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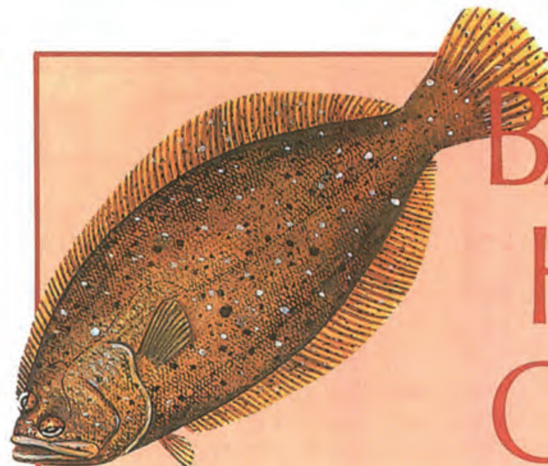
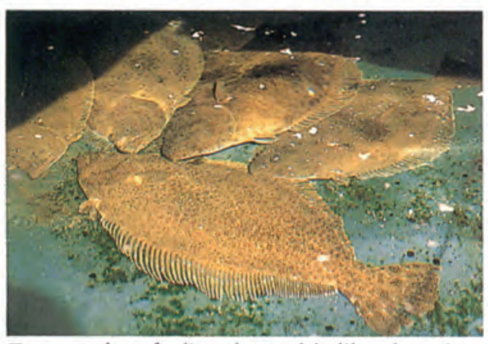


BASTARD HALIBUT CULTURE

The big shift from trawl fishery to fish farming and aquaculture



Except when feeding, bastard halibut kept in tanks or cages spend most of the time lying quietly on the bottom. The fish lie one on top of another not as a result of a swarming instinct but rather as a manifestation of their habitual need, known as thigmotaxis, to constantly be in contact with some surface.

Closed-area system aquaculture using net cages hung in surface waters is conducted by family labor. The feeding operation can be performed by one person, while the selection work, net cleaning and shipping preparations are performed by 2～3 people.

The aquaculture being conducted in Japan today can be divided into two major categories; open-sea system fish farming that utilizes open areas of natural sea environment, and closed-area system aquaculture conducted in artificially enclosed sectors of water.

The fish farming method is one that relies basically on the natural productive capacity of a given sea area.

The object of this method is to release fish seeds in the natural sea environment and control or maintain that environment in ways beneficial for growth of the young so as to increase and maintain the reproductive capacity of the marine resources involved.

This in turn leads to recovery of fishing ground productivity and helps stimulate fishing boat fisheries within the cycle of the resources' natural reproductive patterns.

The aquaculture method, on the other hand, is by nature a commercial pursuit. This method provides the fishery operator the means to actively control the growth of his marine products, create added value and gain commercial profit from sales. Particularly in the case of closed-area system aquaculture of fishes, the tendency is to choose high-value fish with rapid growth characteristics and engage strictly in feeding aquaculture.

In Japan, the market price of fish varies greatly by species. High class fish like bastard halibut, red sea bream and tunas for example draw market prices that are more than ten times the price per kilogram of mass-catch fishes like sardine, sand lance and mackerels. This price gap between different species of fish has been the largest single factor contributing to the growth of commercial-type aquaculture of fishes in Japan. The present price structure for these types of marine products is based on traditional Japanese eating habits with regard to seafood. But in another sense, it also reflects the development of Japan's consumer economy that has accompanied the high economic growth rate the country has enjoyed since the 1960's.

The species we introduce in this issue, bastard halibut, *Paralichthys olivaceus*, is a prime example of a high-class consumer fish that has become the object of commercial aquaculture under the unique conditions of Japanese marine production mentioned above. In all parts of Japan today, the production of bastard halibut is being actively expanded by means of both fish farming and aquaculture methods (**FIG.1**).

Bastard halibuts and righteye flounders have been important fishery products in Japan since the Edo Period (17th～19th centuries), caught actively in inland sea areas, bays and outer sea coasts with sand and mud bottom composition throughout the country. The fishing methods have included seine net, sailing seine, gill net, long line and hand-and-line.

Among these, seine net and sailing seine methods became mechanized in the Meiji Period (1868～1912) and later developed into small-scale trawl net methods. The trawl net method using motorized boats is the most efficient fishing method of all for catching demersal fish, and, with the growth of fisheries in modern times, its use has spread beyond coastal fisheries into offshore and even far sea fishing grounds.

Flatfish fishery is no exception to this tendency, with the trawl net method continuing to be responsible for the largest amount of catch.

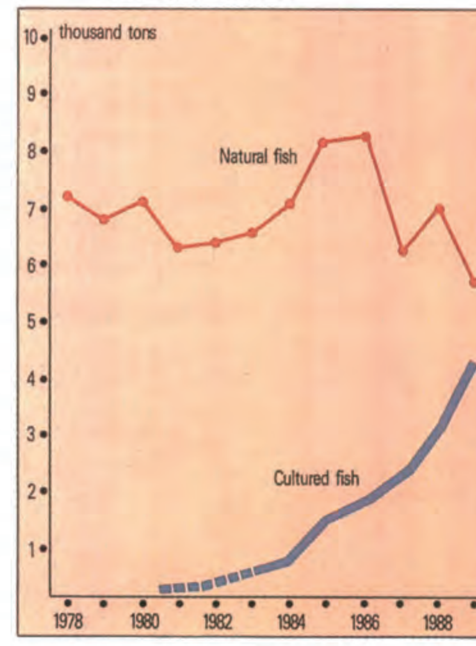
In recent years, however, trawl net fishery has diminished somewhat in importance. Since around 1980, a strengthening of international restrictions on trawl fisheries in the northern North Pacific Ocean, has led to a sharp reduction in catch. In some cases it has become necessary to suspend fishing operations completely. In the case of offshore fisheries for flatfish, total catch has been decreasing steadily since the latter half of the 1970s. Furthermore, in coastal small-scale trawl net fishery, although fish farming has proven effective as a means to increase resources of shellfish species, the catch of demersal fish such as bastard halibut continues to decrease.

In light of these conditions, revitalization of coastal fisheries through propagation of resources has become an important subject of industry attention. And, in the case of high-class fish like bastard halibut with its strong market demand, conditions are ripe for a major expansion of commercial-type aquaculture. Artificial production of bastard halibut seeds began on a mass scale at the Fisheries Experimental Stations of Aomori, Tottori and Niigata Prefectures around the year 1975, after which release of fry was begun.

Since then, the number of prefectures engaging in fish farming of bastard halibut has continued to increase. In the year 1988, the nationwide production of bastard halibut seeds at national and prefectural sea farming centers was approximately 15.2 million fish, of which about 8.9 million were released in the sea after intermediate rearing.

Meanwhile, closed-area system aquaculture of bastard halibut was begun by fishery operators in about 1980. Since then, operations have spread to all parts of the country, including entries by operators from outside the fishery industry. At present there is an annual production of about 4,000 tons coming from the warm current coasts of Western Japan including the three dominant prefectures of Ehime, Kagoshima and Mie. (**FIG.1**)

FIG. 1: Japanese production of bastard halibut



The bastard halibut's mode of life and suitability to aquaculture

Almost all flatfish varieties are saltwater species, and they inhabit all of the world's oceans. They are distributed from the cold water regions to the tropics, but the largest resources are found in the temperate zone.

Flatfish are a heterosomata group. Immediately after hatching they have symmetrical bodies and swim in a vertical position. As they grow, however, one of the eyes gradually moves along the periphery of the head to the other side, finally becoming fixed in a position above the other eye. Its swimming posture then changes from the vertical to the horizontal, the structure of the head bones, nerves and muscles change and it enters a benthic life with its eyeless side against the sea floor and its eyed side facing up.

Within the family Paralichthyidae, Japanese halibut is a variety with very distinct characteristics. Its eyes are small and its mouth large and strong with large, sharp teeth aligned in a single row.

In the natural state, bastard halibut reach an average body length of 3cm two months after hatching and 6cm within three months. After this the growth rate increases rapidly and, if conditions are favorable, the young will grow to a length of 30cm and weight of 250g one year after hatching, 40cm and 700g by the second year and 50cm and about 1.4 kg by the third year. At their largest, bastard halibut will reach a body length of 70 ~ 80cm and a weight of 4 ~ 5kg. In many fish species there is a tendency for the growth rate to slacken after sexual maturity is reached, but it is a characteristic of bastard halibut that growth continues without regard to sexual maturity. While the body growth rate is somewhat inferior to that of yellowtail, it far exceeds that of red sea bream for example. **(FIG. 2)**

Bastard halibut is a bottom-dwelling fish that belongs to the order Pleuronectiforms, a group commonly referred to as flatfish. **(FIG. 3)** Among the flatfish inhabiting Japanese waters, the largest resources consist of two families of the suborder Pleuronectoidei; Paralichtyidae (bastard halibuts) and Pleuronectidal (righteye flounders). These two species groups also have higher value as marine products. While both groups are distributed throughout the coastal waters of Japan, bastard halibuts are generally distributed more in the south, with both the number of varieties and size of catches increasing the farther south one goes. On the other hand, righteye flounders are northern type species found most abundantly in Hokkaido, the northern island of Japan, with its number decreasing in southern waters. **(FIG. 4 and FIG. 5)**

When bastard halibut reach a body length of about 11mm, about 25 ~ 30 days after hatching, the left-right symmetry of their body structure begins to distort and they enter a period of metamorphosis. This metamorphosis is completed by about the 50th day after hatching. The swimming fry inhabit surface and middle layer waters at a depth of greater than 20 meters. Upon entering the bottom-dwelling stage at about 12mm of body size, however, they move to sandy bottom areas at a depth of less than 20m, most commonly inhabiting river mouth areas or areas with eddies. For purposes of spawning or feeding, adult fish will make migrations between waters of different depths and between north and south. Prior to spawning they approach shore and live in shallow waters at a depth of 20 ~ 30m. After spawning they will migrate in a northerly direction in search of food. When water temperatures begin to drop in the fall they will move to depths below 50 meters and begin to migrate south, where they eventually spend the winter at depths of 90m or more. Throughout their life cycle, they consistently inhabit sea areas with sand and mud bottom composition.

Bastard halibut is a typical carnivorous fish. During the larval stage they feed on planktons, but after reaching a body length of about 3cm they gradually shift to a piscivorous nature. Among bastard halibuts and righteye flounders are varieties that feed mainly on bottom-dwelling marine animals, but bastard halibut, with its well-developed teeth and strong swimming capability, feeds abundantly on the young of small and middle sized fishes that inhabit its habitat, as well as bottom-dwelling crustaceans. In its natural state, bastard halibut feeds primarily on anchovy and sand lance. In addition to these, it also feeds on the young of horse mackerel and chub mackerel, together with Japanese whiting, scorpionfish and righteye flounders. Its feeding habits are greatly affected by water temperature. At water temperatures below 10°C bastard halibut ceases to feed altogether. Within the range of 10 ~ 20°C it can be said that the higher the temperature the greater their feeding activity. When the temperature reaches 25°C their appetite begins to weaken, and at temperatures over 27°C they again cease to feed.

(Note) The abovementioned statistics derive from a thesis by Prof. Akira Ochiai.

For operators of bastard halibut aquaculture, the following three characteristics of the fish are extremely beneficial:

1) It is a high priced fish.

2) It is an active feeder with a fast growth rate.

3) Being sedentary by nature, it is easy to handle.

However, there are several problems connected with bastard halibut aquaculture that until recently have caused production to remain at a comparatively low level. These detrimental factors are all based in the ecological characteristics of the fish, and they include:

1) Diseases at the fry stage: A bacterial nebula of the intestines occurs around the time of metamorphosis, sometimes causing all the seed fish to die in a few days.

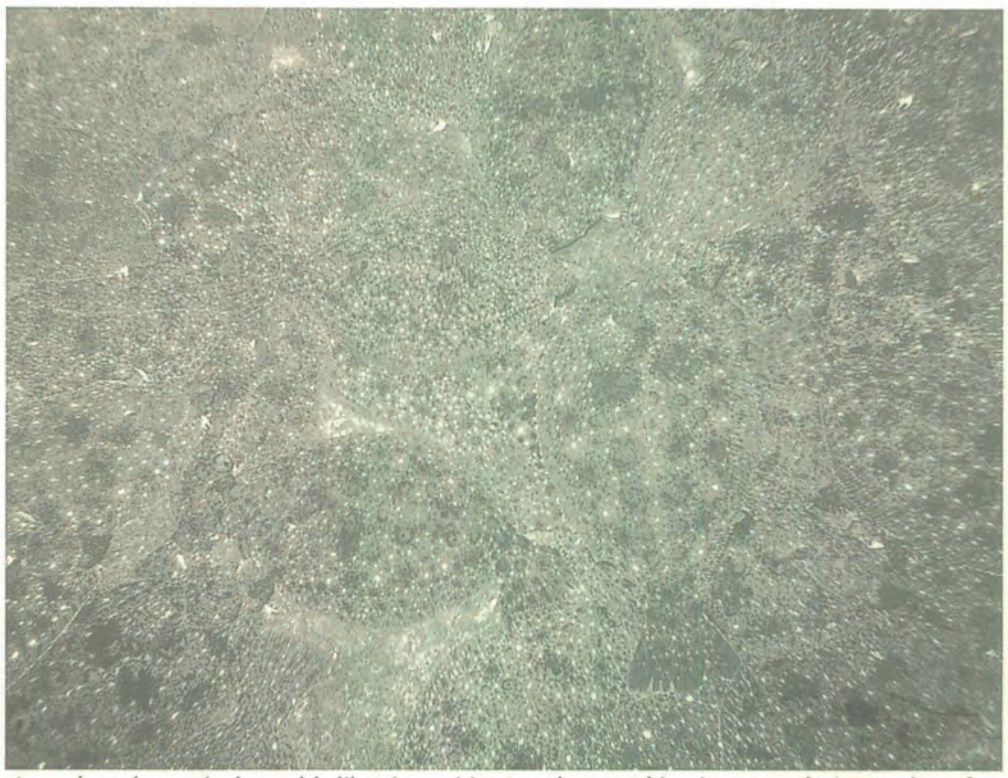
2) Cannibalism following metamorphosis: After the metamorphosis period, feeding habits change and the young show a preference to feed on small animals. At this stage cannibalism occurs with increasing intensity, resulting in a dramatic drop in the survival rate of the seed fish.

3) The difficulty of building culture facilities suited to the behaviour of the fish: With conventional net cage culture facilities commonly used in fish aquaculture, net vibration resulting from wind and wave motion causes flounder lying on the bottom to react by swimming up. This results in increased energy expenditure and reduced feeding efficiency. Also, net abrasion can cause external injury to the flounder that increases the mortality rate.

4) Appearance of whitened individuals: Among artificially produced bastard halibut seeds there is a high occurrance rate of whitened individuals that do not form a colored membrane on the surface of their eyed side.

5) With cultured bastard halibut, dark patches often form on the surface membrane of the eyeless side.

Of the abovementioned problems, **1)**, **2)** and **3)** hinder the economics of aquaculture production, while **4)** and **5)**, although not affecting the quality of the fish meat, are factors which decrease the commercial value of the product, thus threatening the economic feasibility of culture operations. However, the experimental efforts of researchers and the adaptations worked out by operators in recent years have served to alleviate these problems and stimulate a growth in production.



As a photochromatic, bastard halibut is sensitive to color, matching its own coloring to that of the bottom it inhabits. The photo shows the case of fish in the shaded part of a concrete tank.

FIG. 2: Comparison of growth for natural bastard halibut and righteye flounders

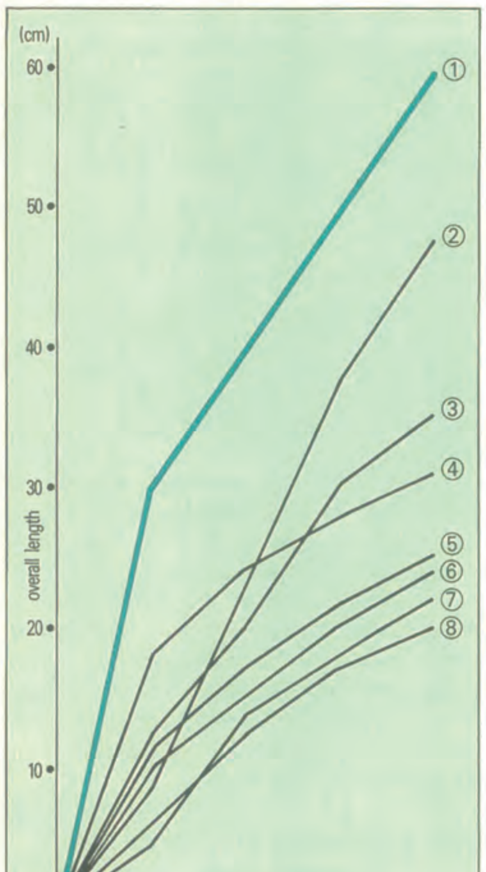


FIG. 4: Catch of natural bastard halibut (1989)

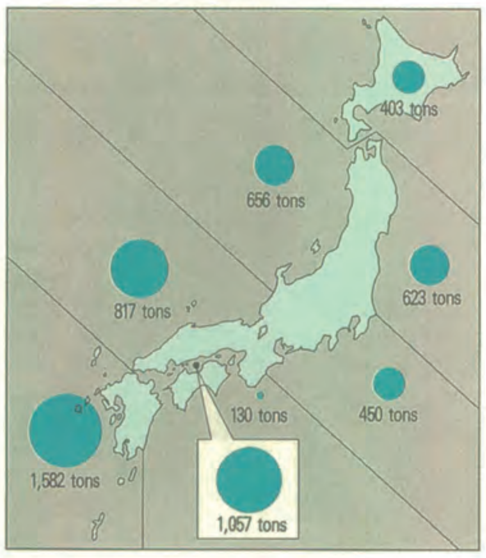


FIG. 5: Catch of natural righteye flounders (1989)

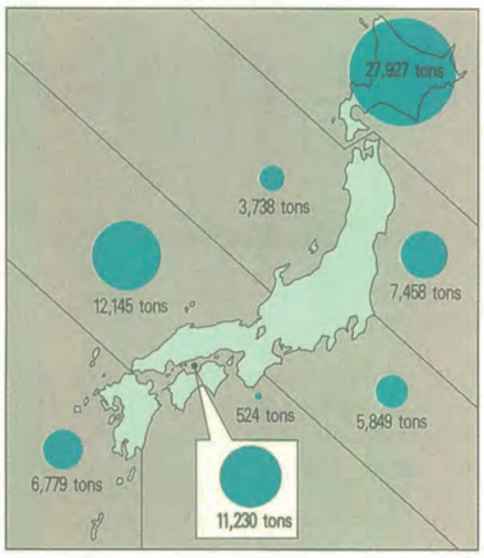
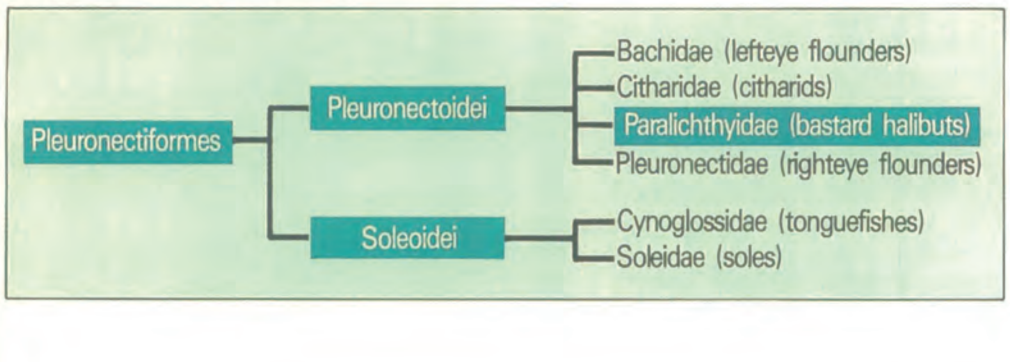


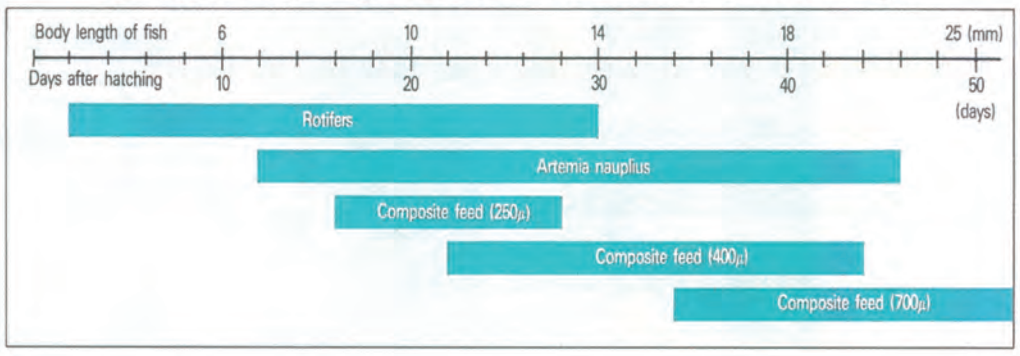
FIG. 3: Taxonomy of bastard halibuts



The key lies in the fishermen's maintenance of the fishing grounds

The first attempt at artificial breeding of bastard halibut were made at the end of the 19th century, but at that time there was little success in raising the young after hatching. In 1965, Prof. Teruo Harada of the Marine Research Laboratory of Kinki University undertook the insemination and hatching of eggs obtained from natural fish and succeeded in rearing the offspring for over one year. Then, in 1969, the same professor succeeded in rearing the young obtained by artificial hatching into parent fish from which he was able to gather eggs, thus making a complete life-cycle aquaculture possible for the first time.

FIG. 6: Example of a feeding schedule from the Miyako Office (Iwate Pref.) of the Japan Seafarming Association (after Mr. Tatsuhiro Fukunaga)



Seed production

In the case of bastard halibut, it was in the 1980s that systems for mass production of seeds became established. These systems resulted from the perfection of technology for rearing hatched young produced by means of artificial insemination to an intermediate fry stage (body length 3～5cm) in large-sized (150-ton) or small sized (50-ton) water tanks on land. In one example, hatched young are placed in a 50-ton tank at a density of 20,000 fish per cubic meter of water, then thinned to a density of 10,000/m^3 upon reaching a body length of 8mm and again to a density of 5,000/m^3 upon reaching a length of 13mm. Each production batch thus requires four tanks, and two or three productions can be made a year, meaning a total annual output of two to three million seed fish.

Until 1985, a variety of feeds were used for the fry and young, including Rotifers, Artemia nauplius, fish eggs, frozen mysids, minced fish meat, etc. Since 1987, however, the diet has been simplified to include just three elements; Rotifers, Artemia nauplius and composite feed. (**FIG. 6**)

The most important things to watch for in the seed production process for bastard halibut are the outbreak of diseases caused by bacteria or parasitic insects and the occurrence of individuals with abnormal coloring. The former tend to be infectious diseases that result in extremely high mortality rates. Research to identify the bacteria responsible for each disease is in progress, and it has become clear that some of the infectious diseases are transmitted by organic feeds. The basic disease prevention measures include maintaining sanitation during the seed production process and obtaining disease-free parent fish. Meanwhile, concerning the occurrence of abnormal coloring in flounders, whitening of the eyed side is a well-known phenomenon. The phenomenon is the result of a non-contagious disease and is a partial body discoloration that is different from albinism. The appearance of coloration in bastard halibut is closely related to the metamorphic process by which the fish acquires its left-right asymmetrical characteristics. And it is now believed that the whitening occurs as a result of nutritional deficiencies during the fry stage.

Recently, positive results are being achieved in the prevention of whitening by feeding the young a nutritionally fortified, fine-grained composite feed beginning about 10 days after hatching.

EXAMPLE 1

Fukushima Prefectural Fisheries Experimental Station

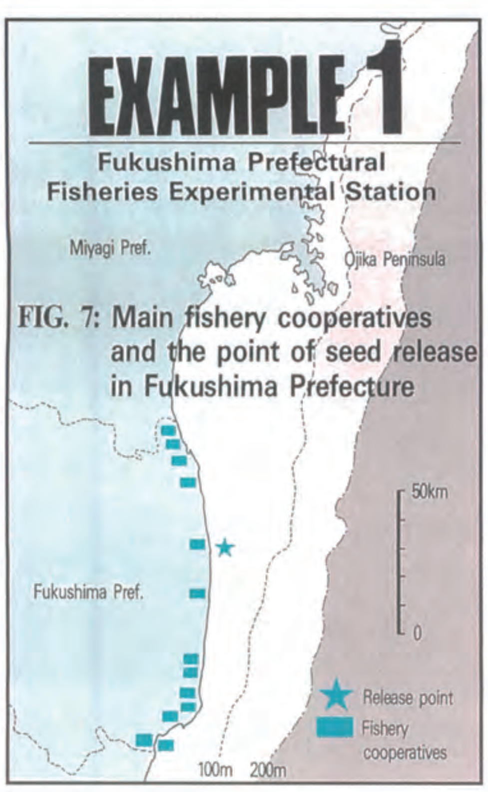


FIG. 7: Main fishery cooperatives and the point of seed release in Fukushima Prefecture

Achieving results with large-scale release of seed fish

Fukushima Prefecture is located along Japan's Pacific coast at a latitude of 36° 50'～37° 50'N. Its roughly 100km of relatively straight coastline stretches north-south with a coastal bottom composition mainly of sand and silt (**FIG. 7**). The offshore area is a complex one in terms of its oceanographic makeup, due to the fact that it is the meeting point of the southward-moving Oyashio cold current and the northward-moving Kuroshio warm current. As a result, the area is interspersed with cold spots and warm spots and current rifts that made it an abundant breeding ground for planktons and, thus, a good fishing ground. These offshore waters have long been developed as fishing grounds for saury, skipjack and tuna fisheries.

In the coastal fishing grounds, the main objects of fishery are chub mackerel, sand lance and saury among the pelagic fishes, and bastard halibut, righteye flounder, octopus and crab among the bottom dwellers. The principal fishing boats used in coastal fisheries here are 19-ton class offshore trawl boats, 8-ton class small trawl boats and 5-ton class small gill net boats.

Bastard halibut, one of the main coastal fishery resources of this region, has shown a decreasing trend since the 1970s. The year 1984 saw an exceptionally large survival rate, and large catches continued for the following 2～3 years, after which catches returned to the previous low levels. In the case of bastard halibut, 60～80% of the catch comes from bottom trawl fisheries and 20～40% from gill net fisheries. In years when resources are large there is an increase in the catch by trawl fisheries. It is probably correct to assume that the decline in resources in recent years is due to the fact that the intensity of trawl fishery is exceeding the reproductive capacity of the resources.

The Fukushima Prefectural Fisheries Experimental Station began the experimental release of bastard halibut fry in 1982. And, these releases have been accompanied by continuing surveys of the migrations, distribution and re-capture by fishing boats of the released fish. Although the released fish show patterns of migration between shallow and deep waters of the coastal and offshore areas as they grow, there seems to be little north-south migration. It has been judged that the majority of fish released in the central part of the prefectural waters are eventually caught as yearling or second-year fish within the boundaries of the prefectural waters. Growth of the released fish has been found to be greatly affected by the body length at the time of release and the season in which they are released. It has been shown that fry that have been raised after hatching at an accelerated rate by using warm exhaust water from a thermal electric power station and released in July or August at a body length of 7～10cm, will grow at a faster rate than natural flounder, reaching a length of 20～30cm within the first year. Between the years 1982 and 1986, the Fisheries Experimental Station continued to release fry at a rate of 5～39 thousand fish a year. When national and prefectural subsidies became available in 1987, however, the Station switched to local seed production and radically increased the size of its experimental releases. In connection with this, they also intensified their surveys of recaptured fish landed at the prefecture's fishing ports. Under this intensified program, a total of 246,000 fish were released in 1987, 336,000 in 1988, 217,000 in 1989 and 392,000 in 1990.

The extent to which these large-scale releases have contributed to local fisheries has gradually become apparent. The number of released fish recaptured by bottom trawl and gill net fisheries in 1987 was estimated at 40,000 (16% of the released stock), while in 1988 the number was roughly 97,000 (29% of the released stock).

The economic return on the releases can be calculated as in **TABLE 1**.

According to this calculation, a production yield of ¥220～248 is gained for each fish released, and when the cost of producing the seeds is subtracted, it creates an added value of ¥150～200 per fish. Fishery catches include a mixture of natural and released fish, and the ratio of released fish in the total catch is shown in the **TABLE 2**.

TABLE 1: Estimated economic return on fish released

Year released	Number released	Number recapture	Recapture ratio	Sale price	Expected return per fish released	Sale price per recaptured fish
1987	246 thousands	40 thousands	16.3%	61 million yen	248 yen	1,525 yen
1988	336 thousands	97 thousands	28.9%	74 million yen	220 yen	763 yen

TABLE 2: Catch composition with regard to released bastard halibut

Year class		1987	1988	1989
Gill net fishery, by area	A	17.9%	23.3%	23.5%
	B	14.7	12.5	21.4
	C	15.2	19.8	79.3
	D	58.5	65.0	77.8
Traul fishery, by area	E	18.8	34.2	34.5
	F	34.4	29.0	45.7
	G	18.0	9.6	19.6
	H	19.0	9.5	4.5

Having judged that it is reasonable to assume that effective propagation of resources can be achieved by releasing seed fish in the prefecture's coastal waters, and seeing an increasing recognition of the value of seed release among the local fishermen, the prefectural government decided to call an end to the experimental stage and begin promoting the transfer to full-scale project operations. In 1991, studies were begun concerning the best methods for implementation of operations. When operations are begun, the fishermen will bear a certain percentage of the seed production costs and the local fishery cooperatives will be responsible for the work of releasing the seeds.

Although there are hopes that fish farming of bastard halibut will help restore the coastal resources, there are still a number of serious problems lying ahead. They involve the following:

When looking at the catch statistics concerning recaptured fish, we see a big difference in age and size structure between 1987 and 1988. In 1987 we see that the greater percentage of recaptured fish were second-year fish with a body length of around 30cm, while in 1988 the majority were first-year fish with body length of around 20cm. This represents a very poor fishery condition from an economic standpoint. It can be said that this situation resulted from the fact that the depth to which the released fish migrated to spend the fall and winter season corresponded with the operating depth of offshore trawl fisheries, and that the fishermen deliberately concentrated their operations in areas with the greatest concentration of young fish.

In the future, the following types of measures will be necessary to ensure the effectiveness of fish farming operations:

1) Establishment of protected areas around the points of release.
2) Restraint from conducting fishing operations in areas inhabited by first-year fish.
3) Prohibiting the sale of small-sized flounder on the market.
4) Regulations concerning the mesh size of fishing nets

Only when these essential measures are met will it be possible to achieve a balance between the maximum yield from the resources and economically sound fishery production.

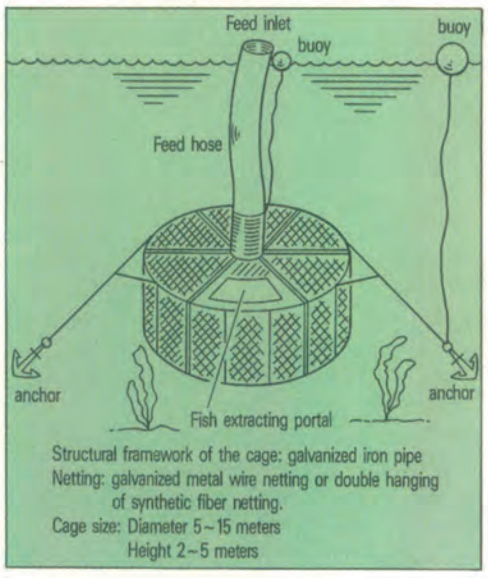
Creating a culture environment as close as possible to nature itself

After their metamorphosis, bastard halibut enter a benthonic life mode. For this reason, culture facilities different from those used for yellowtail or red sea bream had to be developed. At first, between the years 1978 and 1980, bastard halibut culture using the existing net cage type of facility began to spread. However, the nets were found to cause abrasion injuries that increased the incidence of disease, resulting in a high mortality rate especially in the hot summer months. This caused most culture operators to either switch to another type of fish aquaculture or to quit their culture business altogether.

After this, a new method appeared in which large-scale on-shore water tanks were built and fed with sea water for culture purposes. Also, a number of on-land culture facilities raising kuruma prawns in Kagoshima Prefecture began to switch to the culture of bastard halibut. It was with the emergence of this on-land water tank method that aquaculture of bastard halibut became a full-fledged industry, and today this method is still the dominant one.

However, in recent years a number of new materials have been developed for spreading on the bottom of conventional net cage facilities. This has led to successful use of surface water net cages in the aquaculture of bastard halibut in the Seto Inland Sea, with its year-round calm sea conditions and long period of suitable water temperature.

FIG. 8: Sea bottom type sunken culture cage for bastard halibut



And use of this method seems to be spreading. Also, in some areas a method by which net cages are lowered to the sea bottom and held in place by means of anchors is being tried. **(FIG. 8)**

Thus, culture facilities for bastard halibut can be roughly divided into two types, the on-land tank method and the sea-surface net cage method, each having its distinct advantages and disadvantages. **(TABLE 3)**

Since bastard halibut is one of the highest priced fishes of all, operators were still able to recover their investment on high-cost on-land facilities and power supply by taking

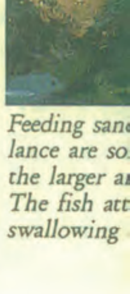
TABLE 3: A comparison of on-land tank and sea-surface net cage methods

	On-land tank	Sea-surface net cage
Advantages	•The bottom is stable and the fish can live undisturbed •Ease of observation makes it possible to spot disease outbreak early, easy to monitor •Environmental factors such as water temperature and salinity can be controlled •Feeding and shipping work are more easily performed on land than on the sea •By spreading sand on the bottom of the tank, a perfectly suited life environment can be achieved to raise better quality fish	•Culture facilities can be built at far less cost than on-land tanks •No power costs are incurred •Operations can be performed by family labor •It can be conducted as a side business with agriculture or boat fishery.
Disadvantages	•It is not easy to obtain sites that can supply good quality sea water •A large investment is necessary to build facilities, large investment risk •Large energy cost is involved in pumping up sea water to the facility •Electric supply cutoff or pump breakdown can cause production losses	•The facilities are on the water, making daily operations more difficult •Fish growth is somewhat slower than in on-land tanks •There is a danger of losing fish due to net damage


Cultured bastard halibut 3 full years after hatching. On this 1.5kg cultured fish black spots have been formed on the eyeless side (right). It is believed that this coloring abnormality is caused more by the culture environment than by nutritional factors. In some on-land tank culture operations sand is spread on the bottom of the tank to give the fish a natural life environment. This enables the culture stock to grow to adult fish with the same coloring as natural fish.

To prevent cannibalism the fry are placed in separate cages according to size, after which sorting is repeated once every 2 or 3 months, as growth requires, to keep the size of the fry in the different cages uniform. The guideline for culture intensity is 10kg/m². Even in waters with good tidal exchange, the rate is kept below 20kg/m². The nets are changed 3~4 times before the stock reaches a size of 400~600g, each time replacing them with nets of larger mesh to improve flow-through. When changing the nets and bottom material is also cleaned.

Except at feeding time, the cages are kept covered with tarps.
*The aims of this practice are to **1)** darken the cage to keep the fish relaxed, **2)** to cut out sunligh formation of black spots and therefore blackening of the fish skin, **3)** to prevent the flounder fr escaping, and **4)** to restrain the growth of seaweeds.*



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advantage of large scale operating merits. In the future, however, if growing nationwide production leads to a drop in the market price of bastard halibut, the lower-cost net cage method should prove more advantageous. In such a case, it is concievable that the present on-land tank operations may switch to the culture of an even higher priced fish like puffer.

Feeding

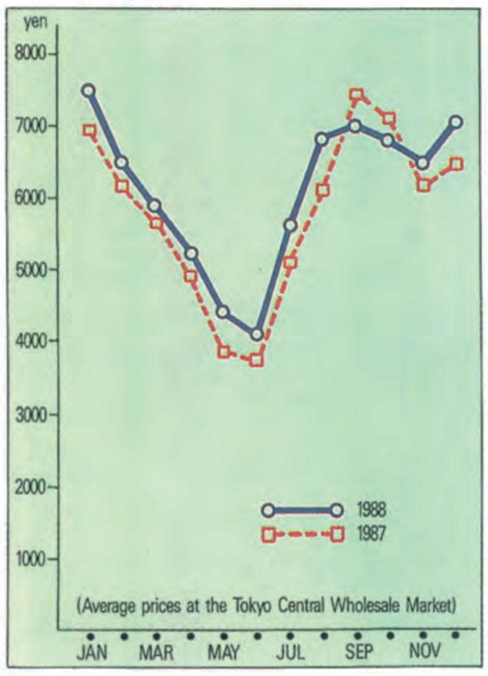
In bastard halibut culture today, there is still use of both fresh fish feeds and composite feeds. After the fry stage, there are three types of feeding methods that are used by different operators or at different stages in the fish's growth; **1)** small fish like sand lance and anchovy can be fed to the fish whole, **2)** they can be fed dry pellet form composite feed or, **3)** the meat of fish like sardine or mackerel can be minced and mixed with composite feed material, nutritional additives and fermented foodstuff, and fed to them in the form of moist pellets.

Generally speaking, however, because of the rising price of fresh fish for feed purposes and such social factors as concern about water pollution, the trend is moving away from fresh fish feeds in favor of composite feeds. Bastard halibut is a fish whose meat consists of less fat and a higher percentage of protein than the feed fish like sand lance and anchovy. Thus it requires a greater amount of protein. From feed experimentation it has been determined that the preferred ratio of protein is about 56% (in dry weight).

The culture schedule

In April when the water temperature rises above 14°C, the bastard halibut culture operators purchase fry that have been raised through an intermediate stage to a body length of 5～6cm from the seed producers and release them in their culture facilities. Because this is a feeding type of aquaculture, the fish grow at a faster rate than natural fish, reaching the minimum marketable size of 400～500g in November of the same year after six months of culture. If raising is continued, the fish will reach a size of 1kg by September or October of the following year, after about 18 months of culture.

FIG. 9: Market prices for bastard halibut



The market price of bastard halibut varies with the season, and there is also a different price scale depending on the body size. The prices are high in the season from summer into autumn and in the winter, with the peak prices coming in the year-end and new year season from December into January. The price then begins to drop in the early spring, reaching the lowest levels in May and June, when the largest shipments of natural fish are reaching the market. **(FIG. 9)**

In terms of size, the highest price is placed on "one kilo class" fish between 900g and 1.2～1.3kg. By way of example, the prices in one producing area market in Ehime Prefecture during May of 1991 were ¥2,100/kg for 400g class fish, ¥2,500/kg for 600g class and ¥3,300/ kg for 1kg class.

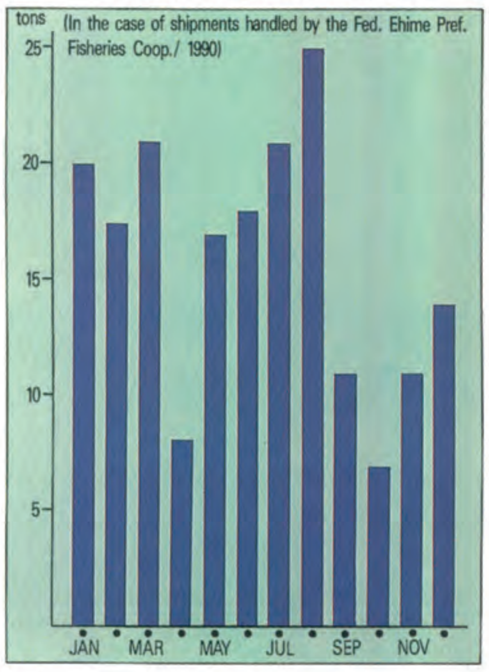
Cultured bastard halibut are shipped almost year-round from the producing areas to the consuming areas. And, based on the seasonal fluctuations of market prices and the growth schedule of the fish they are raising, there are two basic policies by which the producers plan their production/sales schedules.

1) A policy by which 400～600g fish are shipped at the year end/new year season
2) A policy of raising the fish to a size of about 1kg and then choosing a time of high market price for making their shipments.

The histogram of **FIG. 10** shows the volume of bastard halibut shipments sold at the Federation of Ehime Prefectural Fisheries Cooperatives by month. Here we see two peak periods; one from Jan. to Mar. and the other from June to Aug.

The former consists of fish shipped at a size of 400～600g, while the latter represents "one kilo class" fish that have been raised by the culture operators for a year and several months. Most shipments are concluded within the month of August. This is because in the months of August and September when the water temperature is at its highest, feeding efficiency decreases and culture operations become economically disadvantageous, and because September is the month when typhoons present the threat of net damage. In the case of on-land tank culture, most operators adopt a policy of shipping 400～600g fish within their first year because of the fact that an extended culture period means increased power cost.

FIG. 10: Seasonal changes in the amount of shipment of cultured bastard halibut



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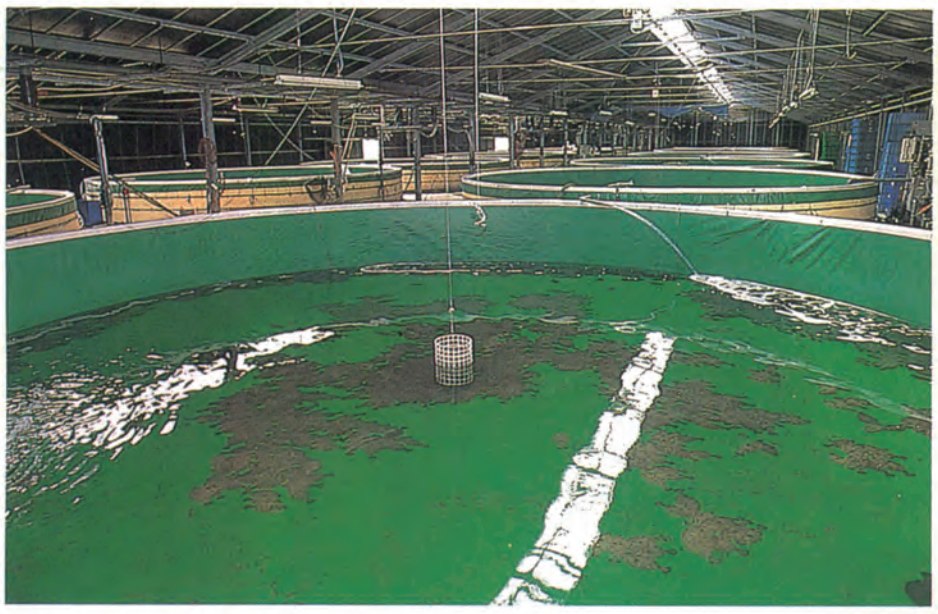
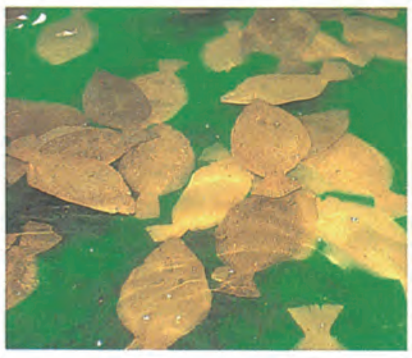
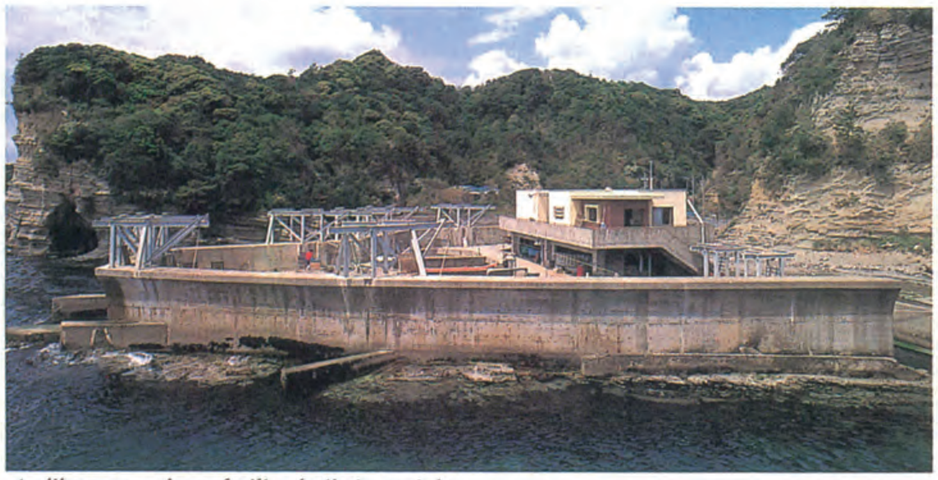




This is a bastard halibut culture facility in Asahi City, Chiba Prefecture, located about 10km inland from the coast. Seawater is supplied to the facility every day by means of a 30-ton tank lorry, and the water is circulated through a filtration system while in use. Because it is a closed life environment the water temperature is maintained in a range from 20～25°C. The facility is made up of 30 tanks, each 8m in diameter, and the production schedule is aimed at 60,000 adult fish per year. This highly unique culture operation is a joint venture between a pig raiser and a manufacturer of water purification equipment.

In the circulation/filtration system the water is purified by a combination of physical, chemical and biological means.



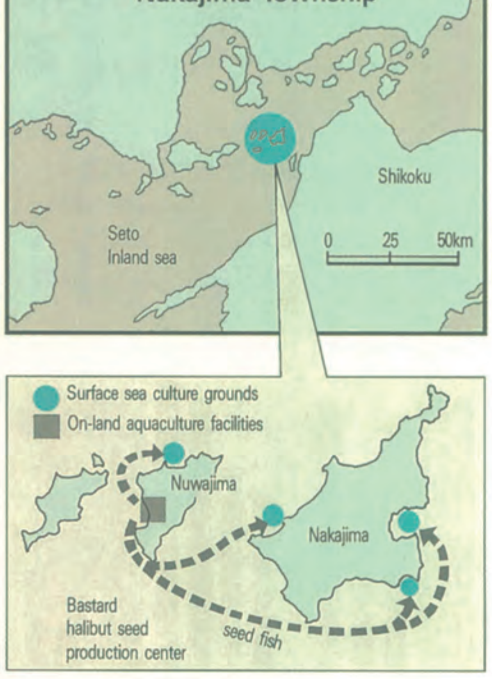
A dike type culture facility built in an inlet.

A square type tank (6m×6m). A drain is located in the center.

EXAMPLE 2

Cage net aquaculture in surface sea waters: Nakajima, Ehime Pref.

FIG 11: The geographic layout of Nakajima Township



Changeover from orange growing to bastard halibut culture

FIG 12: Progression of population demographics by age and sex

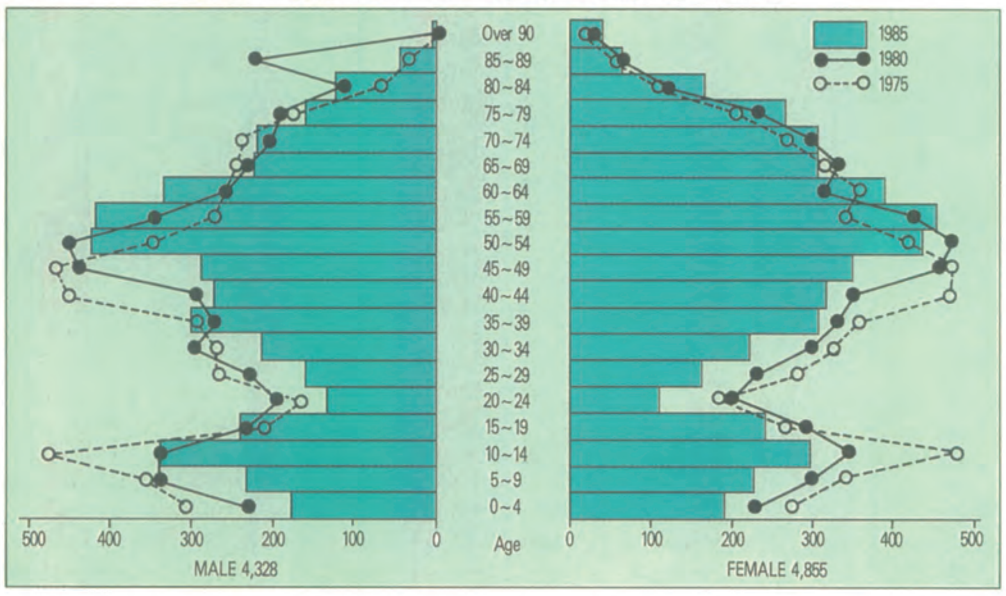
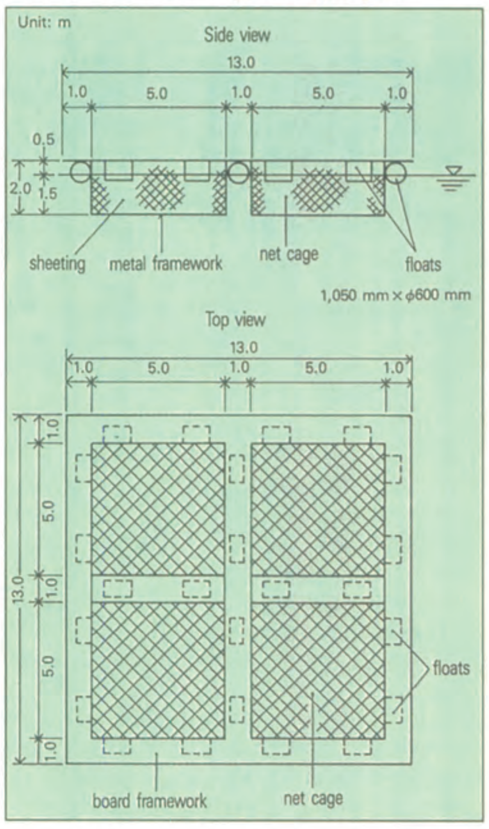


FIG 13: Culture cages employed



Nakajima is a township made up of six inhabited and 22 uninhabited islands in the Seto Inland Sea, located a distance of about 15 km from the prefecture's principal city, Matsuyama. The islands are covered with steep-sloped hills that rise to an elevation of 100～200m, and the population of roughly 9,000 is concentrated in the few areas of flat land to be found on the islands. Of a total area of 3,838 ha., some 1,735 ha. (45%) of the land has been developed for agriculture, mostly in the form of terraced land on the steep hill slopes. Having soil with poor water retention characteristics, about 98% of the available agricultural land is devoted to mandarin orange growing. In addition to orange growing, the residents of these islands have traditionally engage in gill net, angling and diving fisheries, thus making their livelihood from a half-agriculture, half-fishery economy.

In the 1960s, Nakajima prospered as one of the major orange-producing areas in the prefecture. After that, however, the high growth rate of the national economy brought about changes that sent the orange-based economy of Nakajima into decline. Young jr. high and high school graduates began to leave the islands to seek employment in the cities, causing population decline especially in agriculturally deprived areas. Then, nationwide overproduction of mandarin oranges caused market prices to drop drastically in 1968 and again in 1972. Furthermore, the other half of the local economy, fishery, was hurt by a decline in resources of red sea bream and abalone in recent years and a lack of commensurate growth in the market price of such high-class fishery products. This situation has been worsened by an overall aging of the fishery labor force as young people began to leave fishery for other jobs in the late '70s. Negative factors like these eventually resulted in a general weakening of the industry, with both the volume of catch and total fishery sales continuing to decline after reaching their peak in 1983. Then, the final blow came to the weakened regional economy of Nakajima when the government agreed to open its orange market to imports in 1989. With this, local leaders and the population in general began to have serious doubts about their economic future. (FIG. 12)

Meanwhile, during the years 1985 and '86, the Ehime prefectural government conducted a survey aimed at regional development for the one city and four townships along the prefecture's Seto Inland Sea coast. The conclusion of this survey was that this area possessed high developmental potential in the fields of both fishery and tourism. Based on this conclusion the "Iyonada Central Marinovation Plan" was adopted in 1989 to utilize the region's fishery industry and the unique environmental qualities of the individual townships in an integrated development project. As one of the townships within the auspices of this project, Nakajima set about the work of revitalizing their local economy under the slogan "Cultivating the Sea".

This "Marinovation Plan" sought to deal with the challenges presented by such contemporary trends as the increasing internationalization of agriculture and fishery,

PHOTO COURTESY OF NAKAJIMA TOWNSHIP

Sorting mandarin oranges

PHOTO COURTESY OF NAKAJIMA TOWNSHIP

The cage nets are set up in quiet bay areas. On the mountains behind are terraced mandarin orange orchards.

Transportation between islands and from the islands to the city of Matsuyama consists of three car ferries and two high-speed passenger boats.

In this area cage frames are constructed of cedar legs with cedar boards tied thereto as strength members und footboards as well.

social changes resulting from advancements in technology and communications, the aging of the work force and the diversification of life styles. Towards these ends the project set the following four goals as the main items of its agenda:

1) Development of marine resources and the promotion of fisheries

2) Renovation of local fishery centers and strengthening of distribution and processing capacities.

3) Rationalization of fishing household economies and raising the next generation of successors to the fishery business.

4) Preparing the basic facilities for marine recreation and improving transportation links to the urban areas.

Bastard halibut in a marketable size of 1kg.

To undertake substantial development of this type requires a revolutionizing force strong enough to break out of conventional habits and life styles. In a word, it requires both a pioneering spirit and entrepreneurship. Bastard halibut aquaculture in Nakajima got its start through the efforts of ten enterprising volunteers on one of Nakajima's islands, Nuwajima, in 1988. These ten people, who until then had made their living by orange growing and assorted fisheries, decided to undertake bastard halibut aquaculture after making a visit to Kamiura Township, the prefecture's pioneering region for sea-surface bastard halibut culture, and seeing the culture methods that were prospering there. They began by purchasing 15,000 fry as seed fish for their first experimental culture stock. Within half a year the bastard halibut had been raised successfully to a size of 500g with a 65% survival rate. These represented the same standards being achieved by culture operations in Kamiura.

The success of this initial culture venture convinced local authorities that bastard halibut culture could play a significant role in promoting local fishery development, and it was decided that the township's government offices would open a new section to serve as an administrative outlet through which support would be offered to local fishermen seeking to invest in materials for culture operations or to sell their bastard halibut production. By the following year, new operators began to engage in bastard halibut culture one after another in Nuwajima and other islands. Nakajima has four independent fishery cooperatives, one for each of the main islands. But, in order to facilitate smooth development of the culture operations in the area, an inter-cooperative council was set up to deal exclusively with this new fishery, and it now functions as a venue for the exchange of information and opinions between members of the different cooperatives.

In the meantime, a different movement emerged among the younger generation of the township's orange growers. Four young orange orchard operators in their twenties and thirties got the idea to begin bastard halibut seed production as a business to supplement their agricultural income.

They began by interning themselves at the Ehime Prefectural Fisheries Experimental Station to receive training in the techniques of fry raising. Next they made a joint capital investment to set up a company.

Three 10-ton size fry-raising tanks and four 10-ton tanks for raising feed planktons were built, and in March of 1989 raising operations were begun.

By May of the same year they were able to supply 120,000 fry to culture operators in the township. Presently, the company is aiming toward an annual production of 300,000 culture seeds, and if this goal is realized it is expected that the township will become self-sufficient in the entire culture process from seed production to the raising of mature fish.

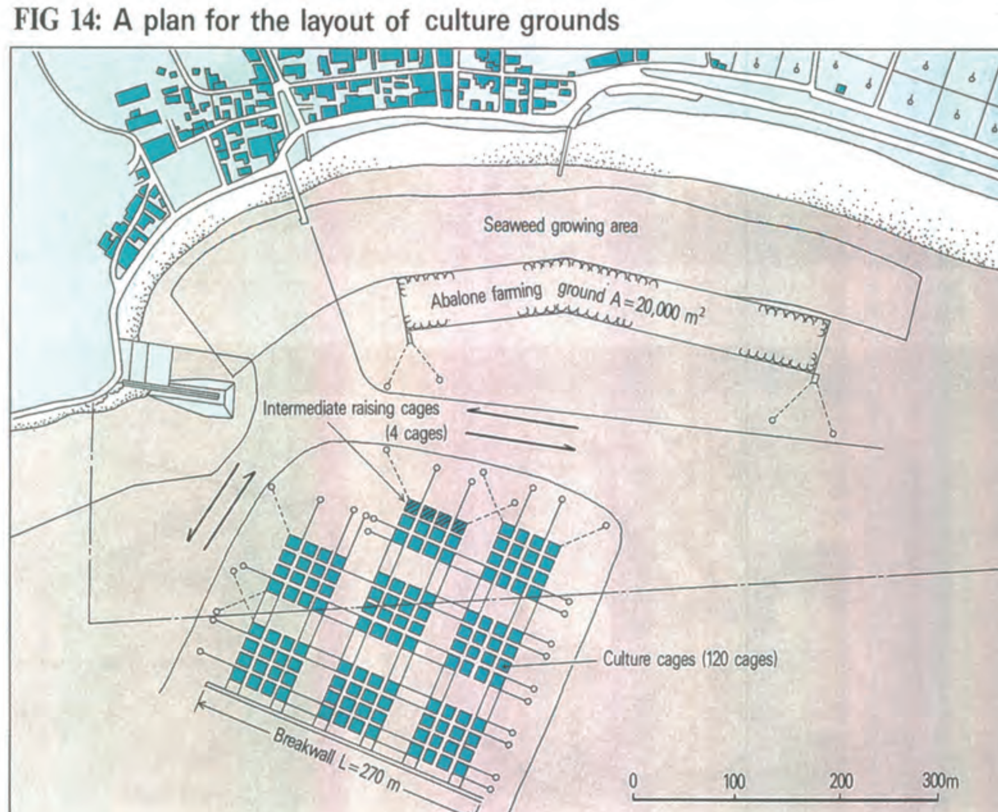
In Nakajima the bastard halibut aquaculture industry is growing yearly and, as of 1991, thirty of the roughly 600 local fishermen are involved. In all they operate 215 surface cage nets, in which some 320,000 fish are presently under culture.

Being an area where inland sea waters mix with outer sea waters, both the current conditions and water quality of the waters around Nakajima's islands are well suited for aquaculture. However, the water temperature here, which ranges from a low of 10°C in winter to a high of 25°C in summer, makes these waters too cold for winter culture of either yellowtail (suitable range: 15 ~ 20°C) or red sea bream (suitable range: 20 ~ 28°C). As a result neither of these fish has been cultured in the area.

Concerning the reasons why bastard halibut culture has taken hold so well in Nakajima, one of the leaders of the culture operators and director of the inter-cooperative council, Mr Masatoshi Tanaka, suggests that, in addition to the fact that the area has optimum water conditions for bastard halibut culture, the operator's long years of experience as orange growers involved with such jobs as seed selection, fertilization, elimination of weeds and disease-carrying pests, has given them the basic sensitivity and know-how necessary to successfully manage living things and their life environment. He believes this expertise has helped them in acquiring the essential techniques of fish aquaculture: choosing seeds, feeding, cage cleaning and disease prevention. He goes on to stress that the ultimate goal in promoting bastard halibut culture is to get the young people who will eventually be the successors to the industry involved so that they will stay on the islands. And in order to do this, he believes there is a need to increase the number of operators and build it into a substantial industry that contributes to the local economy with an annual production in the range of one million fish (500 ~ 700 tons of adult fish).

As the goals of its "Cultivating the Sea" program, the government of Nakajima Township decided to **1)** invest government funds in the abovementioned seed production company for the construction of a fishery cultivation center that will eventually be integrated into the fishery cooperative organization, and **2)** to create areas strictly for concentrated aquaculture by building breakwalls around the main island of Nakajima and to build artificial reefs for abalone and top shell farming. These projects are scheduled to be completed by the year 1995. **(FIG. 14)**

FIG 14: A plan for the layout of culture grounds



Quality in white-meat fish

The Japanese have a preference for eating fresh fish raw in the form of "sushi" or "sashimi". With regard to sea food, it seems the Japanese tastes and culinary art have evolved basically around the enjoyment of raw fish. Thus, the Japanese are especially sensitive about the freshness of fish meat. In the Japanese sushi and sashimi tradition, white-meat fishes like bastard halibut and red sea bream are appreciated as delicacies because of their low fat content and light flavor, and also because of the special texture they derive from the high myofibril content of the meat. Also, because of the low fat and oxygen content in their meat, they tend to lose their freshness and deteriorate at a slower rate than red-meat fishes. The protein contained in fish meat is different from animal protein in that it contains a much lower percentage of the basic muscle protein from which muscle membrane is made and a higher percentage of myofibril protein from which muscle fiber is made. This means that the meat has a softer consistency that makes it especially well suited for eating in the raw state. On the other hand, the low muscle membrane protein content means that the muscle tissue is much weaker and the fat and protein content less stable than animal meat. This in turn means that changes in meat quality occur more quickly, which makes it more difficult to handle properly.

In the case of fish meat, the way the fish is handled, stored and shipped after being caught results in significant differences in the meat quality of the end product. In order to preserve the unique characteristics of fish meat and achieve the desired meat quality in the end product, the Japanese have devoted much effort to the perfection of shipping methods since olden times. In recent years it has become a popular method in some areas to ship live fish from the producing area to the consuming area or, as shown in the photo, to build stock points for keeping live fish near the urban centers.

At the same time the Japanese have also developed techniques for making processed foods from a variety of fishes. In the case of white-meat fishes, dried whole fish, dried fish flakes and "surimi" (minced fish meat products) are most popular.

1) Dried whole fish ... At times, fish like cod, flatfish and bastard halibut contain a large amount of body fluid that reduces the flavor of the meat. In such cases the fish can be dried naturally in the sun, heat-dried or smoke dried to reduce the moisture content and increase the flavor.

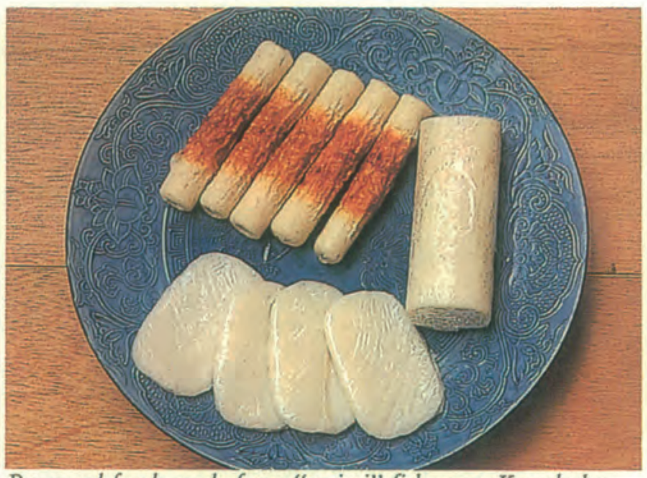
2) Dried fish flakes ... The meat of red sea bream, cod or bastard halibut is boiled and soaked in water to remove the fat, after which the meat is compressed and shredded into flakes and flavored. (Note) Red-meat fish contains a high percentage of sarcoplasm that causes the protein to coagulate when boiled, thus hardening the meat. White-meat fishes on the other hand have a low sarcoplasm content, so the meat can be easily shredded after boiling.

3) Surimi ... After removing the fat content from the meat, it is minced well until it achieves a sticky consistency and then used as the raw material for such processed foods as "kamaboko", "chikuwa" or "hanpen". A wide variety of white-meat fishes, including lizard fish, croaker, Japanese whiting, shark, flatfish, sharp toothed pike conger and Alaska pollack, can be used as raw material for surimi.

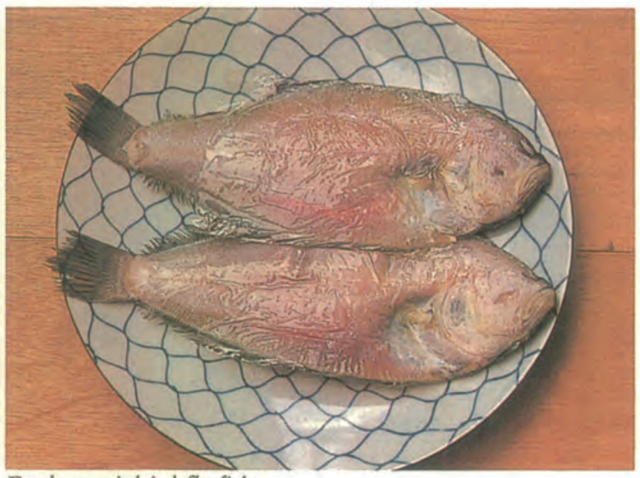
The Hota Fisheries Cooperative, located on the shores of Tokyo Bay near the Tokyo metropolitan area, has built ten circular fish tanks (diameter: 10m) with prefectural grants, and 28 square fish tanks (6m × 6m) strictly with cooperative funding. With these facilities the cooperative cultures 100 tons of bastard halibut annually in addition to culturing or keeping a wide variety of high-priced fishery products such as red sea bream, silver salmon, black sea bream, spiny lobster, sea urchin, abalone, oysters, scallops and top shell, which it then sells to the Tokyo market.

*Taking advantage of its location just 100km from the enormous metropolitan consumer market, the cooperative seeks to **1)** buy young fish from other regions, raise them for about a year and then ship them to market at an appropriate time, and **2)** to build up a "Live Fish Center" that keeps live stocks of a variety of high-priced fishery products that can be supplied to the Tokyo market at any time in response to changing market demand.*

The sashimi section at a supermarket. In this expensive delicacy, slices of fresh white-meat fish like red sea bream and flounder are sold in assortment packs along with tuna slices.



Processed foods made from "surimi" fish meat: Kamaboko, chikuwa and hampen.



Fresh, semi-dried flatfish.

An auction at the Central Wholesale Market. Flounder is often auctioned off in its live state.