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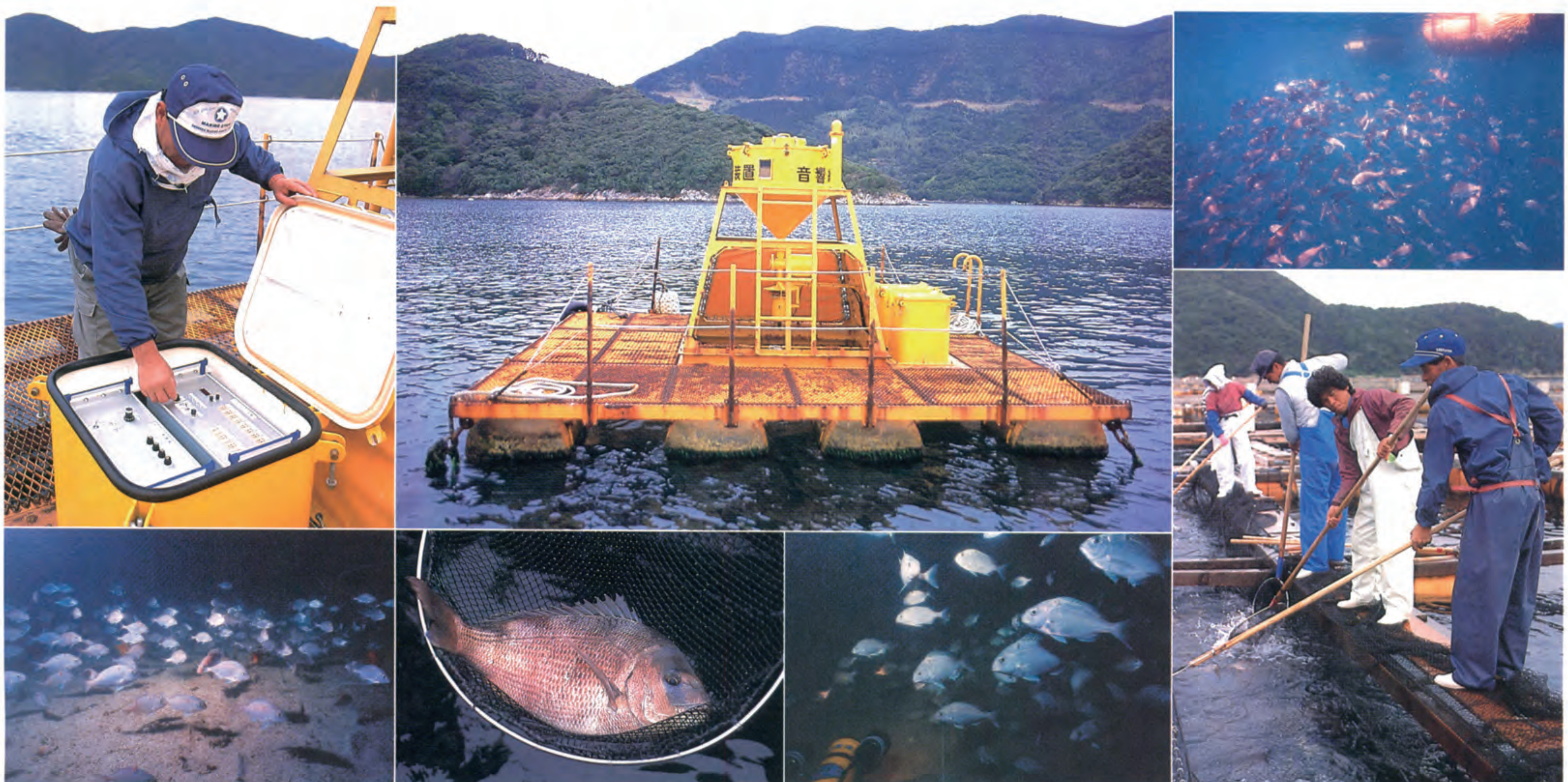
# RED SEA BREAM CULTURE

# The "King of Fish," its history and development as a fishery



*Young red sea bream released for audio signal-trained raising at Tamanoura, Nagasaki Pref. (Underwater photos courtesy of Nagasaki Experiment Station.)*

The red sea bream, *Pagrus major* has been hailed as the "king of fish" in Japan since olden times. Its handsome shape, vivid scarlet color and the fine taste of its meat have made it a prized delicacy. The high value attached to red sea bream, however, seems to be a unique bit of Japanese culture not necessarily shared by other countries. For example, in neighboring China it is carp that is the fish of choice in gourmet cooking, while in Korea it is the bartail flathead and in Hong Kong the rudder fish that command the highest prices in their respective fish markets.

Several reasons can be cited as to why the red sea bream came to be treated as the highest-class fish in Japan:

**(1)** Since before recorded history, the Japanese diet has included a wide variety of marine products, a fact that remains true to this day. And within this rich tradition of varied sea foods, a system of values has evolved regarding the prices of different species of fish.

**(2)** Although the Japanese habitually prepare fish by various boiling and baking methods, there is also a strong tendency to prefer fish eaten raw as "sashimi" or "sushi". When eating fish raw, of course, the freshness of the meat is of utmost importance, and white fleshed fish like red sea bream, flounder and black porgy with their low fat content are known to deteriorate less quickly than other fish. The fact that red sea bream retains its freshness longer than most fish is one of the reasons it ranks as a higher class fish.

**(3)** From the 17th to 19th centuries, Japan witnessed an exceptional development in coastal fishing technology. This development was supported by a growth in demand for fish as fertilizer in the growing agricultural sector, and by increased demand in the fresh fish market in the major urban centers. It was at this time that the market value of red sea bream increased and its presence became irreplaceable as a dish at ceremonies and celebrations.

In 1988, the total Japanese catch of sea breams, Sparidae, was 69,000 tons. Of this, 58,000 tons were red sea bream. Considered against Japan's total fish production that year of 9,948,000 tons, the Sparidae catch represents 0.7% and the red sea bream catch 0.6%. With regard to the red sea bream catch of the same year, 13,000 tons were the product of capture fisheries and 45,000 tons the product of aquaculture. (TABLE 1).

Looking at Japan's marine production by species for the past 10 years or so, we see that with the exception of the even performance or slight increase in the production by small scale trawl fisheries in coastal waters, production by all other types of capture fisheries are on the decline. And it is believed that the relatively good performance by these trawl fisheries can be accredited in part to the contribution made by artificial stocking practices for red sea bream being conducted in inshore and nearshore waters areas around the country. Meanwhile, the nationwide production of cultured red sea bream has continued to grow at an annual rate of 10 ~ 20%. This fact owes to the good profitability of red sea bream culture attracting newcomers to the industry, and also, to some extent, to former yellowtail culture operators switching over to red sea bream because of the drop in the market price of yellowtail in recent years. Red sea bream production in Japan today is based completely on a policy of stressing the development of coastal water fishery potential.

In recent years we are also seeing a substantial amount of Sparidae being imported to Japan. Records for 1989 show that imports treated as sea bream in the Japanese market include 3,600 tons of fresh and refrigerated fish and 18,600 tons of frozen fish, for a total of 22,200 tons. Imports of fresh and refrigerated fish come from a total of 13 countries, with New Zealand, the primary supplier (2,900 tons), and Hong Kong (300 tons) and Australia (260 tons) following. Among the 29 countries exporting frozen sea bream to Japan, the leaders are Argentina (3,300 tons), Panama (3,100), Gambia (2,700), Mauritania (2,600), New Zealand (1,500) and Morocco (1,000). In contrast, Japanese exports of red sea bream are minimal, accounting for only several dozen tons a year.

**TABLE 1: Red sea bream production in Japan (1988)**

| | | (in tons) |
|---|---|---|
| Capture Fisheries | East China Sea trawl | 400 |
| | Offshore trawl | 700 |
| | Coastal small scale trawl | 2,500 |
| | Gill net | 1,200 |
| | Hand line | 3,200 |
| | Long line | 1,500 |
| | Boat seine | 2,300 |
| | others | 1,200 |
| | sub-total | 13,000 |
| Aquaculture | | 45,000 |
| | total | 58,000 |

## Notice

The term "red sea bream culture" is a general term that includes both **(1)** rearing fish in net cages and **(2)** releasing seeds to the natural environment for the purpose of increasing fishery resources. In accordance with Japanese fishery production statistics, the catch from **(1)** is reckoned up as aquaculture production and the catch from **(2)** is included in capture fishery production. In this issue, pages 4 through 7 will be devoted to an introduction of the essentials of **(1)**, net cage culture. With regard to **(2)**, release of seeds for the cultivation of resources, we will introduce on page 3 a technique that has become the focus of much attention in recent years by which the released fish are trained to respond to an audible signal for feeding.

# Geographic traits of the fishery

## The Species

In Japan, sea breams, the family Sparidae, are referred to generally by the term "tai", while red sea bream, *Pagrus major*, is called "madai", a name inferring that it is the "true tai". Sea bream species are found the world over in coastal or continental shelf areas of the temperate and tropic zones. It is a highly diversified family of fishes that includes over 100 species that can be classified into the 6 sub-families of **(1)** *Denticinae* (yellow sea bream), **(2)** *Pagellinae* (European sea bream), **(3)** *Pagrinae* (red sea bream), **(4)** *Sparinae* (Hedai), **(5)** *Diplodinae* (African chinu), and **(6)** *Boopsinae* (African sea bream). Of these, the sub-families **(1)**, **(2)** and **(3)** have a reddish coloring and inhabit continental shelf areas at a depth of 50 ~ 200 meters, while **(4)**, **(5)** and **(6)** are dark gray or silver gray in color and tend to inhabit rocky coastal waters or bay waters at a depth of 10 ~ 70 meters. Sea breams are distributed over a range of waters extending to 55° latitude north and south of the equator. Geographically their distribution follows the following patterns:

**(1)** Japan, Southeast Asia and Australia
-Yellow sea bream sub-family, red sea bream sub-family and Sparinae sub-family are found in these regions.

**(2)** Mediterranean and African regions
-All six sub-families are found in these regions.

**(3)** Atlantic Coast of the Americas
-Pagrinae sub-family, Sparinae sub-family and Diplodinae sub-family are found here.

The species of sea bream important for the Japanese fishing industry are red sea bream, *Pagrus major*, yellow sea bream, *Dentex tumifrons*, crimson sea bream, *Evynnis japonica*, and black sea bream, *Acanthopagrus schlegeli*. With the exception of yellow sea bream, all three remaining sub-families are the object of both fishing for naturally occurring resources and aquaculture.

In addition to the fish referred to by the Japanese as "madai" (*Pagrus major*), the red sea bream sub-family also contains such species as *Pagrus auratus*, *Pagrus pagrus* and *Pagrus africanus*. All of these species are similar in shape to "madai", and *Pagrus auratus* in particular is so similar it is almost indistinguishable.

## The geography of red sea bream fishery

Natural red sea bream is found distributed throughout Japanese waters with the exception of the Eastern and Northern coasts of Hokkaido and the waters of the Ryukyu Archipelago. **FIG. 1** and **2** show developments in red sea bream production and the conditions of production by region. Despite a gradual decrease in catches of naturally occurring red sea bream in recent years, the development of the aquaculture industry since about 1970 has enabled a continued increase in overall production.

With regard to both fishing and aquaculture operations for red sea bream, production is centered in Western Japan. Looking at production figures by sea area for 1988, we see that 42% of the total production comes from the East China Sea, 28% from the southern Pacific area, 13% from the central Pacific area and 11% from the Seto Inland Sea. These four areas account for 94% of Japan's production. A particularly important producing area is Nagasaki Prefecture, which leads the nation both in fishing and aquaculture production of red sea bream with 18% of the national total. Now, let us take a look at the present situation in Nagasaki Prefecture regarding red sea bream fisheries.

### *A bountiful multi-island sea

Nagasaki Pref. is situated on the western edge of Kyushu, one of the four major islands of the Japanese archipelago.

**FIG. 1: Developments in red sea bream production**

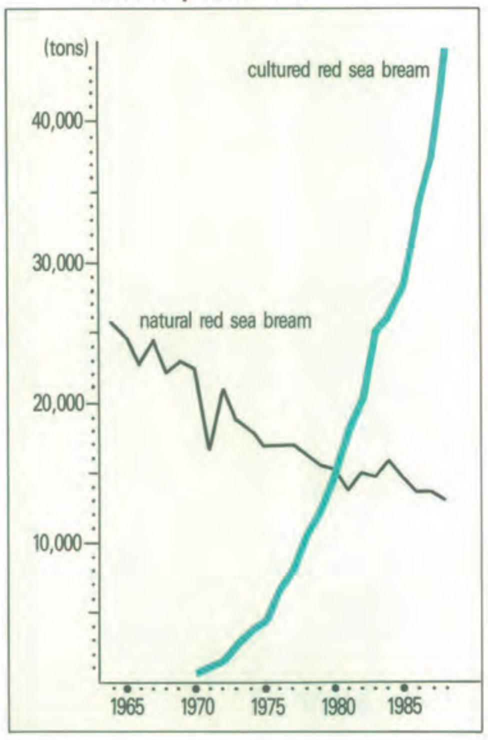



**FIG. 2: Red sea bream production by region (1988)**

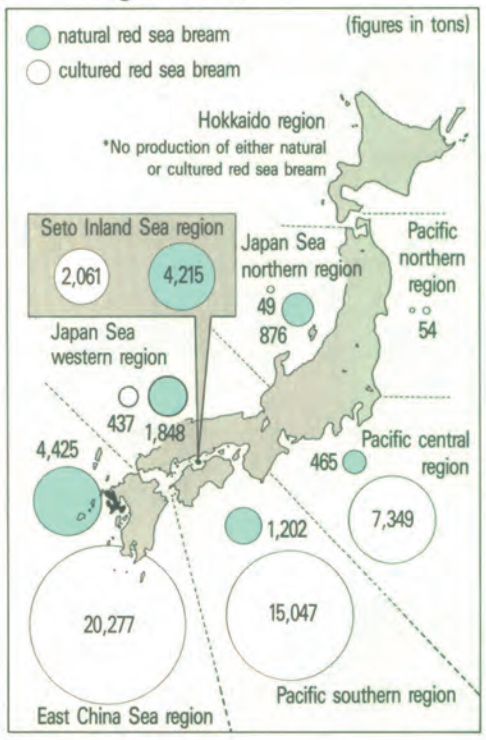
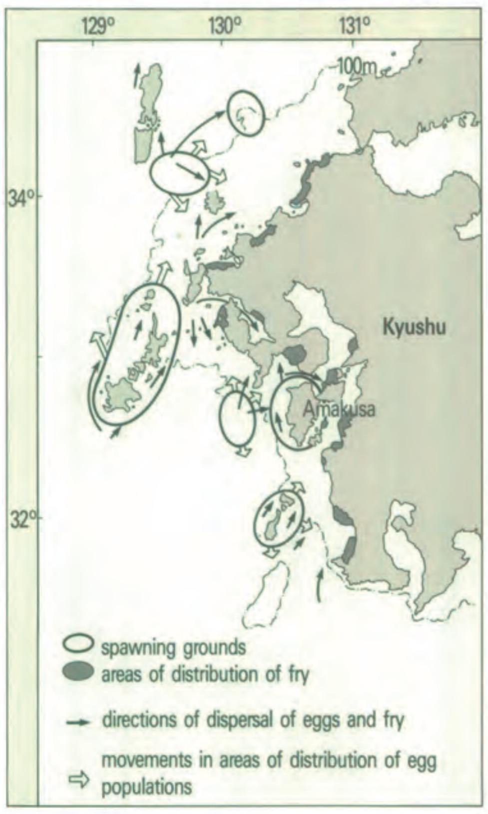



**FIG. 3: Spawning and nursery grounds for red sea bream young in the northwest sea areas of Kyushu**




Although it is a small prefecture, it ranks along with Hokkaido as one of the leading "fishing prefectures". Consisting of many peninsulas and islands, the prefecture's total area of 4,110km$^2$ represents just over 1% of the nation's total area of 377,835km$^2$.

But with its almost cactus-like array of peninsulas and roughly 600 islands of varied sizes, the prefecture's coastline winds for some 3,720km, or a full 14% of the country's 26,700km coastline. (By the way, the total coastline of Japan is roughly equivalent to the combined coastline of the U.S.A. and Canada.) This geographical peculiarity is the primary factor that led to such a development of marine industries in Nagasaki. And it has also given the prefecture a highly advantaged position with regard to red sea bream fisheries, as well.

In addition to its intricately varied sea-bottom topography, one more factor which contributes to Nagasaki's bountiful fishery resources is the Tsushima Warm Current. The Tsushima Warm Current branches off from the Kuroshio Current in the offshore waters southwest of the western coast of Kyushu, flowing north along the western edge of the Goto island chain. Sending off sub-branches toward the Sea of Goto and the Yellow Sea along the way, it flows through the Korea Straits into the Sea of Japan.

Due to the extremely complex topography of the sea bottom along Kyushu's western coast, the Tsushima Warm Current gives birth to many upwellings and eddies along its course. Also numerous water fronts are formed between coastal waters coming from the Asian continent and those coming from the western coast of Kyushu. Not only do these upwellings and eddies and water fronts form excellent fishing grounds for such migratory fishes as sardine, mackerel, jack mackerel and yellowtail, they also form important spawning grounds for all kinds of fishes. Furthermore, coastal waters of this nature are excellent rearing grounds for the fry and young of these fishes.

Blessed with bountiful fishery resources and prolific bays and inlets to serve as good natural harbors, fishing villages have been found along the peninsulas and the offshore islands of Nagasaki since olden times. Here, a wide range of fishing techniques, including surrounding net, set net, gill net, longline and angling have also developed. About 1/10 of Japan's 370,000 fishermen, by the way, are concentrated in this prefecture. The fact that the quiet waters of its many deep inlets make ideal sites for setting up culture cage facilities has also contributed to the development of various forms of fish culture.

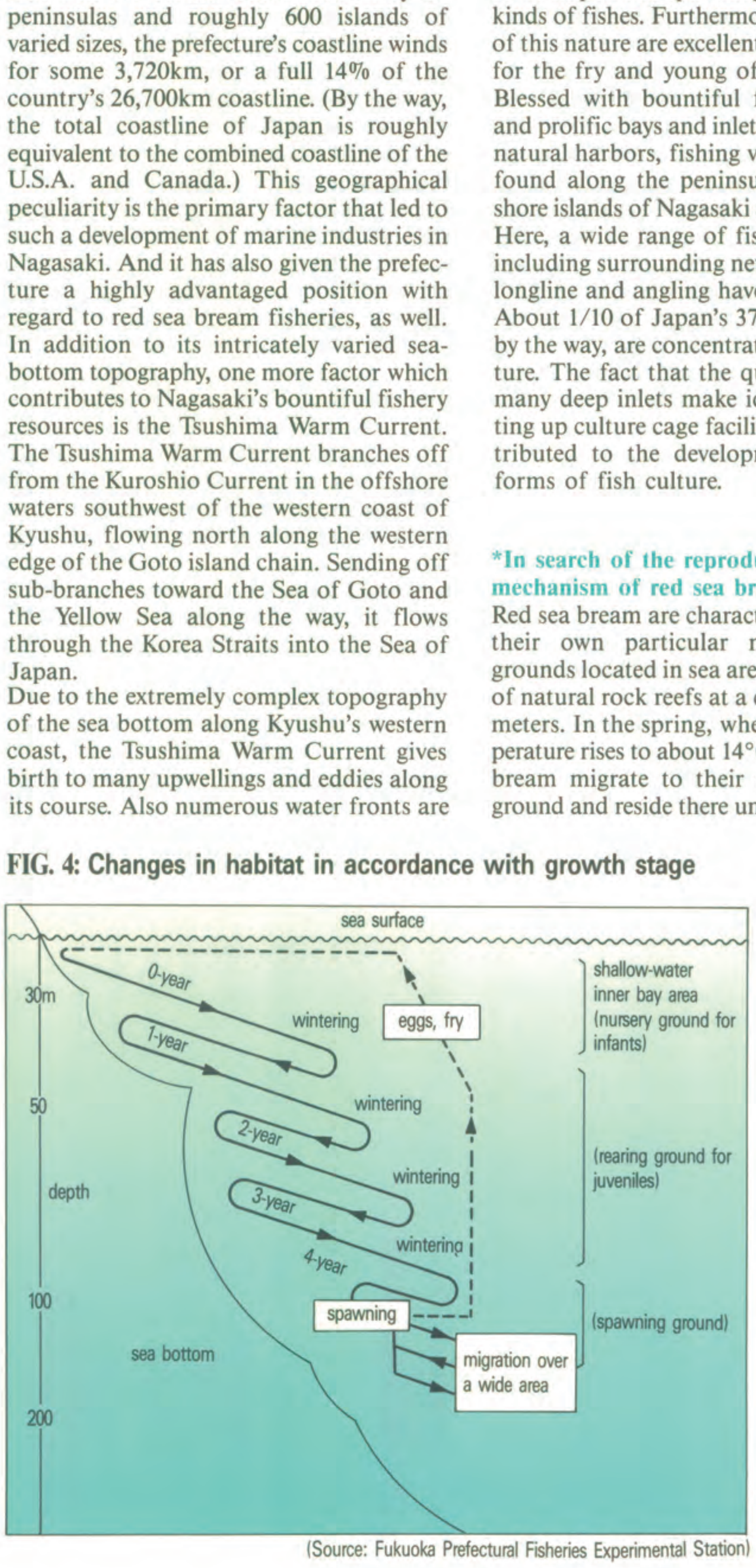
### *In search of the reproductive mechanism of red sea bream resources

Red sea bream are characterized by having their own particular native spawning grounds located in sea areas with a bottom of natural rock reefs at a depth of 50 ~ 150 meters. In the spring, when the water temperature rises to about 14°C, mature red sea bream migrate to their native spawning ground and reside there until the water temperature reaches the spawning range of 15 ~ 17°C. When spawning commences, the parent fish rise to the surface waters in the hours around sunset to lay their eggs. After hatching, the young are carried by the currents as they float in the upper layer until they reach a coastal water area with a depth of 30m or less. In this way, we see that the spawning ground and nursery ground for red sea bream are separated. **FIG. 3** shows the patterns of distribution of these spawning and nursery grounds.

It has long been known that red sea bream change their habitat in the different stages of growth. In infancy they live in seaweed beds in the inner waters of bays. During the juvenile stage after one year of age, they begin to broaden the range of their habitat by seeking deeper waters in the winter season when water temperatures drop. After reaching 4 years of age they move out into the offshore waters, migrating widely through the middle and lower depths. **(FIG. 4.)**

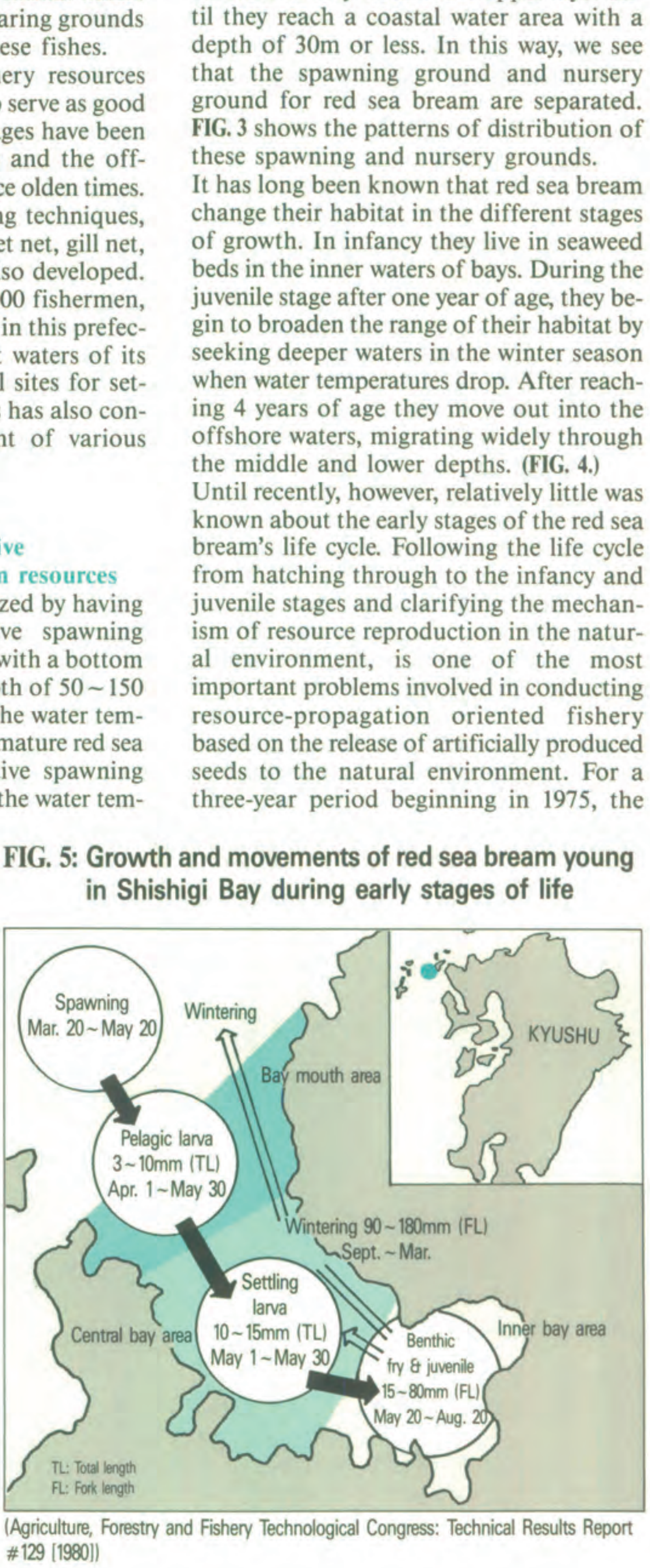
Until recently, however, relatively little was known about the early stages of the red sea bream's life cycle. Following the life cycle from hatching through to the infancy and juvenile stages and clarifying the mechanism of resource reproduction in the natural environment, is one of the most important problems involved in conducting resource-propagation oriented fishery based on the release of artificially produced seeds to the natural environment. For a three-year period beginning in 1975, the

**FIG. 4: Changes in habitat in accordance with growth stage**




(Source: Fukuoka Prefectural Fisheries Experimental Station)

**FIG. 5: Growth and movements of red sea bream young in Shishigi Bay during early stages of life**




(Agriculture, Forestry and Fishery Technological Congress: Technical Results Report #129 (1980))

Japanese government's Agriculture, Forestry and Fishery Technological Congress undertook a joint survey and research effort directed at clarifying the mechanism of resource reproduction for young red sea bream. From this study many pieces of vital biological information were gathered. Although the areas researched showed some differences in the process which the larva follow in their course from the time they leave the spawning grounds until they reach their destined nursery grounds, the basic elements of the process are clear. **FIG. 5** gives a step by step picture of the territorial progression of red sea bream through their growth stages in the case of Shishigi Bay, Nagasaki Pref. The following is a summary of what has been learned from the study of red sea bream in Shishigi Bay.

*With regard to natural characteristics such as topography, bottom type, water qualities (water temperature, salinity, nutrient salts, suspended oxygen, transparency, etc.), water movements and distribution of organisms such as planktons and benthos, the waters of Shishigi Bay can be divided into three distinct areas, **(A)** the bay mouth area, **(B)** the central area and **(C)** the inner area of the bay.

*The larva carried to the bay by sea currents, concentrate first in the eddy waters of the bay mouth area. Although some are carried farther into the bay by the water currents, the majority continue their growth for some time in the middle and lower depths of the bay mouth waters.

*Later, as the larva begin to take on the body shape of mature fish and their organs form, reaching the fry stage, they begin to move under their own power up into the surface water layer and beyond the barriers of the water area into the central area of the bay.

*The fry then move to the lower depths of the central area of the bay and distribute themselves in spots where their primary food of this stage, Copepoda, is found in abundance.

*As they grow in size their main food changes from Copepoda to Gammaridea and they move again, concentrating themselves in the *Zostera marina* beds of gravel bottomed parts of the inner bay area where Gammaridea proliferate.

*By the time they reach a body length of about 40mm, the young begin to extend their feeding grounds to the *Zostera marina* beds of the central area of the bay, as their feeding habits diversify to include Caprellidea and Mysidacea as well as Gammaridea.

*Reaching a body length of about 100mm, the majority of the young now extend their habitat outside the bay waters, although some will continue to spend the winter within the bay waters.

In this way, we see that in the early stages of life biological and chemical characteristics of the sea environment play a large part in determining the red sea bream's habitat. As the fry and young grow, however, feeding factors play an increasingly important role, and we recognize the formation of large shoaling groups migrating in order to choose environs offering abundant supply of the organisms on which they feed.

# Instilling a conditioned response to sound -An experiment in fishery resource propagation

Wouldn't it be wonderful if tamed fish could be let out in open sea waters to graze in the same way a rancher sends his livestock out to pasture? In Japan today, people are trying to realize this dream through a number of varied experiments based on the concept of "sea ranching". One such experiment which has been conducted since 1986 in Tamanoura Bay of the Goto Islands of Nagasaki Prefecture, involves the rearing of red sea bream released in the natural environment by means of feedings that are signaled by an audio signal that the fish have been conditioned to respond to. By this method it has been proven that young red sea bream can be made to stay within the desired bay waters for long periods of time. At present, surveys and quantitative analysis of the results of this cultivation method are continuing, along with research concerning improvement of the cultivation methods and investigations into the problems of integrating these cultivation operations and other branches of the local fisheries industry.

Tamanoura Bay is a long, narrow inlet ranging from 1 to 1.5km in width and 13km in length. **(FIG. 6)** It has a total surface area of 17.6km$^2$ and a depth that reaches 60m in the bay mouth area and maintains a depth of at least 30m far into the inner end of the bay. Strongly influenced by the Tsushima Warm Current, its surface temperature drops no lower than 13°C in the winter season. Tamanoura Bay was chosen for this resource propagation experiment because of its shape as a relatively closed-off bay, a bottom characterized by an abundance of rock reefs and seaweed beds suitable as nursery grounds for infants, an abundant distribution of organisms the fish feed on, and the fact that the winter water temperature makes it suitable as a wintering ground for red sea bream.

The practice of keeping fish in a prescribed area by means of regular feedings so that they can eventually be caught by fisheries, has been conducted for yellowtail in certain regions since olden times. And, regarding fishery that relies on the fish's response to an audio signal, we find there exists a kind of angling for red sea bream in Chiba Pref., called "Boko-tsuri". In this fishery a "bell-shaped sinker" is attached to the end of the fishing line. When the line is lowered near the sea bottom and jerked strongly, the air trapped inside the "bell-shaped sinker" makes a sound that attracts the fish. Concerning the response of various fish to sound, several researchers since the 1960s have conducted studies that confirm the fact that red sea bream do respond strongly to certain frequencies of sound in the water. The experiment in Tamanoura seeks to propagate fishery resources within the Bay by conditioning the fish with a combination of audio signals and distributing of feed with the aim of keeping the fish in a prescribed area for long periods of time, and thereby preventing their migration to the outer sea. The experiment is being conducted according to the following itinerary:

**(1)** In August or September, red sea bream young purchased from an artificial seed producer are introduced to net cages set up in the bay waters. Three times a day a beeping sound is transmitted from underwater transducer at 300Hz at one-second intervals for several minutes, after which a composite feed in crumble form is thrown into the cages by hand.

**(2)** After rearing the young and conditioning them with such feedings for about 2 months, identification tags are placed on the backs of the fish just below the dorsal fin. Then the cage is towed to one of two feeding stations located at the inner end of the bay. Next, the fish are released into the bay waters near to the feeding stations.

**(3)** The feeding stations consist of automatic feeding machines set up on rafts. The stations are also fitted with equipment for making regular sound broadcasts from underwater transducer automatically, to be followed by automatic dispensing of pellet-form composite feed. In summer the systems are set up to dispense a 5-kilogram feeding four times a day, and in winter one-kg feedings four times a day.

**(4)** After the fish are released into the bay waters, underwater observation and catching by means of longline are performed regularly at designated points around the bay, thus keeping track of the distribution of the fish population. Reports of tagged fish that have been re-captured are also gathered from local fisheries and from sport fishermen for analysis.

Statistics regarding this resource propagation experiment since 1986 are shown in **TABLE 2.**

Looking at the results appearing in local red sea bream fisheries based on imformation gained from reports of tagged fish being re-captured, we see that as of December 1989, the catch of fish released in 1986 was 10,258 fish, or 18.5% of the total released. This catch had a total weight of 3,729kg and an average body weight of 360 grams. Of those released in 1987, the catch was 25,882 fish (10.3%), with a total weight of 4,204kg and average body weight of 160 grams. With regard to results appearing in fisheries within the bay, it can be assumed that 15~20% of the red sea bream catch by small scale set net are fish released by the experiment. Meanwhile, the effect on longline and angling fisheries conducted outside the bay, although it varies with the season, stands in the range of 2~3% or 4~5%. The effect on gill net fishery and sport fishing are as yet unknown.

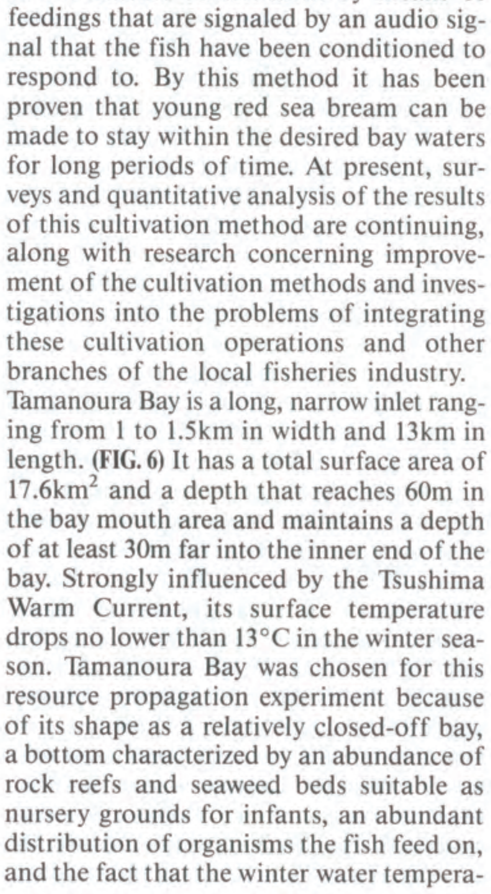
At the present stage, the experiment results clearly demonstrate that Tamanoura Bay is indeed a good rearing environment for red sea bream juveniles of up to three years of age, and that while some of the released fish do migrate out of the bay, the vast majority winter in the bay and remain there for at least 2 years.

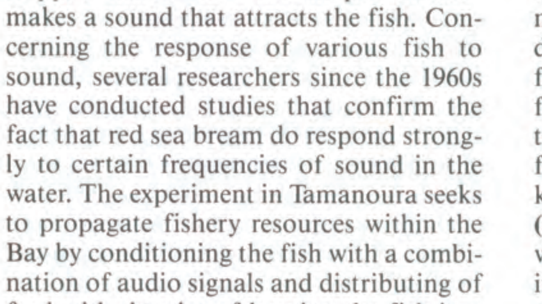
The financial outlay for this experiment during 1986 and '87, including the cost of purchasing the acoustic systems and feeding equipment, came to about ¥20 million a year. Since 1987, the total outlay for purchasing seeds (¥40 per fish), feed costs and labor costs came to about ¥3 million a year. In the future, if the feasibility of this sound-conditioned red sea bream resource propagation method in terms of ecosystem capacity and economic merit can be proven, its operation will be taken over by the local fisheries cooperative associations. In such a case, the enterprise will be pursued with attention to **(1)** providing a fishery alternative for aging fishermen that can be conducted inside the bay, **(2)** stimulating the local economy by encouraging a tourism based on sport fishing for red sea bream in the bay, and **(3)** contributing to the overall prosperity of local fisheries in a way that will encourage the next generation to pursue a career in fishery.

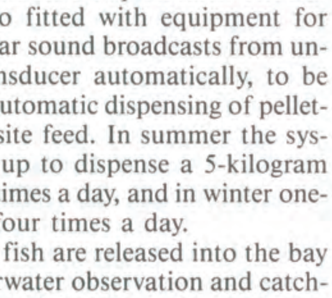
**TABLE 2: Operational statistics for the release project**

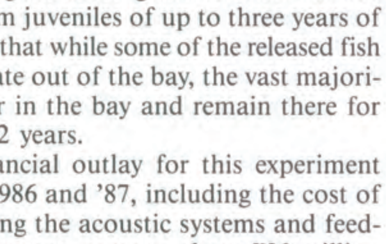
| year | # of fish released | # of fish tagged | average fork length at start of intermediate rearing stage | average fork length at time of release | length of intermediate rearing stage |
|---|---|---|---|---|---|
| 1986 | 55,000 | 55,000 | 92~122mm | 120~137mm | 69 days |
| 1987 | 250,000 | 50,000 | 65mm | 99mm | 49 days |
| 1988 | 50,000 | 15,000 | about 40mm | 80~100mm | 55 days |
| 1989 | 50,000 | 25,000 | about 30mm | 60~100mm | 118 days |
| 1990 | 55,000 (plan) | | | | |

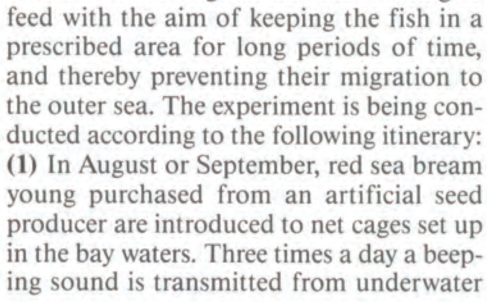
**FIG. 6: Tamanoura Bay, Goto Island**

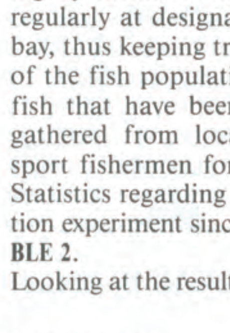


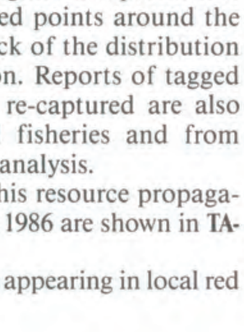


*A view of one section of Tamanoura Bay*

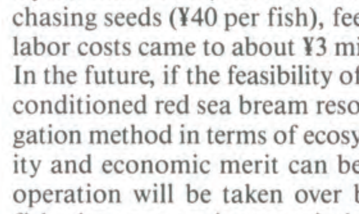

*The automatic control device*


*A fish at time of release (left) and a re-captured 2 year-old*


*The automatic feeding equipment of this sound-conditioned feeding station runs on batteries and is completely automatic with a feed holding capacity of 7 to 10 days.*


*The feed hopper*


*Composite feed*


*Red sea bream gathering at the feeding station at feeding time*

# Red sea bream culture in Japan

In Japan, the culture of red sea bream in cages began about 1965, and by the early '70s it had become widespread in many parts of the country. Although there had long been a desire on the part of Japanese fishermen to engage in red sea bream culture, the knowledge that it takes 4 to 5 years to raise fish to marketable size had prevented many from undertaking it earlier. In the early years, red sea bream culture began with the practice of rearing the young red sea bream caught by boat seine fisheries from naturally occurring resources. But in this practice, the supply of seed fish was inevitably unstable. Furthermore, since the color of fish reared in cages tended to darken, their reduced product value on the market proved to be a disadvantage.

Several important factors can be cited as contributing to the beginning of full-scale cage culture of red sea bream after about the year 1970. **(1)** The successful development of methods for the artificial mass production of red sea bream seeds for culture purposes around 1970 made a stable supply of seeds available to culture operators for the first time. **(2)** Improvements in rearing techniques made it possible to raise red sea bream to a saleable size of 1kg within 2 1/2 to 3 years. **(3)** Research and development in composite feeds and adaptations in the rearing methods led to a dramatic improvement in body color.

Ever since the onset of these improvements, both the number of fishing families undertaking culture and the overall national production of cultured red sea bream have continued to increase steadily. In addition to this conventional production, a growing demand for especially high quality red sea bream for consumption as raw "sashimi" has led to attempts to improve meat quality by changes in types of feed and the feeding methods themselves.

## Growth

Although we also see red sea bream with a body weight of 150 grams or more being traded on the Japanese fish markets as "Kodai" (small fish), it is the fish weighing from 500 or 600g to 1kg or more that are bought and sold on the market as high-quality fish at premium prices.

The growth rate of red sea bream varies according to its environmental conditions. Among natural red sea bream considerable differences have been noticed in the growth curve in different sea regions. It is believed that these differences are due not only to such factors as water temperature and food supply, but also to variations in the strains among local stocks in the respective regions. The cultured fish grow and mature generally faster than natural fish. **(FIG. 7)**

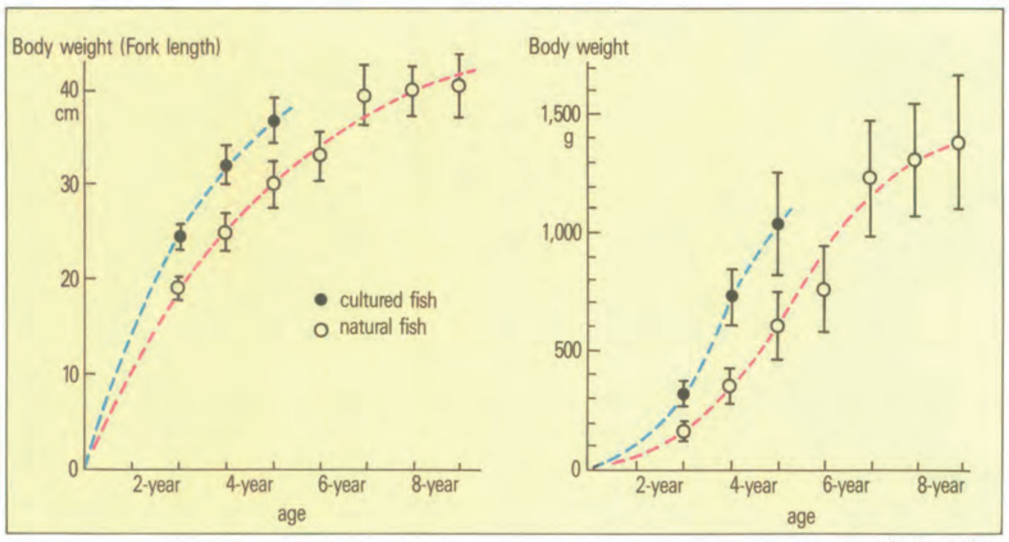
Furthermore, it has been shown that when natural seeds and artificially produced seeds are used in culture under identical conditions, the latter grows at a faster rate.

## Seed production

Fish fry which are released to the natural sea environment for the purpose of resource propagation or released in net cages for aquaculture, are commonly referred to as "seeds". Although the fry being sold as seeds may vary in size, there are two basic qualifications they must meet. **(1)** They must have passed the stage where they feed on zooplanktons and entered the stage where they feed on benthos or other small fishes or shellfish. **(2)** They must be receptive to feeding by minced fish meat or composite feeds. In the case of red sea bream, fry that are traded as seeds generally have reached a body length of 30mm (50 ~ 60 days after hatching) or more.

Artificial hatching and larva rearing for red sea bream has in fact been the object of research efforts for quite a number of years. But it was in 1965, that a breakthrough coming with the use of *Brachionus plicatilis* as feed in the early stages of rearing led to the first successful method of mass production for red sea bream seeds. Seed production is divided into a primary rearing stage conducted in water tanks on land, and a secondary stage in net cages set up in the surface of the sea. In the primary stage *Brachionus plicatilis* is the primary feed, with *Artemia spp.* being used as a supplementary feed in the secondary stage. About 20 days after hatching the larva reach a body length of about 7mm. When they reach a size of 30 ~ 50mm, they are moved to net cages set up in the surface of sea waters and the second stage of rearing begins. Just about the time the second stage starts, difference in size among the fry causes them to begin cannibalism, feeding on each other. Therefore, keeping rearing density in the cages low enough to prevent substantial population loss due to cannibalism becomes one of the most important aims. When moved to the new environment, the fry must have the durability to withstand changes in water conditions and other physical stresses. In the case of red sea

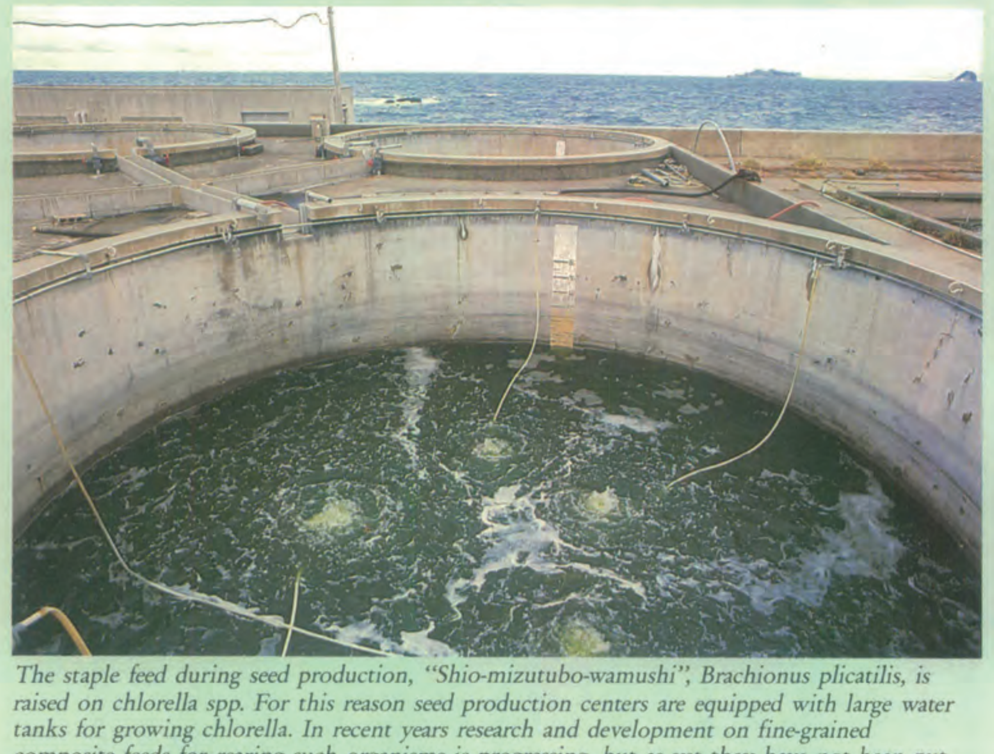
**FIG. 7: A comparison of the growth of red sea bream (between cultured and natural fish)**




(Kitajima, 1978)

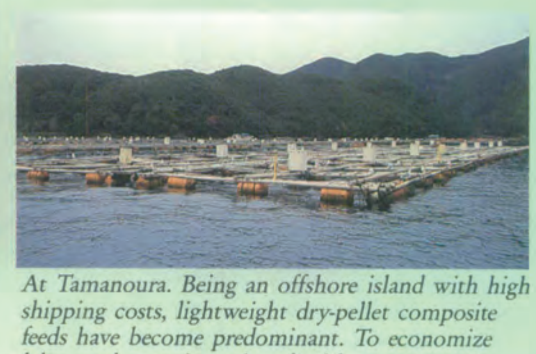
*Secondary stage rearing cages for fry in sea waters*

*A seed production facility (Nagasaki Prefectural Culture Research Center). In the lefthand building are holding tanks for parent fish and hatching facilities. In the righthand building are tanks for the primary rearing stage of fry. The panel on the left gathers solar energy to heat the water in the parent holding tanks.*



*The staple feed during seed production, "Shio-mizutubo-wamushi", Brachionus plicatilis, is raised on chlorella spp. For this reason seed production centers are equipped with large water tanks for growing chlorella. In recent years research and development on fine-grained composite feeds for rearing such organisms is progressing, but as yet they have not been put to practical use in red sea bream culture.*

*Primary stage rearing facilities for fry*



*At Tamanoura. Being an offshore island with high shipping costs, lightweight dry-pellet composite feeds have become predominant. To economize labor each cage is equipped with an automatic feeding machine.*

*A boat used in the feeding operation. In front of the bridge is a machine for forming moist pellets.*

bream, by the time the fry reach a body length of 7mm they acquire swimming abilities necessary to accommodate flowing water. At this stage in their growth they also have the strength to withstand the vibration and shocks occurring during transport and the stresses of handling in the dipper net. At this stage their feed is changed from zooplanktons to minced fish and shellfish or composite feed in crumble form.
Research regarding seed production for red sea bream provided the basic principles to be employed in the development of seed production for other species of fish. Today, among the various seed production operations being conducted for the different types of fish, the technology of red sea bream production has reached the highest level of standardization, and the annual production of over 20 million seeds is one of the largest. Along with the standardization of this production technology has come continued progress in economizing the production process through mechanization, enabling some operations to produce as many as 5 to 6 million red sea bream seeds per year.

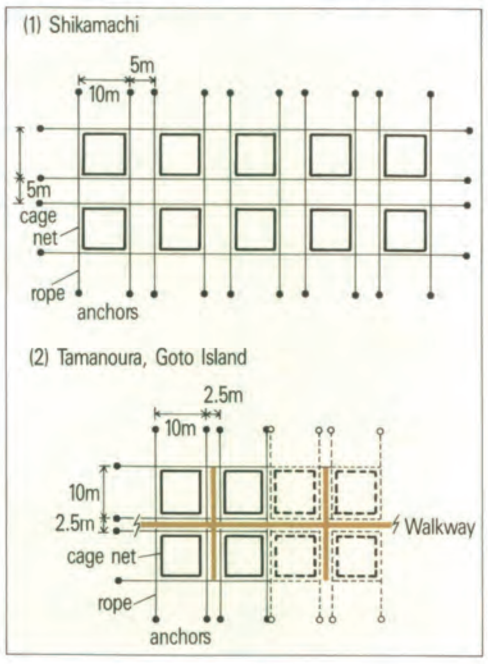
## Areas suitable for culture

The water temperature range at which red sea bream exhibit the most active feeding habits and fastest growth is 20 ~ 28°C. When the temperature exceeds 29°C, the feeding habits become quite irregular, and the fish easily suffer physiological disorders. At temperatures below 20°C, the amount of food consumed begins to decline. Feeding comes almost completely to a stop when the water temperature falls to 10°C or less.
For red sea bream to reach a marketable size requires a rearing period of over 2 years at the least. Therefore, one of the requirements for a culture site is that it be one which the fish can winter in, with a water temperature range that stays between 12° and 28°C year-round. The following are some of the conditions that make for suitable red sea bream culture grounds:
**(1)** The yearly water temperature should range between 12° and 28°C. And to ensure rapid growth, it is best if the winter low does not drop below 13° ~ 14°C.
**(2)** The depth of the water should be more than twice the cage depth of 5 ~ 7m.
**(3)** It should have a good flow of sea water or a good exchange of waters due to tides.
**(4)** It should be in quiet waters protected from the direct effects of wind and waves from outer sea.
**(5)** It should be free of the threat of water quality deterioration due to excessive inflow of dirty river waters or industrial waste waters.
**(6)** There should be good access to feed supply and shipping for the harvested products.

## The culture facilities

There are basically three types of culture facilities; the net cage type, the net partitioned type, and the embankment enclosed type. Of these the net cage type is predominant today, accounting for 90% of the entire area presently used for culture.
Generally, the net cage type culture facilities consist of a series of box-shaped cages with synthetic fiber nets strung on raft frames made of Japanese cedar poles, held up by styrofoam floats and the whole facility held in place by means of anchors. There is no set size for the cages, and in different regions we find cages of 10 × 10m, 9 × 9m, and 5 × 5m respectively being the preferred sizes. But generally speaking, the 10 × 10m size is the most widespread, while the most common depth chosen for the cages is 5 ~ 6m. Taking into consideration such factors as wave effects during storms, the labor involved in the feeding process, and depth of visibility regarding feeding activity of the fish from an observation standpoint, the largest practical cage size is in the range of 10 ~ 15m × 10 ~ 15m × 7 ~ 8m in depth. Figure 8. shows examples of the layouts of net cage facilities. Example 1. in **FIG. 8.** complies with a regulation set by the local fisheries cooperative associations that requires a distance of at least 5 meters between cages in an effort to prevent overly-intense culture conditions. Example 2. is one conceived for rearing an optimum number of fish with a minimum of labor. Each of the cages in this type is equipped with an automatic feeding device.

**FIG. 8: Net cage facility configurations**




## Division of the culture lot and net changing

In order to rear healthy fish under favorable growth conditions, it is essential to maintain a proper population density within the culture cages. Although the proper density varies according to sea conditions, in the case of 10m × 10m × 5m deep box-shaped cages used in Nagasaki, culture operators are instructed to maintain a density of less than 35kg/m². Regarding the mesh size of the nets used, it goes without saying that the larger the mesh the better, because a larger mesh allows for better exchange of sea water between the cage and the surrounding sea. Also, when nets are left in the water for long periods of time marine organisms begin to grow on them, thus clogging the mesh and restricting water flow. For these reasons culture operators must always undertake the two essential practices of culture lot division and net changing, depending on the growth stage of the fish they are rearing.
Culture lot division and net changing are two basic environmental control practices that directly effect how efficiently feeding will take place and how fast the fish will grow. They also have a great effect on the material, labor and feed costs of the culture operation. Each operator searches for his own techniques and answers with regard to these two practices, and their degree of diligence in these two tasks will account for considerable differences in the effectiveness of individual culture operations. **TABLE 3** represents the example of one culture operator in Tamanoura, Nagasaki Pref.

**TABLE 3: Culture population density and net mesh**

| Year | Fish size | # of fish kept in one 10m × 10m × 5m cage | Mesh size |
|---|---|---|---|
| 1st year | fry ~ 100g | 10,000 | 23.3mm |
| 2nd year | 100 ~ 800g | 5,000 | 33.6mm |
| 3rd year | 800 ~ 1,300g | 3,000 | 50.5mm |
| 4th year | 1,300 ~ 1,500g | 3,000 | 75.8mm |


*The cage facility in FIG. 8-2*


*The raft construction of the culture facility diagramed in FIG. 8-2. Down the center is a board walkway that serves as an access for feed distribution and other jobs.*


*In recent years we have seen the appearance of circular net cages utilizing galvanized steel pipes of 50mm diameter and held up by steel floats with a flotation capacity of 200 ~ 250kg.*


*A wheelbarrow used for carrying feed*


*The framework of the culture raft.*


*An automatic feeding machine*


*Composite feed. One day's supply is 60kg per cage.*


*The feeding in progress*

### Feed

Red sea bream is a fish that feeds on a highly varied diet. As fry they feed on zooplanktons, and as they grow their diet centers around crustaceans of shrimps, mysis, crabs, and squillas. Their diet further expands as they mature to include species of starfish, smaller fishes and other organisms that inhabit the sea bottom.

The feeds used in red sea bream culture are fresh fish and composite feeds. The fresh fish feeds include mass catch fish like anchovy, sand launce and mackerel, and other frozen fish supplied in minced form. When frozen fish is used it is first thoroughly thawed and then rinsed well in sea water to remove the fat that surfaces.

In the case of composite feed it is important to choose a feed with a suitable nutritional composition for the red sea bream's needs. When comparing the dietary needs of yellowtail, red sea bream and carp, for example, with regard to the three basic nutritional elements of fat, protein and carbohydrates, we find that yellowtail prefer a high fat content while carp get most of their calories from carbohydrates. Red sea bream classifies as a carnivorous preferring a nutritional balance lying somewhere in between those of yellowtail and carp.

Because it is more convenient than fresh fish feeds from the points of transport, storage and ease of handling, composite feed is becoming more widely used throughout the country in recent years. In Japan several brands of composite feed for red sea bream are marketed, with the standard nutritional composition consisting of 40 ~ 45% protein, 3 ~ 6% fat and less than 20% carbohydrates, to which are added various vitamins and inorganic ingredients.

Also popular throughout the country in recent years is a "moist pellet" feed that combines the characteristics of both fresh fish and composite feeds. This moist pellet feed is one in which minced fresh fish meat is mixed with granular form composite feed and pressed by machine into pellet form. The benefits of moist pellet feed include the fact that it can utilize inexpensive fresh fish, the size of the pellets can be changed to suit the growth stage of the culture fish, necessary nutritional supplements can be mixed in, the amount of feed necessary per feeding is less than when using only fresh fish, and the fact that there is less pollution of the culture environment resulting from the accumulation of uneaten feed.

### Maintaining body color

The bright red color for which red sea bream are prized is the result of the carotinoids called astaxanthin. In their natural state, red sea bream live in deep waters and feed primarily on crustaceans. The darkened skin color that cultured red sea bream take on is closely related to the rearing environment and the diet on which they are fed. Red sea bream has the pigment melanin in its outer membrane which turns dark when exposed to excessive amounts of ultraviolet light. Furthermore, the pigment astaxanthin is found in large quantities in crustaceans like prawns and crabs.

Culture operators allot the last several months before shipment of marketable size red sea bream to altering their coloring to a bright red. First of all, the cages are covered with a sun screen which makes light conditions in the cages similar to the red sea bream's natural habitat to help reverse the phenomenon of skin darkening. Next, the fish are fed continuously on krill or red shrimp for 2 or 3 months to adjust the carotinoid composition in the outer membrane. Because the longer the period of sun screening the better, cages with fish scheduled to be shipped in the New Year's season are covered from the months of strong sunlight in July and August.

### Shipments to market

In the case of both natural and cultured red sea bream, the fish are either killed immediately after landing and packed with ice for shipment or else shipped live to the major urban markets.

When the fish are to be shipped live, feeding is stopped in advance so their bellies will be empty when they are shipped. In summer this involves stopping the feedings for 5 ~ 7 days before shipment, and in winter 2 ~ 3 weeks. The purposes of this feeding stoppage are: **(1)** to prevent the water in the shipping containers from becoming dirtied as a result of regurgitation, **(2)** to keep excretions during shipment to a minimum, and **(3)** to restrict the metabolic rate and thereby reduce oxygen consumption during shipment.

Shipment of live fish is done by specially outfitted fish trucks, boats or air freight.

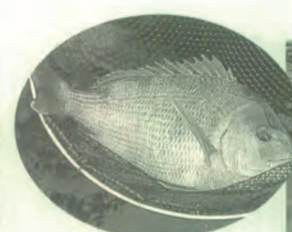

*Fresh fish feed. Mackerel and sand launce.*

*Moist pellets.*

*Sun screens stretched across the surface of the cages for the purpose of altering body color.*

*Fattening cages at a center for shipping live fish.*

*The sorting process in preparation for shipment.*

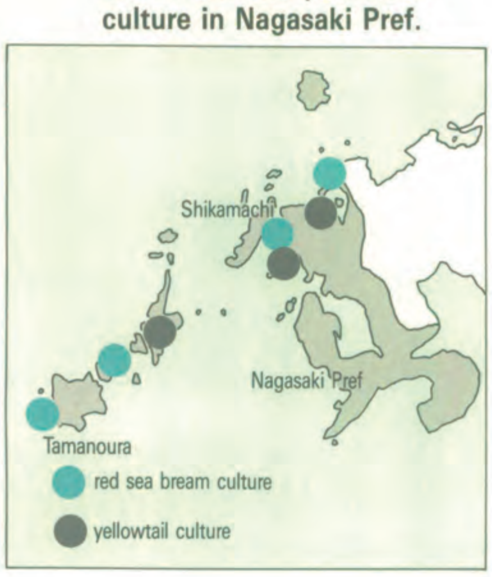


*A 1kg red sea bream showing darkened body color.*

*Weighing.*

# Management of aquaculture in Nagasaki

**FIG. 9: Main producing areas for red sea bream and yellowtail culture in Nagasaki Pref.**




There are 170 fishery cooperative associations in Nagasaki Prefecture, and of these 68, or 40%, are engaged in aquaculture. The objects of these aquaculture include red sea bream, yellowtail (Japanese amberjack), hardtail, tiger puffer, gold striped amberjack, parrot fish, bastard halibut, Kuruma prawn, oysters, Undaria seaweed and pearls, with the most important fish in terms of the total value of the culture crop being yellowtail and red sea bream. The main producing areas for yellowtail and red sea bream are shown in **FIG. 9.** Aquaculture with the largest production has developed primarily in coastal areas washed by the Tsushima Warm Current with a large inflow of clean offshore water.

The culture of yellowtail began in the early 1960s and saw a rapid growth after 1965. By 1975, however, the cultured yellowtail market had already reached a saturation point verging on overproduction in all parts of the country, and beginning in 1979 the market price for yellowtail began to fall. Since 1980, restrictions have been placed on production, and at present supply and demand seem stabilized at a nationwide annual production of 150,000 ~ 160,000 tons.

In contrast, red sea bream culture began in Nagasaki in 1965, and until today the annual production has continued to increase every year while maintaining high market prices. In the last few years, though, the market price seems to have reached a ceiling. All in all, the investment returns from red sea bream culture are good and, with the inclusion of some operators changing over from yellowtail culture, the number of red sea bream culture operators continues to increase gradually.

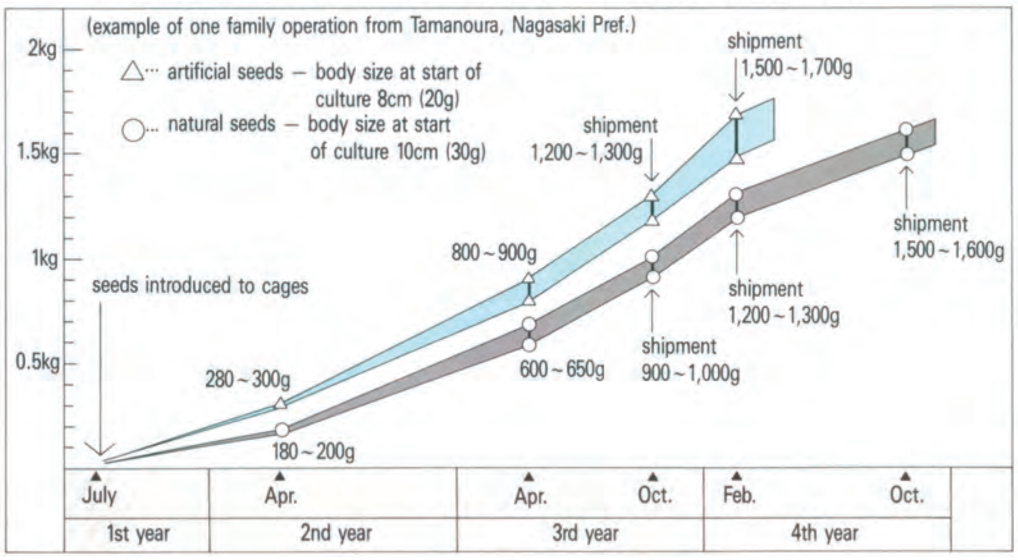
**FIG. 10** shows an example of the culture schedule for one family operation in Tamanoura, Goto Island. Meanwhile, **TABLE 14** shows the breakdown of costs involved in the rearing of a 1kg red sea bream raised over a period of 2 years and 3 months by the same family.

Let us now take a look at the conditions under which red sea bream culture is conducted in the two cases of Shikamachi and Tamanoura, two different towns in the main producing area.

**TABLE 14: Production cost per fish for 1kg red sea bream**

| | |
|---|---|
| seed cost | ¥100 |
| feed cost | ¥600 |
| cost of feed for finishing period | ¥200 |
| labor cost and depreciation | ¥50 |
| production cost total | ¥950 |
| anticipated price when sold | ¥1,300 ~ 1,500 |

**FIG. 10: Growth and shipment schedule for red sea bream culture**




## Shikamachi

Although yellowtail was the first object of culture operations here, a sharp drop in the market price in 1972 caused many to abandon this culture, and in 1973 full scale culture of red sea bream was begun. At present there are 160 members in the local fisheries cooperative association, of which 40 are engaged in red sea bream culture. Each family operation is limited to ten 10m × 10m × 5 ～ 6m deep cages according to cooperative rules, and the average operation introduces 15,000 seed fry per year to its culture facilities and harvests about 600,000 red sea bream of the 1kg class each year. In this locality are seven purse seine fleets catching anchovy and mackerel from which the culture operators have been able to get their supply of fresh fish feed. But in recent years moist pellet feed is becoming more popular. The local fisheries cooperative's policy regarding the development of aquaculture is that the first priority is to establish sales routes, after which production can be increased in accordance with demand. In the cooperative association there are five people who specialize in selling the cooperative's produce wholesale, and their combined selling power amounts to about one million fish annually. In addition to this, the cooperative association has recently undertaken the development of a direct-delivery service for urban consumers. Culture operations here, by the way, are all conducted by means of family labor.

## Tamanoura

Since there are no purse seine fleets on the island to provide the fresh fish feed necessary in such large quantities for yellowtail culture, it was decided that some of the fishing families would undertake red sea bream culture in 1969. At present, 42 of the 250 members of the local fisheries cooperative association are engaged in red sea bream culture. Since the cooperative association set no limits on the scale of culture operations, we see large differences in the volume of production between individual operations, with some operating forty 10m × 10m × 5m deep cages and some operating more than one-hundred. The individual operations introduce between 50,000 and 100,000 seeds to their facilities per year, and although the majority of these fish are sold to culture operators in Oita or Kagawa Pref. after only partial rearing, some of the larger operators here in Tamanoura have now progressed to the point where they raise their fish to a size of 1 ～ 1.5kg and complete the color alteration process themselves and then sell the fish. In 1989 the production of cultured red sea bream in Tamanoura sold for a total of ¥2.38 billion, or 72% of the local fishery cooperative's total sales of ¥3.3 billion. Today, supplementary culture fisheries for yellowtail, bastard halibut, tiger puffer and hardtail are also under development here. Most of the culture operators here have incorporated their culture businesses.

# The characteristics of red sea bream as a fishery

In every case, the fish that are the object of aquaculture are high-class fish, and their culture flourishes as an industry in the context of decreasing natural resources of the given fish.

One of the great advantages of aquaculture is that fish or other marine products can be supplied to the market regularly according to a planned schedule. Since 1960, the high growth rate of the Japanese economy and the resulting rise in people's standard of living has supported a healthy market demand for high-class marine products, and consequently the steady growth of culture fisheries.

And as aquaculture developed into an industry that supplied a large volume of produce on a regular basis, they brought new stimulus for the development of the essential infrastructure of the producing area. Their development thus has had far-reaching effect on such related industries as suppliers of construction materials for culture facilities, transporters and marine food processors.

Because aquaculture involves the production of biological organisms, the "products" grow over a period of time. As each species has its own growth characteristics, and seasonal changes in water temperature effect feeding efficiency, the degree to which the culture operator understands the biological and ecological characteristics involved with the species he is rearing, can account for substantial differences in the productivity and profitability of a culture operation. Furthermore, the price which the operator is able to get for his produce will depend on factors like the size of the fish and fluctuations in market conditions. In order to make the most of his business, the culture operator must have a thorough understanding of the relationship between the market value and the production cost of his produce at the various stages of growth and formulate his production schedule accordingly.

Let us compare red sea bream culture with yellowtail culture by way of example. Yellowtail are active eaters with a rapid growth rate. Fry introduced to culture in May will have grown to a marketable size of 1kg within half a year, making it a species suitable for short-term culture. By contrast, red sea bream are small eaters that consume small portions of food at a time over long periods. The growth in body size is slow, requiring at least 2 $^{1}/_{2}$ years to reach a marketable size of about 1kg. **(FIG. 11)**

When a given fish requires a long culture period, it means not only increased feed and labor costs but also a lengthening of the period of investment turnover. Furthermore, there is an increased danger of death among the culture stock. Red sea bream is therefore not suitable as an object of culture for fishermen with limited financial resources. For these reasons, three basic patterns for red sea bream culture management have emerged. These serve to distribute the responsibilities among fishermen in each area according to their ability to absorb financial risk, as follows:

**(1)** Fry are obtained as seeds and reared to a size of less than 1kg and then sold still immature to culture operators in other areas.

**(2)** Fish are reared from fry to a size of 1 ～ 1.5kg and then sold to operators who undertake the finishing stages of culture, including body color alteration.

**(3)** One operator completes the entire culture process from fry rearing through maturity and the finishing stages and then sells the produce by himself.

Depending on the diligence and technical proficiency of the operator, aquaculture can be a very productive business. However, because it is a fishery that completely occupies a given area of water, if the operator uses the fishing grounds solely for the purpose of his own profit, it can lead to the depletion of the natural productivity of the area and the destruction of other types of fisheries.

Since 1960, Japan has seen aquaculture for fish, shellfish, crustaceans and seaweeds develop one after another, all of which have followed the same basic pattern of development. **(FIG. 12)**

In every case, the development of aquaculture depends on well-planned policies concerning the proper use and supervision of the fishing grounds, establishment of sales routes and adjustment of production schedules to meet market demand, with initiative taken by the local fishery cooperative associations with consideration for specific regional conditions.

**FIG. 11: Income vs. cost curves for fish culture**

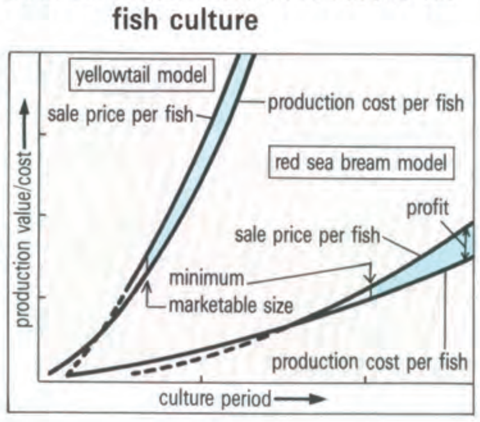
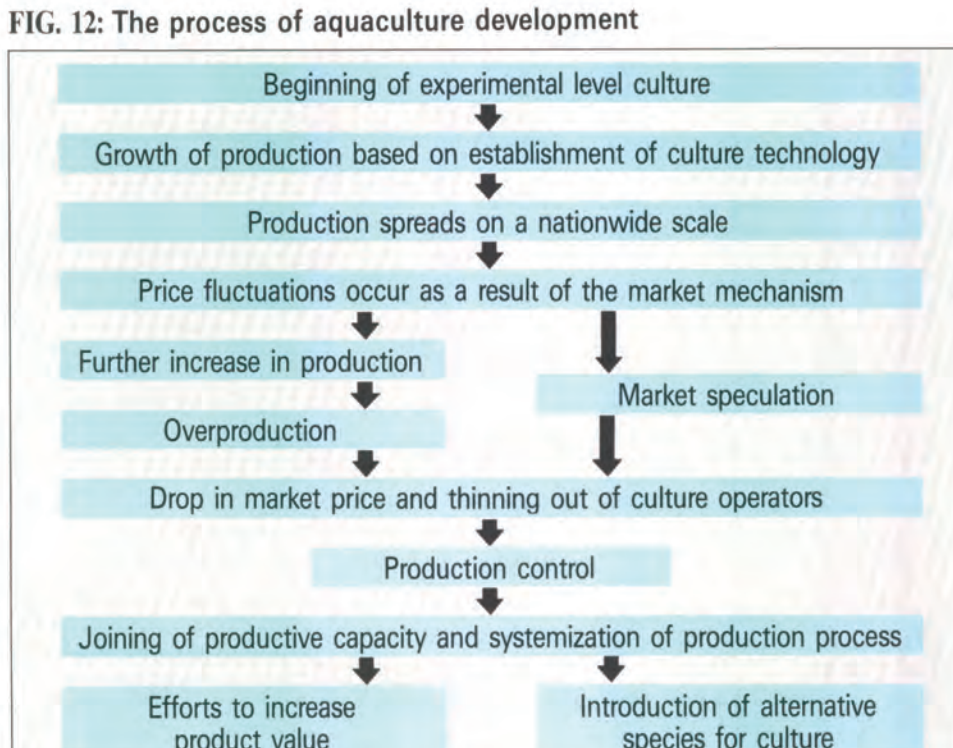



**FIG. 12: The process of aquaculture development**



# The Red Sea Bream Market

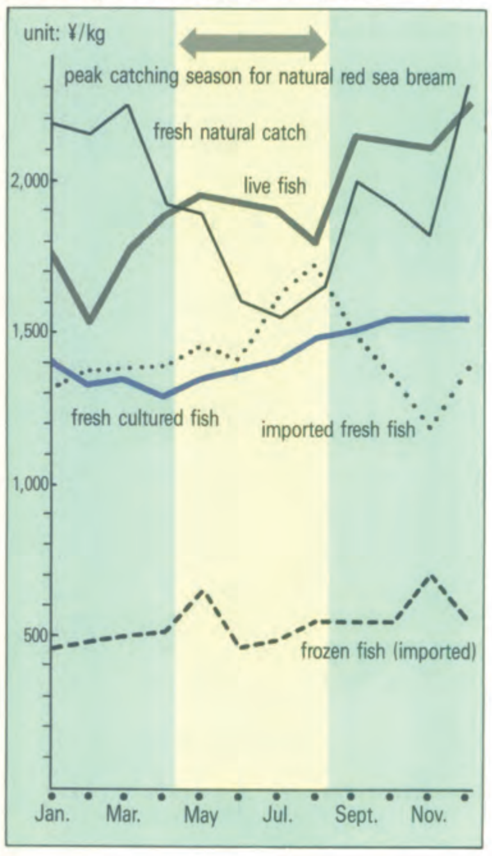
## The pricing system

In Japanese market transactions fish prices are determined by a complicated set of interacting factors.

**(1)** Seasonal changes: Prices fall during the peak catching season for natural resources. On the other hand, high-class fish prices climb during the periods in the spring and fall when Japanese customarily make seasonal outings, and at the New Year's holiday.

**(2)** Body size and meat quality: Larger fish of a given species draw higher prices per kg than smaller ones. And in general, the meat quality of naturally raised fish is considered to be higher and the taste better than cultured fish. This factor results in a continuing price difference between the two. Consequently, natural fish of large body size invariably draw the highest market price.

**FIG. 13: Market prices for red sea bream**
**(Wholesale prices at the Tokyo Central Wholesale Market 1988)**




**(3)** Product types: The pricing system also is determined by the state in which the product is sold, with live fish drawing the highest price, followed by fresh fish and frozen fish respectively.

**FIG. 13** gives an example of average wholesale prices for red sea bream at the largest fish market in Japan, the Tokyo Central Wholesale Market. One of the noteworthy trends in recent years is the increased trading in live red sea bream.

## Freshness and how the fish is put to death

When Japanese refer to the freshness of fish, they refer to the "life" of the meat being good or bad. Freshness does not mean the degree to which bacterial activity has deteriorated the food quality. Freshness is rather an evaluation of the progression of physiological changes that occur immediately after death.

The term "fresh fish" does not refer to dead fish, but rather to fish that have been put to death by specific means directly after being caught. Basically there are two ways that fish are put to death.

**(1)** "Nojime" ... mass catch fish like sardine, horse mackerel, and mackerel are put to death by being dumped into tanks of ice water in the fishing boat's hold and chilled instantly.

**(2)** "Ikeshime" ... fish like red sea bream, bastard halibut and yellowtail are kept in a live preserve on board the fishing boat and then put to death one at a time by making an incision in the afterbrain after being landed.

The amount of time that fish put to death by the "ikeshime" method and then kept refrigerated at 0°C remain fresh enough to be served to customers at restaurants as "sashimi", varies with different species of fish. For red sea bream this period is 12 days, for yellowtail 6 days, for jack mackerel 3 ~ 5 days, and for cod just half a day. This ability to maintain freshness is a result of the amino acid composition in the meat of different fishes. "Freshness" is in fact a standard by which we express the combined product qualities as determined by taste, meat color and texture when comsumed raw as sashimi.

The process by which the muscles of animals deteriorate in freshness and finally begin to putrefy is as follows:

**(1)** After the animal dies and blood circulation stops, the muscle's source of energy, Adensine triphosphate (ATP), ceases to be produced.

**(2)** When the amount of ATP falls below a certain level the muscles begin to contract. The resulting stiffness continues from shortly after death until the last of the ATP leaves the muscles.

**(3)** A certain time after the period of stiffness ends, the action of oxygen causes the muscle protein to begin self-digestion.

**(4)** When the stage of muscle softening is reached, in the case of fish the microorganisms on the body surface or scales or internal organs become active and the process of putrefication begins.

The purpose of the "ikeshime" technique is to delay the beginning of stiffening after death. If the fish are allowed to struggle and spasm in their death throes, large amounts of ATP in the muscles are consumed rapidly. "Ikeshime" is a process that kills the fish instantly and without prolonged suffering by severing the afterbrain portion between the brain and the backbone with a hook or knife. It is important that the ikeshime process be performed skillfully. The fish should be placed on a soft surface like styrofoam and held firmly with the head forward to prevent it from moving. Then the incision is made from the right side of the head or from the inside gill region into the afterbrain. The process requires a well-sharpened cutting instrument and an experienced hand.

## The distribution system for live fish

Since olden times, shellfish, crustaceans and some varieties of freshwater fish have been sold live in the marketplace. With regard to marine fishes, however, the difficulties of live transport caused high-class fish like red sea bream, flounder and yellowtail to be killed first by the "ikeshime" method in the producing area and then shipped to the consuming area.

Entering the 1980s, however, we saw the growth of a live fish distribution system primarily centered in Kyushu and Western Japan that specialized in transporting live fish to the major urban centers. This enabled restaurants to keep the fish live in holding tanks ready for use when ordered by their customers. In this way, the increasingly gourmet tastes of the urban populace and the development of the restaurant industry led to the start of a new type of distribution system.

In 1975, 4,200 tons of live fish were traded at the Tokyo Central Wholesale Market, but by 1988 that figure had reached 11,900 tons. And while the tonnage grew 2.8 times, the wholesale value grew 4.5 times. Of the total volume of live and fresh fish handled by the market, live fish have come to account for 6% by tonnage and 11% by wholesale value.

The following are some of the factors that can be said to support this growth in the live fish market:

### <Factors in the producing area>

**(1)** The desire to create added value in the coastal fishery production

**(2)** The efforts of shipping centers in the aquaculture producing areas to maintain high fish prices through shipment control and stabilizing of supply

**(3)** Research and improvement of live-fish shipping techniques and the emergence of specialized transporters for live fish

**(4)** The advancement of an expressway network of truck transport

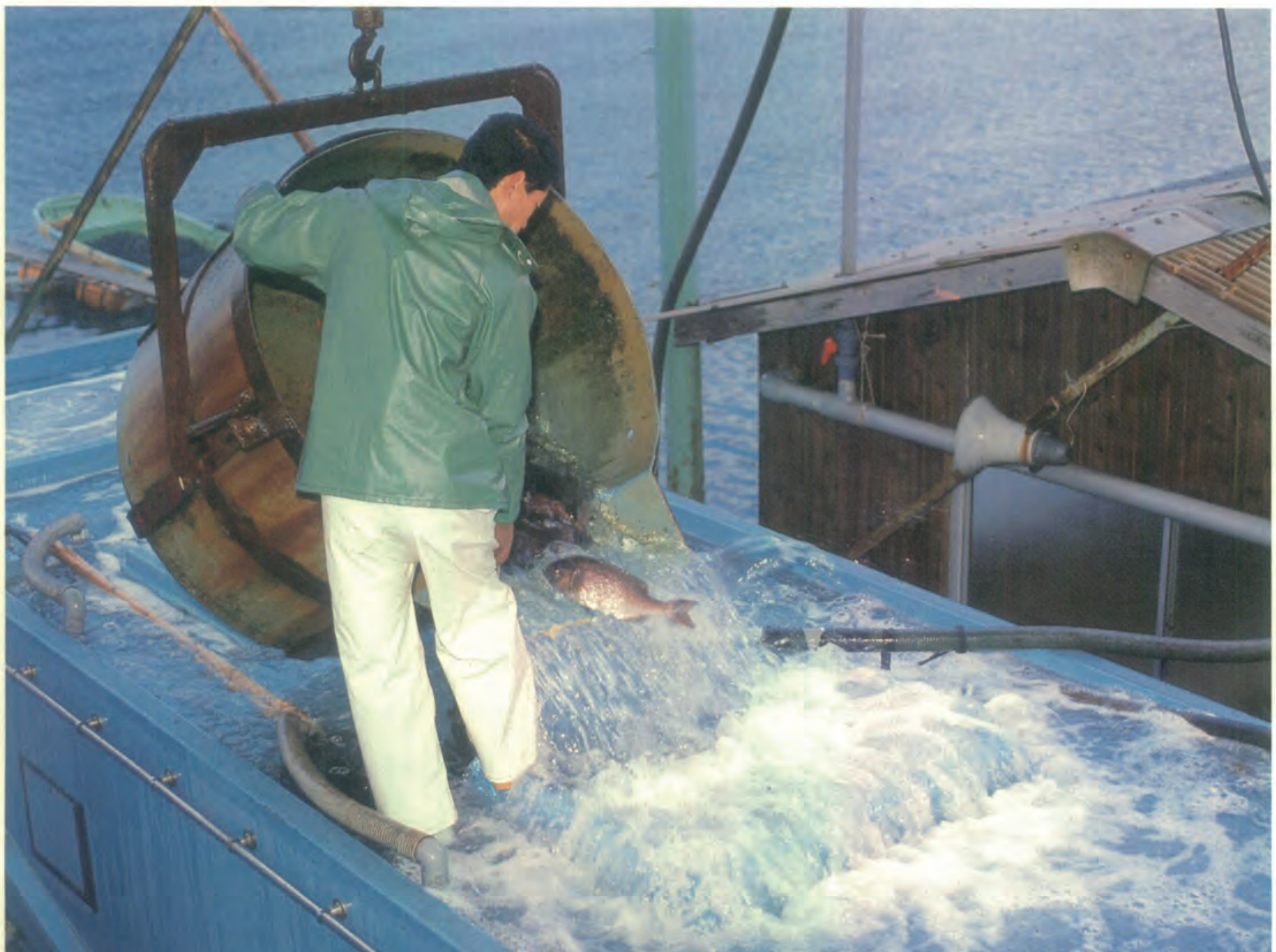
**(5)** The development of special delivery systems that make possible door-to-door delivery from the producing area to the consuming area

### <Factors in the consuming area>

**(1)** The emergence of new business establishments capitalizing on the increasingly gourmet tastes of the consumers (restaurants with live-fish tanks)

**(2)** The reaction of traditional Japanese restaurants to the influx of western-style family restaurants (menus increasingly centered around fish dishes)

**(3)** The entrance into the market by large scale restaurant chains



*Loading fish into a live-fish transport truck along with sea water.*

*The shipping center of a distributor specializing in live fish.*

*Live-fish transport vehicles come in several types, and in general they can be divided into (1) long distance type (10 ~ 11 ton models), (2) middle distance type (4 ~ 8 ton models) and (3) short distance type (2 ton models). Type (1) is equipped with a cooling system, a circulation pump, a filtering system and a blower or aeration pump. (2) and (3) are equipped with a simple oxygen pump and filtering system.*

*An observation window on the tank of a transport vehicle. Since fish are highly susceptible to stimulation by light, the window is kept closed during transport.*