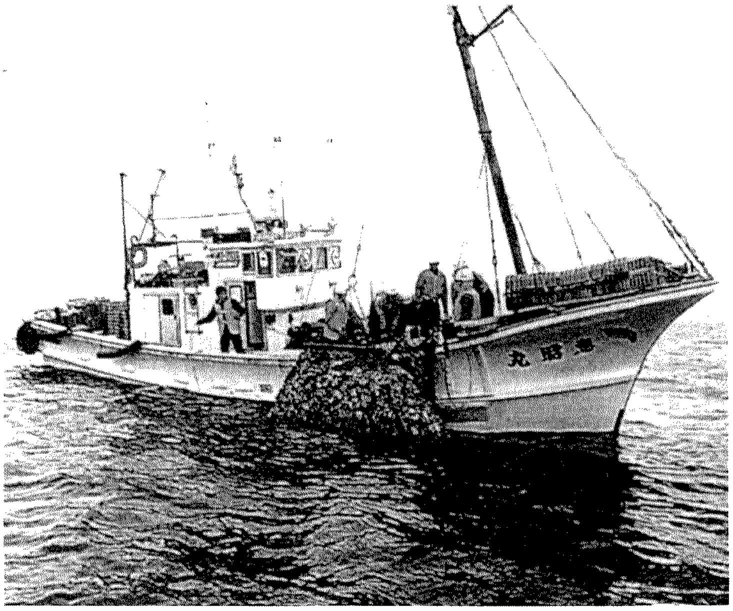
—— Shikaori District - - - Entire prefecture
----- Kesennuma Bay District

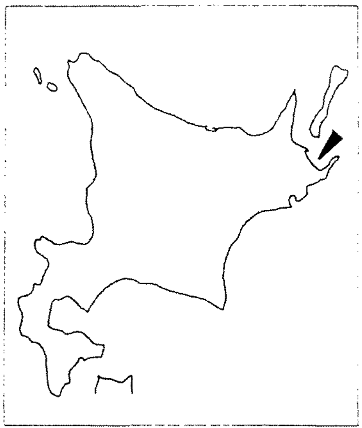


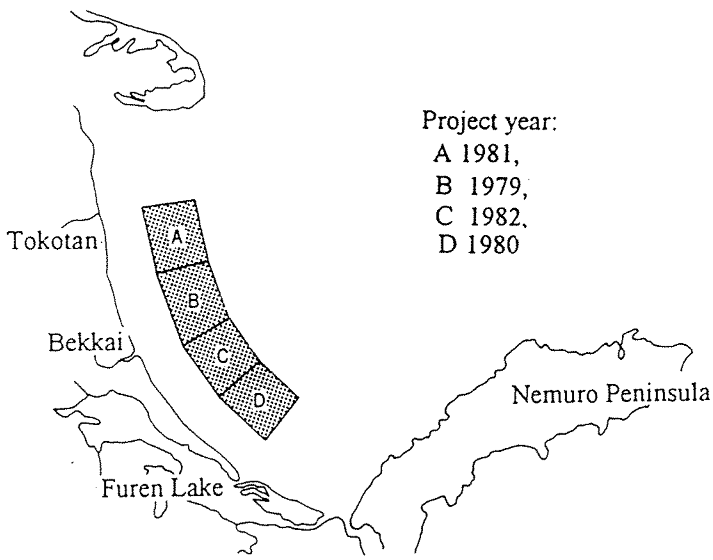
Changes in aquacultural-production amount
(excluding fish aquaculture 1970 as 100)

Figure 66-2

Name of district/ prefecture	Nemuro Bay District, Hokkaido
Type of fish	Scallop







■ Project summary

Project name	Project year	Work volume	Major structure
Large-scale fishery-preservation project	FY 1979-1982	7,840 ha	Removal of sea-bed sediments (starfish, etc.) and tilling of seabed

Figure 67-1

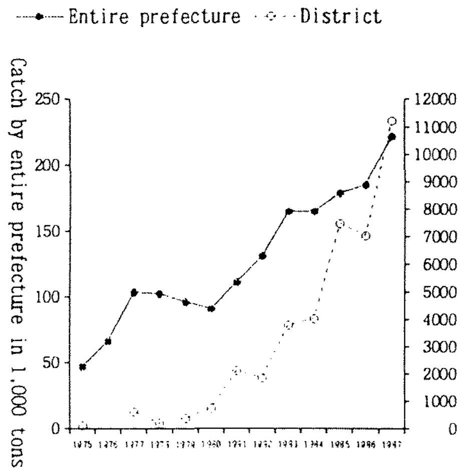
■ Changes in Scallop Production

☐ : Project year (unit: tons)

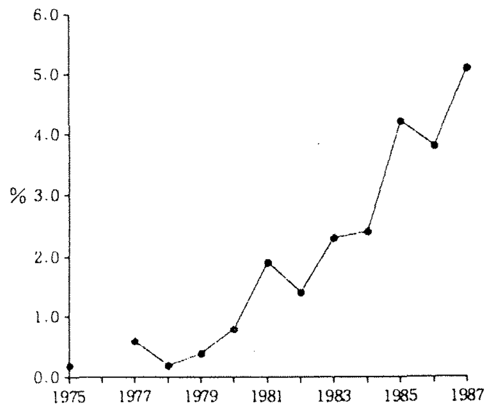
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Catch by entire prefecture	47,079	66,301	104,192	102,711	96,394	91,018	111,482	130,574	164,632	164,479	178,336	184,984	221,689
Catch by district	98	-	596	192	358	723	2,115	1,853	3,788	4,018	7,450	7,028	11,228
District's catch by percentage	0.2	-	0.6	0.2	0.4	0.8	1.9	1.4	2.3	2.4	4.2	3.8	5.1

‡ Catch by district/catch of entire prefecture × 100
= district's catch by percentage

Changes in catch



Changes by percentage of catch



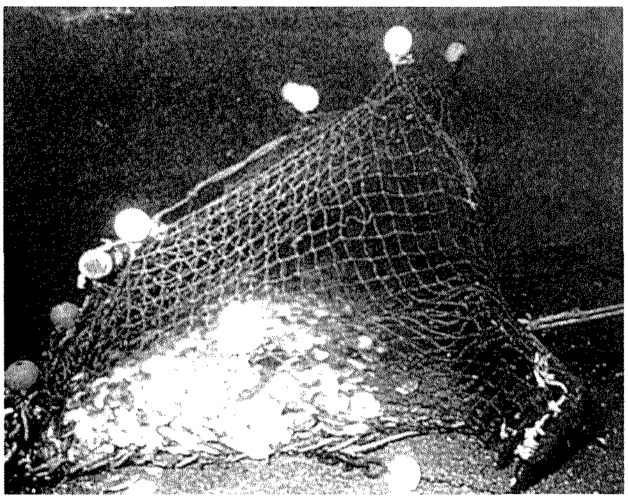


Figure 67-2

参加者名簿（List of Participants）

AUSTRALIA

John SAINSBURY
Minister-Counsellor (Agriculture)
Australian Embassy
2-1-14 Mita
Minato-ku, Tokyo, 108
03-5232-4021
03-5232-4029

BAHRAIN

Jassim Ahmed AL-QASEER
Director
Directorate of Fisheries
Directorate of Fisheries Ministry of Works and Agriculture
P.O. Box 20071 State of Bahrain
973-729595
973-728459
rogeru@batelco.com.bh

CANADA

Leo MARGOLIS
Senior Scientist
Department of Fisheries and Oceans Pacific Biological Station
Nanaimo, British Columbia, V9R 5K6, Canada
1-604-756-7032
1-604-756-7053
baglop@PBS.DFO.CA

CHILE

Marcelo CAMPOS LARRAIN
Head of The Aquaculture Department
Undersecretariat for Fisheries-Chile
Bellavista 168, Floor 17, P.O. Box 100-V
Valparaiso- Chile
56-32-212187 56-32-212811 56-32-234316
56-32-251693

EUROPEAN UNION

Philippe PAULIN
First Secretary
European Union Delegation of The E.C. in Japan
03-3239-0441
03-3261-5194

FEDERATED STATES OF MICRONESIA

Bernard THOULAG
Executive Director
Micronesian Maritime Authority
P.O.Box PS122, Palikir, Pohnpei,
Federated States of Micronesia 96941
691-320-2700 or
691-320-2383

IRAN

Mohammed RABBANI
Head of Hydrology Department
Iranian Fisheries Research and Training Organization
No.24 11th str., Mir-Emad Ave., Tehran, 15877
P.O.BOX 14155-6116, Iran
98-21-8751498/9
98-21-8751495

KIRIBATI

Tinian Felix REIHER
Permanent Secretary
Ministry of Natural Resources Development
P.O. Box 64 Bairiki-Tarawa
Republic of Kiribati
686-21099
686-21120

Willie TOKATAAKE
Cabinet Minister
Ministry of Natural Resources Development
P.O. Box 64 Bairiki-Tarawa
Republic of Kiribati
686-21099
686-21120

MEXICO

Porfirio ALVAREZ TORRES
General Director, Research in Aquaculture
Ministry of Environment, Natural resources and Fisheries
"Pitagoras
1320, Co. Sta., Cruz Atoyac,"
C.P. 03310, Mexico, D.F.
52-5-688-0605
52-5-277-4673
Saviles@Servidor.unam.mx

NEW ZEALAND

Niels HOLM
First Secretary
New Zealand Embassy
03-5478-9680
03-3467-6843

NORWAY

Erlend MOKSNESS
Professor
Institute of Marine Research Station
Flodevigen Marine Research Station, N-4817 HIS, Norway
47-370-59041
47-370-59001
moksness@imr.no

Terje SVAASAND
Head of Division of Marine Enhancement
Institute of Marine Research
P.O. BOX 1870 Nordnes, N-5024 Bergen-Nordnes, Norway
47-55-238306
47-55-238333
TERJE.SVAASAND@IMR.NO.

PANAMA

Elisa E. LOPEZ
Secretaria General
Republic of Panama

Nitzia Rodriguez de VILLARREAL
Ministra de Comercio e Industrias
Republic of Panama

Luis Eduardo VILLARREAL
Republic of Panama

PHILIPPINES

Nelson LOPEZ
Chief, Seafarming Section/Supervising Aquaculturist,
Bureau of Fisheries and Aquatic Resources
860 Arcadia Bldg., Quezon Ave., Quezon City, Metro Manila, Philippines
632-922-2231
632-988-576 or 987-871

REPUBLIC OF KOREA

JEON Im-Gi
Director, Aquaculture Department
National Fisheries Research & Development Agency
408-1 Shirang-Ri, Kijang-Up, Kijang-Kun, Pusan, 619-900, Korea
82-51-720-2400
82-51-720-2439
igjeon@haema.nfrda.re.kr.

YANG Tal-Seung
Chairman, International Cooperation Committee
The Parliamentarians' Society of the Republic of Korea
1-ka Jung-Ku, Eulchi-Ro, Seoul 100-191, KOREA
822-757-6612,3
822-757-6619 822-782-7008

SENAGAL

Ndiaga GUEYE
Derector de Oceanogra
Ministere de la Peche et des Transports Maritimes
Bilding Administratif 4 eme etage Dakar, Senegal
221-214758

SRI LANKA

Sunil Niranjan SIRIWARDENA
Senior Research Officer
National Aquatic Resources Agency
Colombo-15, Sri Lanka
94-522-000/006/005
94-522-932/881
sunil@nara.ac.lk

THAILAND

Udom BHATIYASEVI
Director, Marine Fisheries Division
Department of Fisheries Ministry of Agriculture and Cooperatives
Kasetsart University Campus, Chatuchakr, Bangkok 10900, Thailand
66-2-5620542
66-2-5620543

Oopatham PAWAPUTANON
Director, Coastal Aquaculture Division
Department of Fisheries Ministry of Agriculture and Cooperatives
Kasetsart University Campus, Chatuchakr, Bangkok 10900, Thailand
66-2-571-7077
66-2-579-2421
Cad-df@Kuac.th

UNITED STATES

Linda CHAVES
Director, Industry and Trade Program
U.S. Department of Commerce, National Marine Fisheries Service
1315 EAST-WEST HIGHWAY SILVER SPRING, MD 20910 U.S.A.
1-301-713-2379
1-301-713-2384
Linda.Chaves@NOAA.gov

Rebecca ROOTES
Foreign Affairs Specialist
NMFS, NOAA, U.S. Department Commerce
4-2-41 Roppongi, Minato-ku 106, Tokyo, Japan
03-3423-3348

VENEZUELA

Garcia-Franco,Mauricio
International Consultant, Eco-Friendly Biosystems
Park Hill C-2 Egota4-24-12 Nakano-ku Tokyo 165
03-5343-6979
03-5343-6979
mauricio@twics.com

Course of Marine Ranch System (JICA)

Gracinda Maria DA CRUZ
Chief of Aquaculture Station
Foundation of Fishing Institute of Rio de Janeiro
Rua Sao Seuero No.30 Pedra De Guaratiba Rio De Janeiro Brazil
55-021-4171523

ICHIKAWA Midori
Coordinator for JICA Participants
Marine Ranch System Course Kochi University
JICA
0888-34-1670
0888-34-1670

LIU Wen-hua
Research Assistant
Department of Biology Third Institute of Oceanography
178 Daxue Road Xiamen 361005 PR China
86-592-2085880-261
86-592-2086646

Evaristo MAGONCIA
Voc School Principal II
CHED-Capiz Institute of Technology Department of Fisheries
CIT-Dayao, Roxas City, Philippines
0041-63-2-211-230

Guillermo Gabriel MOLINA PALAVECINO
Fishery Inspector
Servicio Nacional de Pesca (National Fishery Service)
"Melgarejo
955 Coqimbo Chile"
56-51-311331
56-51-322099

OHNO Masao
Professor
Usa Marine Bioloctical Institute Kochi University
0888-56-3311
0888-56-0425

Juan Carlos PAYAN AGUIRRE
Academic-investigator
Centro de Estudios Tecnologicos del Mar, La Paz
BAHIA DE LA PAZ #122 FOVISSSTE LA PAZ
B.C.S. C.P.23080 Mexico
112-1-13-63

Course of Marine Ranch System (JICA)

Uscharee RUANGDEJ
Lecturer
King Mongkut's Institute of Technology Ladkrabang
150 Soi Sophon Petgasem Rd Pasijaroen Bangkok
02-3269976
02-3269979

Amnaj SIRIPECH
Marine Fisheries Biologist
Southern Marine Fisheries Development Center, Department of Fisheries
79/1 Wicheanchon Rd Meang Songkhla 90000
Thailand
074-312595
074-312495

Pedro Hector TOLEDO AGÜERO
Marine Biologist
Universidad Catolica del Norte
Larrondo 1281 Coquimbo-Chile
313475
313475
ptoledo@nevados.cecum.vcn.cl

Training course for management of fishing for sustainable development for fisheries;fishing technology for controlled and selected harvest (OFCF)

ANRAKU Kazuhiko
Assistant Lecturer
Faculty of Fisheries Kagoshima University
099-286-4242
099-286-4015
anraku zero.fish.kagosima-u.ac.jp.

Christophe VELOSON TSIRAFY
Head of Small-Scale Fisheries Service
Direction of Halieutic Resources
P.Box 1699 Ampandrianomby Antananarivo
Madagascar
099-286-4241,261-2-406-50
099-286-4015

Saloa KELESOMA
Fisheries Extention and Development Officer
Fisheries Department Ministry of Natural Resources
Fisheries Department Funafuty Tuvalu
099-286-4241,688-20742
099-286-4015

Michael LAUMANI
Head of the Fishery in the Western Province
Western Provincial Fisheries Gizo Headquarters
Gizo Solomon Island
099-286-4241,677-60107
099-286-4015

Andrew MAGLOIRE
Fisheries Officer
Fisheries Development Division Ministry of Agriculture
099-286-4241,809-448-2401
099-286-4015,801-448-0140

ZHANG Ji-wu
Division of General Director's Officer
Bureau of Fisheries Ministry of Agriculture
099-286-4241861064192936
099-286-4015861064192961

FAO

Devin BARTLEY
Fisheries Resources Officer, FIRI
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla, 00100 Rome, Italy
39 06 57054376
39 06 57053020
devin.bartley@fao.org

ICLARM

Johann BELL
Program Leader: Coastal Aquaculture and Stock Enhancement
International Centre for Living Aquatic Resources Management
PO Box 438, Honiara, Solomon Islands
677-29255
677-29130
ICLARM@FFA.GOV.SB

SEAFDEC

Bundit CHOKESANGUAN
Training Division Head
Southeast Asian Fisheries Development Center
P.O.Box 97, Phrasamut Chedi,
Samutprakan 10290
4258040-5
4258561

SEAFDEC

Maitree DUANGSAWASDI
Secretary-General
Southeast Asian Fisheries Development Center
2922/278 New Petchburi Road, 24th Floor, Charn Issara Tower
Bangkok 10320, Thailand
662-308-2464
662-308-2462

Clarissa MARTE
Head, Research Division
Southeast Asian Fisheries Development Center
Aquaculture Department
Tigbauan, Iloilo,
Philippines
063-33-335-1009
063-33-335-1008
TMS-SEAFDEC@PPHIL,GN.APC.ORG

Somnuk PORNPATIMAKORN
Head of Information and Extention Division
Southeast Asian Fisheries Development Center
P.O.Box 97, Phrasamut Chedi,
Samutprakan 10290
4258040-5
4258561

Sutee RAJRUCHITHONG
Captain of M.V. SEAFDEC
Southeast Asian Fisheries Development Center
P.O.Box 97, Phrasamut Chedi,
Samutprakan 10290
4258040-5
4258561

SHIMOMURA Masao
Duputy Secretary-General
Southeast Asian Fisheries Development Center
2922/278 New Petchburi Road, 24th Floor, Charn Issara Tower
Bangkok 10320, Thailand
662-308-2464
662-308-2462

Kachornsak WETCHAGARUN
Assistant to the Chief of the Training Department
Southeast Asian Fisheries Development Center
P.O.Box 97, Phrasamut Chedi,
Samutprakan 10290
4258040-5
4258561

JAPAN

AKIYAMA Takafumi
Technical Staff
Yamaguchi Prefecture Fisheries Department
Fisheries Promotion Division
0839-33-3550
0839-33-3559

AMANO Katsuzo
Executive Senior Staff
Fisheries Office Aomori Prefectual Government
0178-27-5858
0178-23-4524

CHUBACHI Hirokazu
Director Invitation Program Division
Overseas Fishery Cooperation Foundation
03-3585-5382
03-3582-4539

EGUCHI Kazuharu
Senior Administrative Officer
Fukuoka Prefectural Fisheries Technical Center
Researching Branch of the Sea of Ariake
0944-72-5338
0944-72-6170

FUJIYA Masaru
Chief Coodinator of Marine Ranching Program
Marino Forum 21
03-3662-4991

HARADA Yasushi
Associate Professor
Mie University
0592-31-9546
0592-31-9538
harada@bio.mie-u.ac.jp

HARAGUCHI Kenji
Assistant Director
Fisheries Administration Division Department of Fisheries Aomori Prefectual Government
0177-22-1111
0177-73-7731

HIROSE Shigeru
Senior Staff
Fisheries Promotion Division of Fisheries Department Saga Prefectural Government
0952-25-7144

JAPAN

HOTTA Kazuo
Exective Assistant Researcher
Toyama Prefectual Fisheries Research Institute
0764-75-0036
0764-75-8116

IIOKA Chikara
Deputy Director General
Department of Forestry And Fisheries of Iwate Prefecture
0196-51-3111
0196-54-1695

IMAMURA Koji
President
Japan Sea-Farming Association
UCHIKANDA 3-14-8, CHIYODA-KU, Tokyo 101,Japan
03-5296-3181
03-5296-7540
iimamura@po.iijnet.or.jp

ISHIDA Hiroyuki
Resercher
Fukuoka Prefectural Fisheries Technical Center Researching Branch of the Sea of Ariake
0944-72-5338
0944-72-6170

ISHIKAWA Masahiro
Deputy Director-General
Fisheries Agency, Government of Japan
03-3502-8111
03-3504-2649

KAWAJIRI Masahiro
Director General of Fisheries Explotation Division
Shizuoka Prefectural Fisheries Expertment Station
054-627-1815
054-627-3084

KIMURA Hiroshi
Senior Chief
Fishing Industries Promotion Division Aomori Prefectual Government
0177-22-1111
0177-22-6164

KITADA Shuichi
Associate Professor
Tokyo University of Fisheries
03-5463-0536

KOIZUMI Hiroaki
Technical Staff
Fisheries Administration Division Department of Fisheries Aomori Prefectual Government
0177-22-1111
0177-73-7731

KOSAKA Tomonori
Oparating Division Assistant Director
Japan Fisheries Association
03-3585-6683
03-3582-2337

MATSUDA Masahiko
Senior Fisheries Officer
Fukuoka Prefectural Fisheries Technical Center Researching Branch of the Sea of Ariake
0944-72-5338
0944-72-6170

MATSUNAGA Shoji
Officer
Overseas Fishery Cooperation Foundation
03-3585-5383
03-3582-4539

MATSUNAGA Shigeru
Councilor
Japan Sea-Farming Assosiation
03-5296-3181
03-5296-7540

MATSUOKA Taira
Managing Director
Japan Sea-Farming Assosiation
078-392-3541
078-392-3543

MATSUSATO Toshihiko
Director of Resource Enhancement Division
Japan Sea National Fisheries Research Institute
025-250-0634
025-224-0950

JAPAN

MIYAUCHI Masayuki
Senior Technical Staff
Fishery Promotion Division of Fukuoka Prefecture
092-651-1111
092-641-8999

MORIKAWA Tohru
President
Marino Forum 21
03-3252-3841
03-3252-8588

MOROTOMI Kazutoshi
Senior Technical Staff
Fishery Promotion Division of Fukuoka Prefecture
092-651-1111
092-641-8999

MUNEKIYO Masahiro
Section Chief of Technical Extension
Fisheries Office of Kyoto Prefecture
0772-22-3288
0772-22-3289

MURANAKA Fumio
Cheaf Reseacher
Shizuoka Prefectural Fisheries Expertment Station
054-627-1815
054-629-7350

NAGANO Kazuhide
Captain of the Reseach Vessel
Nagasaki Prefectural Institute of Fisheries
0958-26-5216
0958-24-4552

NAWA Daisaku
Assistant Director
Fisheries Agency Government of Japan
03-3502-8111内7172
03-3581-0325

OMORI Hiroko
Section Chief
Fisheries Agency, Government of Japan
03-3591-1086
03-3504-2649

OHASHI Takaharu
Senior Managing Director
National Coastal Fishery Development Association
03-3256-6991
03-3256-6976

OOHTSU Yasuo
Technical Staff
Saga Prefectural Genkai Fisheries Promotion Center
0955-74-3021

SANO Hiroya
President
Japan Fisheries Association
03-3585-6683
03-3582-2337

SAOTOME Kouichi
Chief of Research section
Japan Sea-Farming Assosiation
03-5296-3181
03-5296-7540
ksaotome@po.iijnet.or.jp

SHIMURA Shigeru
Fisheries Development Specialist
Japan International Cooperation Agency
03-5352-5250
03-5352-5349

TAJIMA Michio
Vice-Director
Ishikawa Prefectural Fisheries Center
0768-62-1324
0768-62-4324

TAKEUCHI Hiroshi
Chief, Office of Fisheries Cooperation International Division
Fisheries Agency Government of Japan
03-3503-8971
03-3504-2649

TANIKAWA Takashi
Excutive Director
Marine Environmental Management Task Force
03-3584-0955
03-3584-3013

JAPAN

TATARA Atsushi
Technical Staff
Yamaguchi Prefecture Fisheries Department
Fisheries Promotion Division
0839-33-3550
0839-33-3559

TSUKADA Teruo
Director Deputy
Miyagi Prefectual Office Shiogama Fisheries Office
022-366-1231
022-366-1233

UCHIBA Sumio
Technical Assistant Director
Fishery Promotion Division of Fukuoka Prefecture
092-651-1111
092-641-8999

UNNO Kenichi
President
Overseas Fishery Cooperation Foundation
03-3585-5382
03-3582-4539

YAHARA Shonosuke
The Chief of Management
Marine Environmental Management Task Force
03-3584-0955
03-3584-3013

YAMAMOTO Chihiro
Chief Researcher
Fukuoka Prefectural Fisheries Technical Center
Researching Branch of the Sea of Ariake
0944-72-5338
0944-72-6170

YASUMOTO Susumu
Chief of Resources Enhancement Section
Nagasaki Prefectural Institute of Fisheries
0958-26-5216
0958-24-4552

YOSHIDA Yoshihiro
Manager Research and Development Section
Marino Forum 21
03-3252-3841
03-3252-8588

YOSHIDA Yutaka
Exective Senior Staff
Fishing Industries Promotion Division Aomori
Prefectual Government
0177-22-1111
0177-22-6164

HASHIMOTO Yasuyuki
Chairman and President
Anamizu-Hokubu Fisheries Cooperation
0768-57-1841
0768-57-1841

HAYASE Kenjo
Chairman
Ishikawa Prefectural Young Fishermans Associations
0762-34-8818
0762-65-5204

KAMIHAMA Kiio
Vice President
Ishikawa Prefectural Fedration of Fisheries
Cooperative Associations
0762-34-8815
0762-65-5204

KIMURA Isao
President
Senior Fisherman's Sector of Ishikawa Prefectual
Fedration of Fisheries Cooperative Associations
0767-66-1037
0767-66-2035

KUSUNOKI Yasuji
Vice Chief of Sectional Meeting
Fishing Industries Promotion Association of
Nanao-Bay
0767-53-1111
0767-52-7765

NISHIMURA Shinko
Chairman
Ishikawa Prefectural Women's Fedration of Fisheries
Cooperative Associations
0762-34-8818
0762-65-5204

NISIZAKI Shigeo
Chairman
Fishing Industries Promotion Association of
Nanao-Bay
0767-53-1111
0767-52-7765

JAPAN

OHTSUKI Kanzo
Manager
Japan Sea-Farming Assosiation Notojima station
0767-84-1182
0767-84-1184

SASAKI Yutaka
Managing Director
Hokuriku Branch Office, Japan International Cooperation Agency
0762-33-5931
0762-33-5959

TAKAIWA Kenji
Chairman and President
Ishikawa Prefectural Fedration of Fisheries Cooperative Associations
0762-34-8815
0762-65-5204

YAMAGAMI Takayoshi
Administrative Officer
Ishikawa Prefecture Agricultural Production Division
0762-21-8558

YAMAGUCHI Tsuyoshi
Director
International Division of Ishikawa Prefecture
0762-23-9108
0762-21-0200

YAMAMOTO Junji
Director
Agriculture, Foresty and Fisheries Division of Uchiura Town Government
0768-72-1111内215
0768-72-2108

YAMASITA Kazuya
Vice President
Ishikawa Prefectural Credit Fedration of Fisheries Cooperative Associations
0762-34-8815
0762-65-5204

DOI Osamu
Chief Fisheries Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

HADA Mikio
Senior Fisheries Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

KIMOTO Akinori
Fisheries Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

MATANO Yasuo
Senior Fisheries Manager
Ishikawa Prefecture Fisheries Division
0762-38-7473
0762-23-9252

MIYAHARA Masanori
Director
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

NOMURA Hajime
Chief Fisheries Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

SADAKATA Tsutomu
Chief Fisheries Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9252

SAWADA Kouji
Fisheries Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

SHIKIDA Asami
Senior Fisheries Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

TANAKA Tetsuya
Administrative Officer
Ishikawa Prefecture Fisheries Division
0762-23-92526
0762-23-9479

JAPAN

TSUDA Shigeyoshi
Fisheries Specialist
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

UOZUMI Akifumi
Fisheries Specialist
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

YAMANADA Atsuyo
Administrative Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

YOSHIDA Toshinori
Senior Fisheries Officer
Ishikawa Prefecture Fisheries Division
0762-23-9252
0762-23-9479

APPENDIX 2

MESSAGE FROM GOVERNOR

Masanori Tanimoto
Governor of Ishikawa Prefecture JAPAN

Ladies and gentlemen and distinguished guests, it is my great honor to open this International Symposium on *Marine Ranching in Ishikawa 1996*, inviting participants from twenty six countries and three international organizations.

While Ishikawa Prefecture is one of the forty seven prefectural governments in Japan, it is our longstanding policy to promote international exchanges and cooperation and to contribute to the mutual understanding and prosperity of the world. We have hosted various international events here in Ishikawa. But this is the first opportunity for us to welcome to our prefecture so many people representing the governments of so many countries and international organizations. As the leader of the policy of international exchange promotion, 1 am very pleased to host this symposium and at the same time feel responsible for successful outcomes of this event.

I welcome each of you to the symposium and thank you from the deepest part of my heart for having journeyed all this way to Ishikawa Prefecture. 1 would also extend my sincere gratitude to the FAO, the Fisheries Agency of Japan, the Japan Sea-farming Association, Marino-forum 21 and other organizations for their kind support for this symposium.

The rapid growth of a human population is posing a serious problem of the gap between food supply and demand. At the Kyoto Conference on the Sustainable Contribution of Fisheries to Food Security held last December, the importance was reconfirmed of maintaining fisheries' productivity through proper and rational management. Fisheries contribute to sustainable food supply and employment, and are an integral factor to cope with the problem of food shortage.

Against these backgrounds, international interest has been growing in the sustainable use and enhancement of marine-living resources, especially in marine ranching. On this issue, however, efforts have only just begun to exchange information and work together on an international scale. Since the National Convention for Clean Ocean and Abundant Fishery Resources, Japan's biggest fishery event, was scheduled to be held in Ishikawa this year, 1 came up with an idea of holding a symposium on marine ranching concurrently with the Convention as a first step for international cooperation in this field. We decided to invite as many fishery managers and researchers as possible both from within Japan and from overseas.

Fortunately, the symposium we proposed was positioned as one of the follow-up events to the Kyoto Conference held last year, Thanks to the kind support of interested organizations including the FAO and the Fisheries Agency of Japan, today's symposium has become a reality. 1 strongly hope that exchanges of opinions and information here will lead to the establishment of the basis for future international cooperation in this field.

At this time, I would also like to announce a program starting next year to accept overseas trainees in cooperation with the Japan Overseas Fishery

Cooperation Foundation, as one of our continuing efforts for international cooperation in this field. We hope to adjust the training contents of this program according to the outcomes of this symposium and respond to the trainee's requests.

On September 16, following the symposium, the 16th National Convention for Clean Ocean and Abundant Fishery Resources will be held in the presence of their Imperial Highnesses of the Emperor and Empress. The purpose of this event is to promote preservation of the marine environment and to raise people's consciousness for conservation of marine-living resources. The symposium participants are cordially invited to the Convention. We hope that all the participants attend it and see the Japanese fishermen, the administrations and the general public making vigorous effort for the clean marine environment and resource conservation.

It is my sincere hope to work with all of you, the people from all over the world who share the same concern over marine environments and fishery resources, so that the effort for clean oceans and abundant fishery resources will be advanced significantly beyond state boundaries.

Lastly, 1 trust that you will involve yourselves with the beautiful nature, history, culture, and kind people of Ishikawa and enjoy your stay to the utmost.

Thank you.

APPENDIX 3

MESSAGE FROM FAO

Ladies and gentlemen, distinguished guests and friends, on behalf of the Fisheries Department of the Food and Agriculture Organization of the United Nations, 1 welcome you to this International Symposium on Marine Ranching. We are indeed fortunate to be able to meet in these excellent facilities of the Kanazawa City Cultural Hall and 1 thank the Ishikawa Prefecture for all the hard work in making this Symposium possible.

The Fisheries Department of FAO attaches great importance to the subject of this symposium. A human population that is expected to nearly double by the middle of the next century (9.8 billion by the year 2050) will inevitably place extreme demands on the resources of the world's oceans, seas, coastal areas and wetlands. Over the past decade we have seen a leveling of production from the world's capture fisheries, with some major fisheries collapsing and others becoming over-exploited. During this same time we have seen aquaculture emerge as the fastest growing food producing sector with an annual growth rate of over 9% since 1984.

Today, we also see a merging of capture fisheries and aquaculture as hatcheries are utilized to raise species to stock marine and inland waters and as coastal areas are manipulated to provide a better environment for desirable species by the removal of predators, by the management of water flow, by the addition of feed and even fertilizer, and the by addition of artificial reefs and habitat. This "intensification" of fishery management is a global phenomenon in both marine and freshwater and represents a valuable means to increase fishery production and food security.

Yet we still have much to learn about how to accomplish this intensification in a responsible manner. There is more than just technology and biology - ecology, biodiversity, economics, property rights, and sociology will all be involved.

The Government of Japan in collaboration with FAO recently convened an International Conference on Sustainable Contribution of Fisheries to Food Security in Kyoto that emphasized the critical role fisheries and aquaculture can play in ensuring global food security. The "Kyoto Plan of Action" that resulted from this conference calls for a "rapid transfer of technology and know-how in enhancement of inland and marine waters."

Again, we are fortunate to be here in Japan, one of the centers of marine stock enhancement (marine ranching) activity; approximately 80 aquatic species are being utilized or studied for marine ranching. This is a tremendous accomplishment that 1 hope we shall learn about in the coming days.

In closing, 1 note that we have a full agenda with speakers representing the diversity of backgrounds necessary to address this important and difficult subject. The Fisheries Department of FAO anxiously awaits the results of this symposium. As the Italians say, "buon lavoro", which means, I wish you a good work.

Thank you.

D/X1619E/1/4.99/2000