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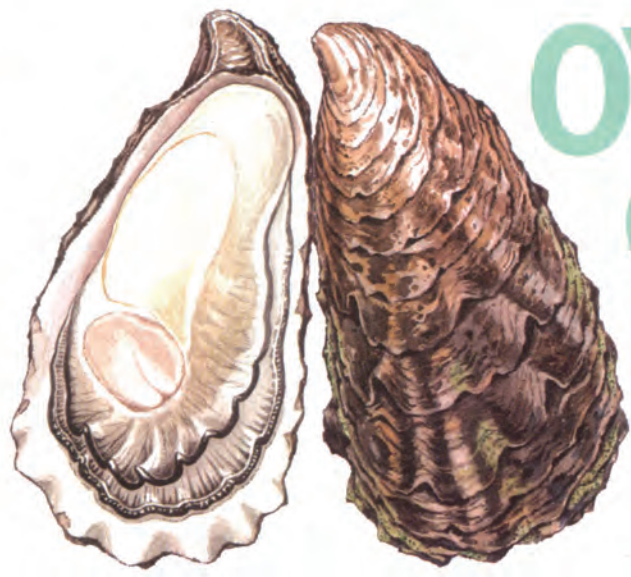


OYSTER CULTURE FISHING

"Magaki" (Pacific cupped oyster)
(Crassostrea gigas)

Making the best possible use of the oyster's propagative power

Among the varieties of shellfish presently inhabiting the earth, the most prolific are the conch (Gastropoda) and bivalve (Pelecypoda) families. Of the conches, there are estimated to be about 85,000 species, while in the Pelecypoda family about 25,000 species are believed to exist. The extremely large number of species is clearly a testament to the exceptional ability of these families to adapt to their environment.

While these two families display an obvious difference in terms of form, they are also in striking contrast to each other in their life patterns. Whereas the conches actively search for food on the ocean floor with eyes and feelers, the bivalves such as clams tend to bury themselves in the sand, or, in the case of oysters, attach themselves to rock outcroppings or reefs.

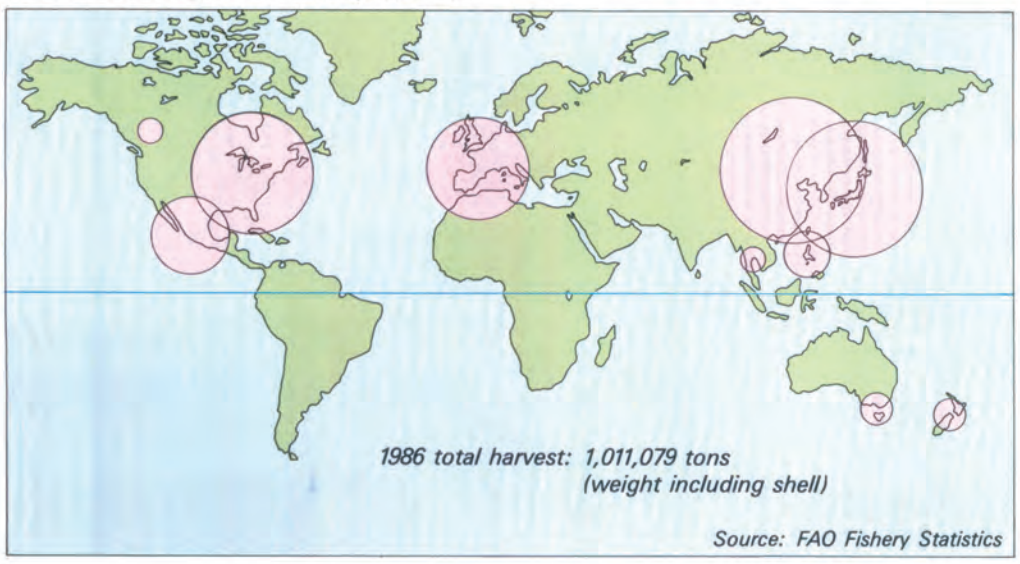
The bivalves appear to be the less active of the two families and their life patterns seem to be more passive in terms of response to their environment. But, when it comes to their appetite and feeding habits, they are no less active than the conches. The soft body of the bivalve is fully enclosed in a shell and a mantle with which the shell is, so to speak, lined. There is also a gill between the mantle and internal organs. Seen on the back edge of the body are a number of water pores through which water is drawn in to pass through the gill and thus constitute the breathing function. At the same time, the gill also functions to separate debris in the water from edible suspended matter such as plankton for the ingestive process. The volume of water thus processed by the gill in the case of "Magaki" (Pacific cupped oyster) is said to be about 10 liters per hour. Research material concerning the "Virginia oyster" (American cupped oyster) indicates a volume of 5 - 25 liters/hour at a water temperature of 20°C. This means that some oysters process more than 1000 times their body weight (without shell) of water every hour. The amount of vegetable planktons consumed by an adult oyster in one day is thought to be between 1 and 5 grams.

The fact that the gill system and the ingestive system are combined in one organ is proof that, among the organisms and life systems that inhabit the oceans of the world, the bivalves are a family that makes very efficient use of their environment. And therefore, if such bivalves are provided with a well suited life environment throughout their life cycle, it can be speculated that they will show an extremely good potential to thrive and reproduce in abundance. Certainly oyster culture fisheries provide excellent proof of the validity of this assumption. History tells us that man has been engaged in oyster culture since ancient times. During the days of the Roman Empire (4th century AD) oyster culture is known to have been conducted in the area of Naples, Italy. At first their method is said to have been a primitive attempt at a random-type proliferation that involved no more than scattering broken pieces of tile on the sea bottom. But eventually it seems to have evolved to a 3-dimensional "hanging type" culture method using a frame structure made of wood. What gave these ancients the idea to begin culture of oysters? It was probably a combination of the fact that it is a species found in abundance in shallow sea areas and the fact that the spats are easily distinguished when they attach themselves to an immobile object. Add to these, the fine taste of the oyster meat itself and it must have been enough to prompt man to attempt the deliberate production of oysters.

Harvesting (Eba, Hiroshima Prefecture: Raft-type hanging culture)
A single raft can produce 2.5 to 3 tons in terms of shucked oysters.

Today, the annual worldwide harvest of oysters is around one million tons (weight including shell), most of which is the product of artificial proliferation and culture fisheries. The principal species include Pacific cupped oyster *(Crassostrea gigas)*, American cupped oyster *(Crassostrea virginica)*, European flat oyster *(Ostrea edulis)*, and Portuguese cupped oyster *(Crassostrea angulata)*, and the main producing nations are Japan, Korea, Mexico, France and the U.S.A. Among these the U.S.A., Japan and Korea are the major producers, each accounting for between 23 and 26% of the total world production. In Europe and the Americas, methods of "bottom spreading" have prevailed, while Japan and Korea have engaged primarily in high intensity hanging culture methods. In Korea, the development of oyster culture fisheries began in earnest in the 1970s with the success of culture techniques adopted from Japan. But, research regarding oysters can truly be said to be an ancient art that is very broad in scope, ranging from biological studies of life cycle to practical studies of culture techniques. Furthermore, it can be said with certainty that the oyster was the first species of marine product to be the object of full-scale research directed at growth improvement.

FIG.1 Worldwide production of oyster culture



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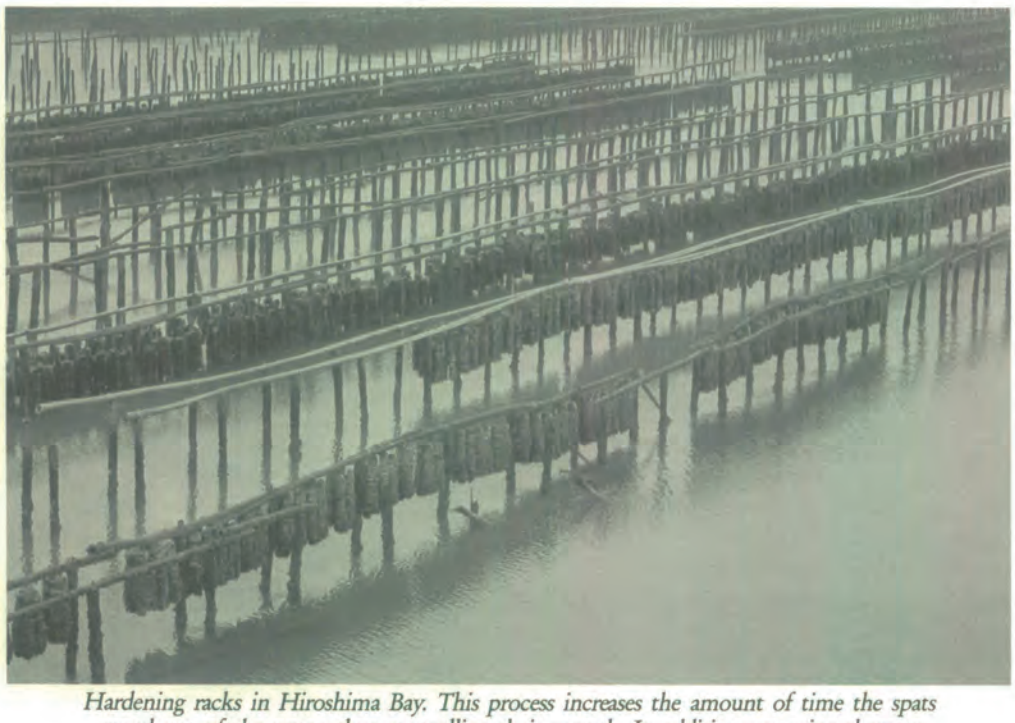
The oyster's life pattern and artificial proliferation



Hardening racks in Hiroshima Bay. This process increases the amount of time the spats spend out of the water, thus controlling their growth. In addition, exposing them to the sun, wind and waves, and also the cold helps them grow stronger shells.

With the exception of the Arctic and Antarctic regions, oysters are found in all the sea areas of the world. Species of oyster vary widely, from those living on the rocky reefs of outer ocean coasts with high salinity waters to those living in the inner recesses of bays with a high degree of fresh water inflow. Among their species can be found a wide variety of life patterns as well. Approximately 200 species of oyster are known to exist in the world, and of these about 25 are believed to live in the waters of Japan. The specific species which are eaten in Japan and have long been the object of fishery operations include "Magaki" (*Crassostrea gigas*), "Suminoegaki" (*Crassostrea ariakensis*), "Itabogaki" (*Ostrea denselamellosa*) and "Iwagaki" (*Crassostrea nippona*). Among these "Magaki" is the representative species, being found in the largest numbers throughout the coastal waters of Japan, west to Korea and the coasts of China and north to Sakhalin. It is used in oyster culture operations throughout these areas and is the single most important species from the standpoint of marine production. Besides the "Magaki", the "Suminoegaki" species is cultured to some degree in the Ariake region of Kyushu, the southernmost of Japan's four main islands. With regard to "Itabogaki", an attempt was made at its culture during World War II, but the collecting of spats proved to be too difficult for it to become a practical industry. Even within the same species of oyster we often find considerable differences in the shape of the shell and other biological characteristics depending on the environmental conditions within which they live. These characteristics have been recognized traditionally and classified into a number of "regional types". For example, within the "Magaki" species it is recognized that those living in the higher latitudes tend to be larger and have shallower ridges in their shells, while those in the lower latitudes are smaller with deeper ridging of the shell. "Magaki" are sexually differentiated into male and female bodies, and are an egg-producing species. The eggs are released into the water and fertilized there. They reach sexual maturity within one year of hatching, but growth in terms of body size is related to sexual maturity and follows a definite seasonal pattern. This growth pattern is therefore an important factor in oyster culture techniques. The most important factors governing the life environment for oysters are water temperature and salinity level. "Magaki" begin dispersing eggs when the water temperature exceeds 20°C in or around the month of June, and cease sometime around the beginning of September. The most productive period comes in July and August when the water temperature climbs to 24° - 25°C. Experimentation has shown that external factors, in addition to body maturity, are essential in egg release and fertilization, and that a sudden drop in water salinity due to rainfall or a rapid rise in water temperature can "trigger" the start of these processes.

The number of eggs produced by a single mature oyster ranges from 50 to 100 million, and at the time of release of eggs and fertilization the water surface around a culture "raft" where parent oysters are concentrated takes on a milky streaked appearance. The fertilized eggs and larvae begin a random process of dispersion and reconcentration in accordance with the whims of forces like tides, wave motion and edding currents. These forces distribute them through the water in an extremely uneven manner, with some of the eggs eventually being sent far out to sea. Then after two or three weeks in this drifting phase they enter the fixed stage of their life cycle in which they attach themselves to some stationary object. Oysters feed primarily on vegetable planktons and detritus, but the amount of food consumed varies by species and also in accordance with the stage of growth and life environment conditions. When the amount of food consumed exceeds the amount of energy expended in consumption, the oyster stores the excess within its body in the form of glycogen or fat. Unlike mammals and many other animals, the oyster stores a larger percentage of its energy reserves as glycogen rather than fat. This is thought to be due to the fact that it has a relatively stationary life. As their life often includes long periods in which the oyster keeps its shell closed in response to environmental changes, the oyster finds it convenient to secure a large part of its energy from the anaerobic metabolism of glycogen.

Regarding the growth of the oyster, it is helpful to view the growth processes of the shell and the soft body portions separately. The growth of the shell is greatly influenced by such factors as water temperature, water salinity, currents and gestation. Therefore, growth is generally most active in the spring and autumn, and tends to stagnate in the spawning season of summer and in winter.

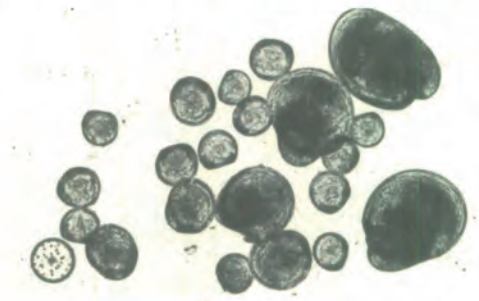
On the other hand, the soft body of the oyster shows marked changes in shape and size in concurrence with its reproductive cycles. Specifically speaking, during the process of sexual maturation from spring to summer cell division and proliferation begin in the reproductive organs. And, as these organs expand into the connective tissue around the internal organs (these tissues contain large stores of glycogen) they begin to grow rapidly. The connective tissue reduces in size and in the period just prior to the release of eggs all of the soft body, with the exception of the digestive system, is dominated by the reproductive organs.

After the release and fertilization of eggs, the reproductive organs promptly shrink in size and the soft body as a whole becomes transparent and loses weight. In the oyster culture industry this state is referred to as "Mizugaki" (watery meat oysters), and at this time the oysters are valueless as commercial commodities.

As the water temperature begins to drop, the cells of the connective tissue become active again, rapidly increasing the volume of body meat, and a thick connective tissue filled with glycogen is formed during the winter months. At this stage the body as a whole becomes thick and plump and the outer surface becomes smooth with a yellowish-white color. This is the stage at which the oyster has the greatest commercial value. In the oyster culture industry, the period in autumn when the oyster is putting on weight is called the "fattening" stage, and this constitutes an extremely important stage in culture technology.

The techniques involved in the oyster culturing process include; **(1) spat collecting, (2) hardening, (3) hanging in culture racks, (4) fattening and (5) harvesting** (Fig.1), and to these are added measures to prevent the growing oysters from being eaten by predators or from dying during the summer months.

1. Spat collecting: In the past, spats were gathered only from spat grounds on tidelands or near river mouths in bay areas.



Larvae

Spat-holding scallop shells

But since the 1960s gathering has been conducted primarily in offshore waters. The reasons for this shift include the loss of natural tideland gathering grounds due to agricultural and industrial reclamation works, and the fact that improvement in culture technology and increased production in the various regions led to a need for an increasing number of spats. This transition was aided by the fact that, beginning around 1950, research concerning oyster spat resources and their distribution progressed steadily, and provided reliable methods for predicting spat gathering grounds.

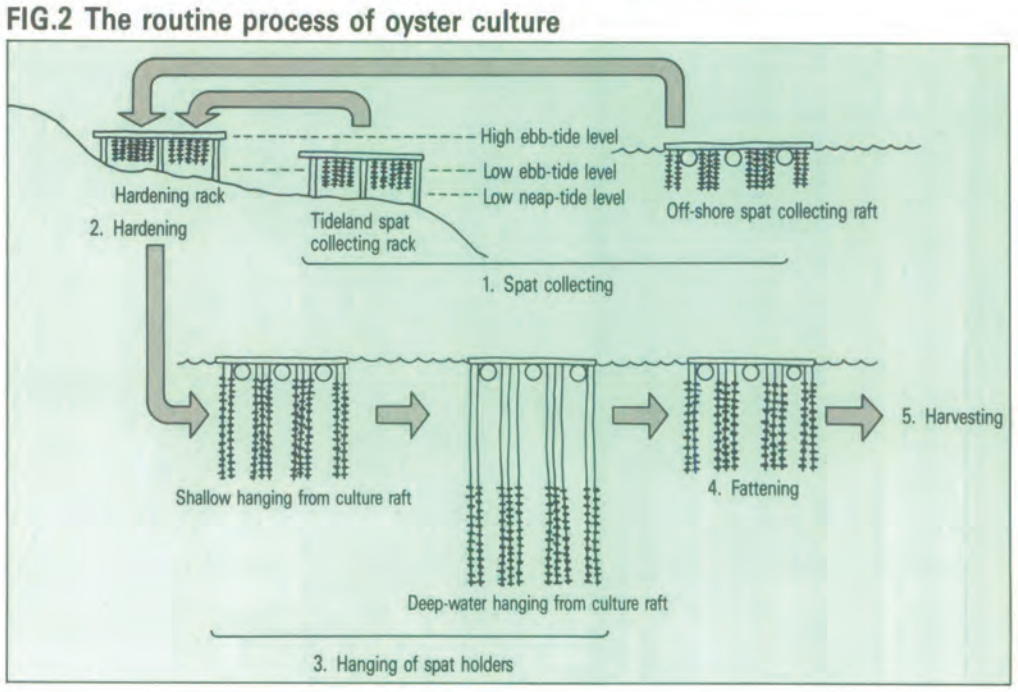
2. Hardening: After gathering has been completed, the spats are placed on a hardening rack in a tideland area for a period of time. Here, the amount of time they spend out of the water is increased gradually each day to encourage optimal growth of the oysters. Exposing the spats to the air serves to weed out the weaker ones and also to ensure that the surviving spats mature in the proper way by hardening their shells to make them more durable with regard to environmental changes.

3. Hanging of spat holders: After the hardening process, the spats are moved to offshore culture grounds to begin the real growth period. At this stage, one of two different kinds of hanging techniques is used. The first is to string the spat-holding scallop shells together and hang them just under the water surface. The second involves attaching some sort of hanging rope to the holders and lowering them down into deep water. The first method is used to take advantage of the high concentration of feed planktons drifting in the surface waters. The second is used to avoid the high water temperatures near the surface in summer and also to prevent the larvae of barnacles or ascidians from attaching themselves to the spat holders and thus interfere with the growth of the oysters. At the time of hanging, therefore, the culture operator has to study the water conditions to decide which hanging method to use.

4. Fattening: This is a technique that is performed for one to two months before harvesting the oysters. It involves moving the cultures to a coastal water area with a high concentration of nutrient salts due to an inflow of freshwater runoff from land. The culture operator has to make his decisions concerning the timing of this move with consideration for his production and shipping schedule.

The reproductive cycles, growth of shell size and fullness of the meat of oysters are all aspects that are governed by different environmental and seasonal factors. And, being a creature that spends its whole mature life fixed in one location, the oyster cannot move in search of a better environment. Therefore, the most important job of oyster culture fishery is to deliberately move the oysters to fishing grounds which can provide the best possible conditions to satisfy the vital biological and physiological requirements of each individual growth stage. It can be said with certainty that the basis of a sound culture operation is the choice of culture grounds and the timing and combination of their use.

FIG.2 The routine process of oyster culture



The history of culturing techniques

The origin of oyster culture in Japan is said to date back about 400 years. At first, we hear that fishermen chose a section of tideland and built a simple framework to prevent the young oysters from being washed away by the waves. Or, they built waterways to prevent the coming and going tides from burying the oysters in the bottom mud and silt as a means to gather and control a crop of oysters. In other words, techniques for simply "stocking" an area with young oysters seem to have been the predecessors to true "culturing" techniques as we know them today. Once the concepts of stocking were established, fishermen found they could increase their harvest by throwing small stones or rocks into the retainer area to help a larger number of larvae make the transition to the attached-life phase. This technique is known as "stone-spreading culture". **(Fig.4)** When they noticed that the young oysters also attached themselves to the wood or bamboo of the retainer wall, fisherman began the technique of sticking branches of wood or bamboo into the bottom of a tideland. In this way "stone-spreading" culture led to "Hibi-date" (standing-pole) culture **(Fig.5)**. This "standing-pole" culturing was divided into two types; one in which the oysters were left attached to the poles until they were harvested, and another in which they were at some point knocked off of the poles and scattered over sea bottom in a type of "bottom-spreading" culture **(Fig.6)**. Gradually the culture techniques developed to include the use of different culture grounds, usually in tideland areas near river mouths, for different stages of the culture process, (namely, spat gathering, winter raising and fattening). The choice of grounds was based on such factors as low tide waterline, strength of tidal currents, winds and waves etc., their effective use contributed to improved productivity and yeild. Meanwhile, another culture technique evolved from the observation that oysters tended to attach themselves to the bamboo-branch "fences" used by coastal fishermen to trap fish by taking advantage of tidal movements in shallow water areas. Soon these "fences" came to be used specifically for oyster culture in a technique called "Yae-hibi" (standing-fence), as shown in **Fig.7**. It has been verified that large scale "standing-fence" oyster culture operations existed in the early Edo Period (the middle of the 17th century) in what is today one of the major oyster producing regions in Japan, namely Hiroshima Prefecture. At the end of the 19th century we know that there were such facilities operating at 40 tideland locations near river mouths in Hiroshima Bay. The last standing-fence operations continued here until 1940.

In 1922, the Hiroshima Prefectural Fisheries Experiment Station succeeded in introducing a simple type of "hanging" culture method. In this method stakes of 1.5m in hight were driven into a tideland area to support a wodden framework. Wire "Ren" (strings) of 2 meters in length that had been strung alternately with pieces of shell (as spat gathering recepticles) and short tubes of bamboo were strung over the poles. These strings served both as the spat collecting recepticles and the growth site for the oysters. Because of its improved efficiency and the fact that the oysters "fattened" better with this method than with either the "bottom-spreading" or "standing-pole" method, this soon became the principal technique for oyster culture. **(Fig.8)**. After its adoption in Hiroshima, oyster culture fishery using this "hanging" culture method spread to other areas such as Okayama, Mie and Ishikawa Prefectures. This simple-type hanging culture method became the basis for the large-scale development of oyster culture in Japan after World War II, primarily because of the following advantages it enjoyed over conventional culture methods;

- Growth and fattening characteristics of the oysters were vastly improved.
- Because it made 3-dimensional use of the surface water, less area was required for an equivalent amount of production.
- Culture operations could be conducted regardless of the qualities of the sea bottom of a given region.
- Previously unused deeper water areas could be used for culture purposes.
- Work could be performed regardless of tidal conditions.
- Organisms which might prey upon the oysters could be avoided.

The full-scale development of oyster culture fisheries after World War II began in the 1950s. In the Hiroshima area there was a shift from simple-type hanging culture methods to "raft" type methods around the year 1950. This change was accompanied by an expansion of the culture grounds to offshore waters. Meanwhile, about the year 1952, long-line type hanging culture methods were introduced in offshore fishing grounds in Miyagi Prefecture.

Today, oyster culture fisheries are conducted to some degree in almost all parts of the country, but there are two principal production centers. One is along the Pacific coast of the Northeast with its center in Miyagi Prefecture, and the other in the Seto Inland Sea with its center in Hiroshima Prefecture. The culture method in the former is primarily "long-line type", while the latter uses mainly "raft-type", while the latter uses mainly "raft-type". The yearly production per operation (fishing family) in Miyagi is 2.3 tons, while Hiroshima ation. This striking difference is a result of the difference in culture method as well as differences in fishing ground conditions and the organization of the culture operation units. Aside from these two regions, there are also minimal oyster culture operations using traditional simple-type hanging method, bottom-spreading and standing-pole methods in inner bay waters and estuary waters in other regions such as Hokkaido, Shizuoka and Nagasaki Prefectures. Now, in the following pages let us look at the present situation and challenges facing oyster culture fisheries in the two main regions where oyster culture has become an organized industry, Miyagi and Hiroshima Prefectures.

FIG.3 The development of oyster culture techniques

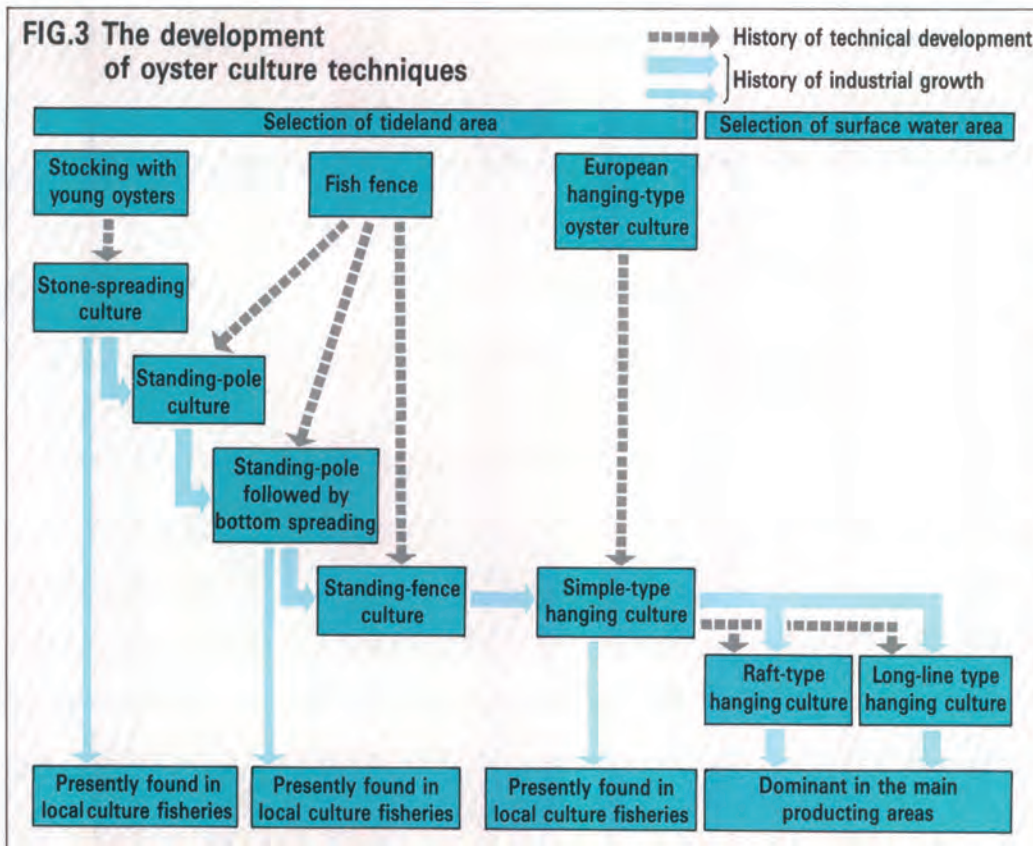


FIG.4 Stone-spreading culture

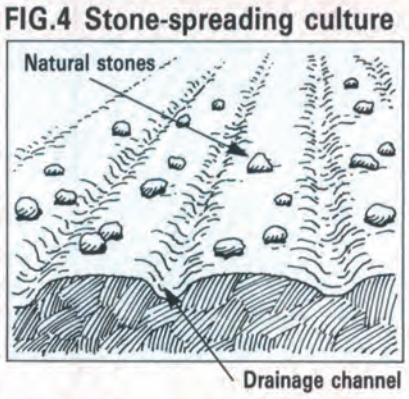


FIG.5 Standing-pole culture

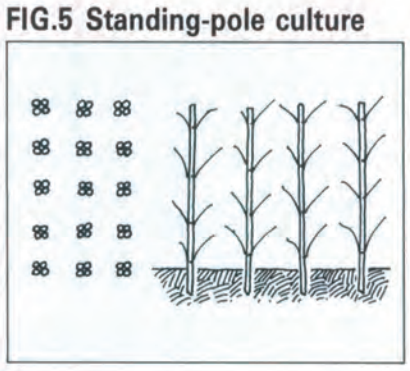


FIG.6 Standing-pole followed by bottom spreading

① Spat collecting
② Bottom spreading
③ Harvesting

FIG.7 Standing-fence culture

FIG.8 Simple-type hanging culture

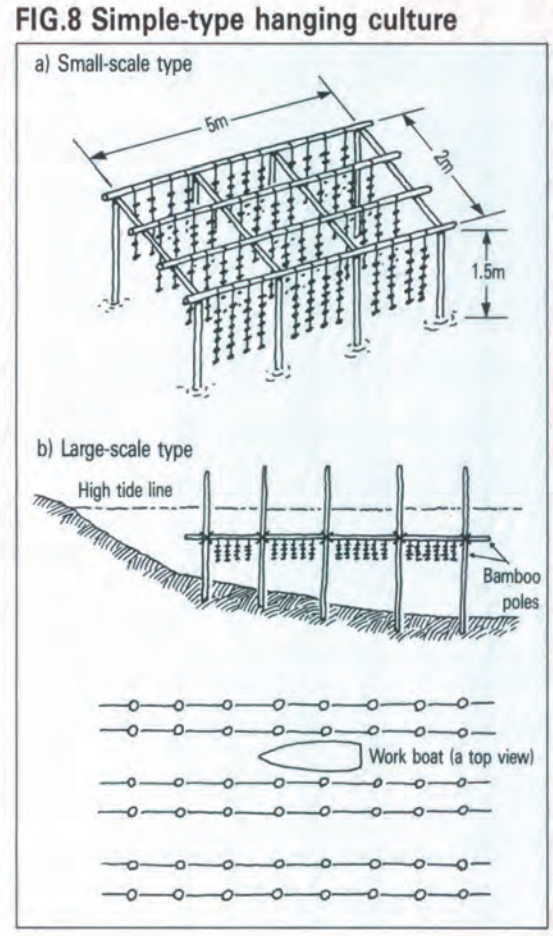


FIG.9 Major producing areas for oysters in Japan

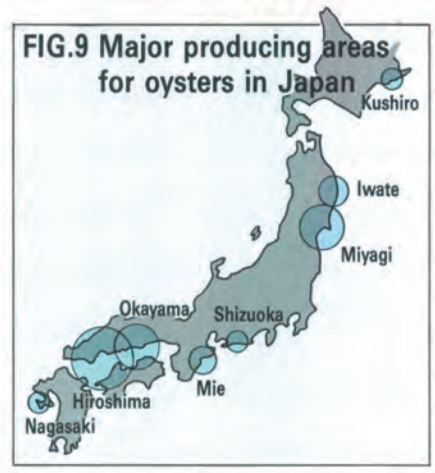


TABLE 1 The state of Japanese oyster culture production (1986)

Major producing areas	No. of oyster culture families	Scale of culture facility					Production (Jan. to Dec.)		Production of shucked oysters per family (ton)
		Raft-type (1,000m²)	Long-line type (unit)	Simple-type hanging (1,000m²)	Bottom-spreading (1,000m²)	Standing-pole (1,000m²)	Oysters in the shell (ton)	Shucked oysters (ton)	
Hokkaido (Kushiro)	152	–	300	1,211	1,490	–	257	22	0.1
Iwate Pref.	1,062	189	4,276	–	–	–	8,380	838	0.8
Miyagi Pref.	1,974	149	17,516	237	–	–	46,496	4,650	2.3
Shizuoka Pref.	88	–	–	664	–	–	1,298	260	3.0
Mie Pref.	277	84	55	–	–	–	8,122	1,248	4.5
Okayama Pref.	302	707	–	–	–	–	20,008	4,435	14.7
Hiroshima Pref.	597	2,528	–	2	–	–	154,009	28,513	47.8
Nagasaki Pref.	74	53	133	–	–	141	973	97	1.3

EXAMPLE 1

Eba, Hiroshima Prefecture

Raft-type hanging culture

Hiroshima Prefecture annually produces between 28 and 30 thousand tons of shucked oysters, accounting for about 70% of the total Japanese production and making it, therefore, the largest oyster culture center in the country. The culture grounds cover almost the entire coastal region of the Prefecture, but the majority of the 600 households presently engaged in culture fisheries are concentrated in the northern section of Hiroshima Bay (indicated by the circled area in **Fig.10**). This is also the area in which Hiroshima oyster culture originated, mainly because it contains the following conditions which make it optimal as a fishing ground for oyster culture:

- Because of the many rivers that flow into this area of the bay, there is a continuous supply of nutrient salts from the land, which makes it an ideal raising ground for vegetable planktons.
- There are many islands in this inland sea area, making for a wide tidal range and strong tidal currents in the straights, which produce a high exchange rate of bay and outer sea waters. This means that there is a constant replenishment of the planktons on which the oysters feed, and that the remains of dead planktons and the waste emitted by the oysters are flushed out to sea at a good pace.
- Being an inland sea area, and having its mouth shut off considerably by islands, the surface of the bay remains relatively calm year-round and, therefore, well suited for setting out culture facilities.

Concerning the rafts used, in 1932 the Hiroshima Prefectural Fisheries Experiment Station developed some rafts made of cedar and cypress, but they proved to be heavy and lacking in seaworthiness. They also required a powered fishing boat in order to be moved, which proved to be beyond the investment capabilities of the fishermen at that time. Therefore, they were not adopted in practical use. After World War II, a new type was developed using a species of thick-stemmed bamboo that proved to be inexpensive, lightweight, flexible and resistant to damage by waves. This bamboo type was quickly adopted, and in the two years from 1953 to 1954 the number of culture rafts jumped from 492 to 1339 and continued to grow after that until the number surpassed 10,000 rafts in 1969.

During the 1960s, to compensate for the loss of tideland area due to landfill operations associated with agricultural and industrial development, there was a general expansion in licensed fishing grounds. Coupled with this increase in the number of culture rafts, new oyster culture grounds were developed offshore and around the numerous islands. This expansion brought a rapid growth in oyster production, rising the total output to 20,000 tons in 1962. Since then, the production has fluctuated between 20,000 and 30,000 tons annually.

Techniques of raft-type culture

Over the years there have been frequent improvements in raft design, but the standard specifications of rafts in use today are the 10 meter by 20 meter construcion shown in **Fig. 11.** Usually 5 rafts constitute one set that is connected by 2 - 3cm diameter wires and anchored to the sea bottom at both ends by concrete blocks.

In the hanging-type spat gathering method used most commonly today, a hole is made in the middle of scallop shells and 60-70 shells are strung on one 2-meter length of wire with 1-1.5cm sections of pipe as spacers. This string is then hung in the water for oyster spats to attach themselves to. **(Photo A)**

As the time for the release of eggs approaches, the Fisheries Experiment Station begins to gather oyster spats by means of a plankton net and check on their growth and distribution. At the same time periodic observations are made on test hangings of spat gathering strings to see how attachment is progressing. Based on this information, it provides the culture operators with predictions for the most suitable time and places to conduct their spat gathering operations.

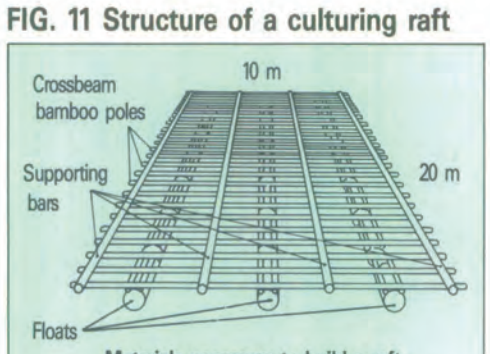
Using these predictions, the operators commence spat gathering, checking regularly on the shells hung from their rafts to count the number of spats that have attached themselves. When the number of attached spats is determined to be sufficient, the strings are removed from the raft and transferred to hardening shelves. **(Photo B)**

After completion of the hardening process, the "seed oysters" are "re-strung" and preparations are made for the real long-term hanging. The shells with hardened spats attached are now strung at about 20cm intervals on a 9-meter length of wire. These new strings, which will now hold between 40 and 50 shells, are then hung at 40-50cm intervals along the bamboo poles of the raft. In this way some 500-600 strings will be hung on one raft, meaning that one raft will account for between 20,000 and 30,000 shells with oyster spats attached. **(Photo C and D)**

Decisions about whether the hanging will be a deep or shallow type, and what the timing and combinations of the "fattening" hangings will be, are all choices that vary according to culture ground conditions and the business plans of the culture operator. But in general, we can presently see three or four major patterns of culture operation that predominate in the Hiroshima area. In the past, a practice of "high-speed raising", in which seed oysters from spats gathered in the summer were raised, harvested and shipped by the end of the same year, was dominant in this area. But in recent years, the high intensity of culture fisheries being conducted in these waters has led to a decrese in feeding efficiency that in turn has lengthened the maturation period required by the oysters and complicated the culture process as a whole.

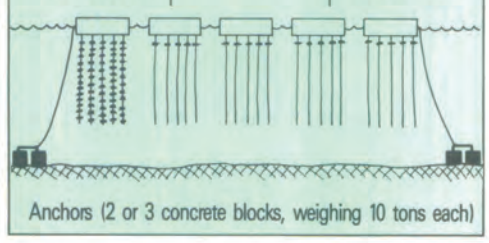
Harvesting the mature oysters involves lifting the string out of the water by means of a winch, clipping off the bottom end wire with a pair of clippers, pulling off the shells and piling them into the hold of a transport vessel to be carried to shore. The total shucked weight of the oysters from one raft comes to 2-4 tons.

FIG. 11 Structure of a culturing raft



Materials necessary to build a raft

Item	Standard size	Quantity
Thick-stemmed bamboo	11 - 12cm in cut section dia.	18 lengths
Thick-stemmed bamboo	9-10 cm in cut section dia.	45 lengths
Thick-stemmed bamboo	11 - 12cm in cut section dia.	12 lengths
Wire	Soft wire, No. 8	1 roll
Floats		24 units
Hanging wires	Semi-steel wire, No. 13 or 14	1,200 lengths
Spat holders		26,000 shells



Management of culture fisheries in the Hiroshima area

The management scale for oyster culture fishery operations in the Hiroshima area can be divided roughly into three classes; **1)** those operating about 20 rafts, **2)** those with 40-50 rafts and **3)** those with 80 - 90 rafts. Each operator must be equipped with one or two workboats (3-5 ton class) and one transport boat (15-20 ton class), a landing facility, a shell washing facility, a moving conveyor, a shucking facility, a washing facility for the shucked oysters and a packaging and shipping facility.

The work to be preformed out on the rafts goes on almost year-round. In the case of scale **1)** operations, the work is done by the members of one family, whlile in **2)** and **3)** the work force will include several hired workers in addition to the family.

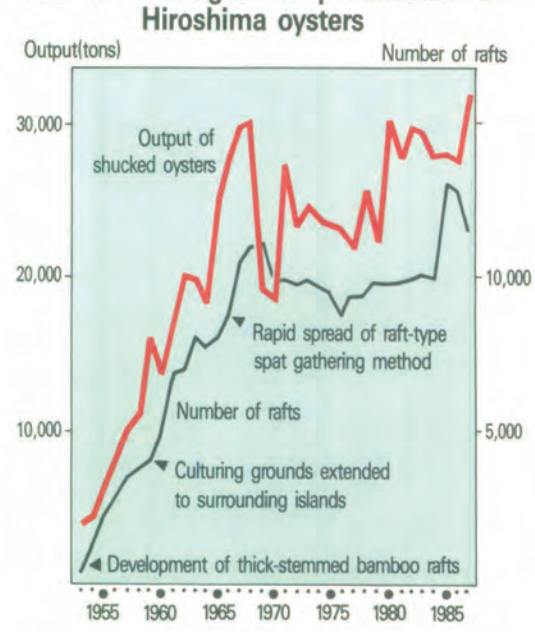
One of the important factors that distinguishes oyster culture business from other fisheries is the large amount of work that must be done on land. In short, with the exception of a small quantity of the catch sold in the shell, almost all of the oysters must be shucked before they are shipped.

An average shucker shucks about two raftsful of oysters in 7 months. Production of shucked oysters depends on the fullness of the oyster meat. While it is less than 2 tons per raft around October, it increases to more than 4 tons around April. Therefore, a single raft produces an average of 3 tons of shucked oysters a year.

The size of an oyster culture workboat is limited to under 20 tons. The transport boat is equipped with a crane. The foredeck is a full open hold type.

Since the shucking process is done by hand, for the roughly 200 days between October and April when harvesting is going on, a staff ranging from a few to as many as 20 or more women "shuckers" must be hired. This labor cost is considerable, accounting for between 30% and 40% of the total operating cost of an oyster culture business. The standard production rate for an experienced shucker working eight hours a day is between 2,300 and 2,800 oysters a day. However, a particularly skillful worker can shuck as many as 4,000 to 6,000 oysters a day.

FIG. 12 Changes in production of Hiroshima oysters



Present conditions and problems confronting Hiroshima oyster culture

Hiroshima oyster culture fisheries showed tremendous growth during the years of high economic growth in 1960s, to the point where it became one of the Prefecture's important local industries.

However, at present it is believed that the number of culture facilities has reached the limit of what the environmental resources of the area can support. The prefectural authorities have therefore adopted a policy of granting no new fishery licenses, and so, no future increases in production can be hoped for. On the contrary, continuing industrialization and economic growth are now presenting oyster culture fisheries in the Hiroshima area with a number of new problems that must be overcome. Namely;

1. High-intensity culture operations over the years have begun to cause an aging of the culture environment. This has resulted in a lengthening of the period necessary for oysters to reach maturity, thereby increasing production costs.
2. With the improvement of shipping and distribution systems, the demand for oysters has spread to all parts of the country. But this trend has also led to the birth of expanded new culture industries in Okayama, Mie and Ishikawa Prefectures, causing stiffer competition in the marketplace.
3. With the high value of the yen today in respect to the U.S.dollar, exports of canned and frozen block oysters to the U.S., Japan's largest export market, are decreasing and, at the same time, the Japanese market is being entered by inexpensive Korean-grown oysters.

A) *Spat collecting rafts*

B) *Hardening process ... 10 months after gathering has been completed.*

C) *Shells with spats are re-strung.*

D) *Real long-term hanging*

EXAMPLE 2

Fuki-ura, Miyagi Prefecture

Long-line type hanging culture

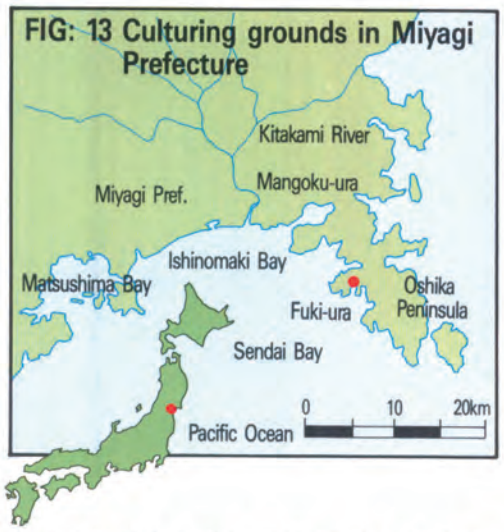


FIG: 13 Culturing grounds in Miyagi Prefecture

A collective workshop. Within this workshop a separate workspace is assigned to each family.

It is 5:00 in the morning. Outside is still dark, but in the lighted oyster workroom of the local Fisheries Cooperative Association the shucking of oysters has already begun. In Miyagi Prefecture, shipment of fresh oysters to the market begins most years on the 29th of September. Here on the Oshika Peninsula, with its clear-water offshore culture grounds, the shipment of fresh oysters approved for raw consumption purposes commences from the very beginning of the season. In Hiroshima, the country's major producing area, the shipment of oysters also begins around the 1st of October. But in the case of Hiroshima, with its coastal culture grounds that produce fast-maturing oysters, the early shipments are sold as oysters for cooking purpose only. Oysters from the clear-water offshore fishing grounds begin to be harvested and shipped to market in earnest around the end of October or early November. **(Fig. 14)**

Households engaged in oyster culture here on the Oshika Peninsula have access to fishing grounds which can produce oysters suitable for raw consumption, which draw a premium price in the marketplace, about one month earlier than those of the Hiroshima area. So, they are understandably in a hurry to complete the harvest and shucking work and ship their oysters off to the Tokyo market while the early-season prices for raw-consumption oysters are high. During the 3-month period from October to December, the shucking work starts at 5:00 a.m. and continues till 5:00 p.m. every day. And during these three months they will ship between 70% and 80% of their total yearly production.

Here in Miyagi Prefecture, oyster culture fisheries are actively pursued in three locations, Oshika Peninsula, Matsushima Bay and Kesennuma Bay, with Oshika's fisheries accounting for about 70% of the total production for the Prefecture. Within Oshika Peninsula, the locality of Fuki-ura boasts the largest production, with the roughly 100 members of its "Ishinomaki City Eastern Sector Fisheries Cooperative Association" accounting for an annual production of 700 tons (weight without shell).

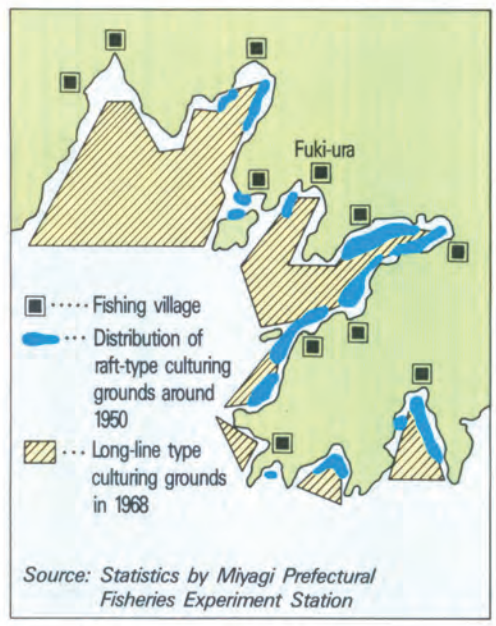
The long-line culture technique

Oshika Peninsula juts out into the Pacific with a rias coast full of indentations. Raft-type culture operations used to be conducted here in the quiet waters of its numerous bays.

With the introduction of the long-line method around 1952, however, the new method quickly took over throughout Oshika Penninsula because of its ability to withstand wave action. And, as a result, culture grounds were extended out to the rougher waters of the mouths of the bays and even to offshore waters. **(Fig. 15)**

The long-line hanging method of oyster culture involves stretching two parallel ropes between floats and hanging strings stocked with seed oysters from these ropes. **(Fig. 16)**. With this method, the fishermen can also avoid such costly disasters as having a culture raft capsize. The method of making the seed oyster strings is also different from that used in Hiroshima. Here, fishermen wedge the shells that serve as spat holders into lengths of rope soaked in coal-tar. This is because, apparently, in the rougher waters of this coast the wave motion causes the wire of Hiroshima-type strings to wear an increasing larger hole in the spat-holding shell until the neighboring shells are able to slide together. The roughness of these waters also causes a higher percentage of the young oysters to be "shaken off" the strings and fall to the ocean floor. For this reason, culture operators here limit the culture period to one year.

FIG: 15 Growth of long-line type culture operations in Fuki-ura and its surrounding areas



Source: Statistics by Miyagi Prefectural Fisheries Experiment Station

FIG: 14 Seasonal fluctuations in shipment volumes and prices

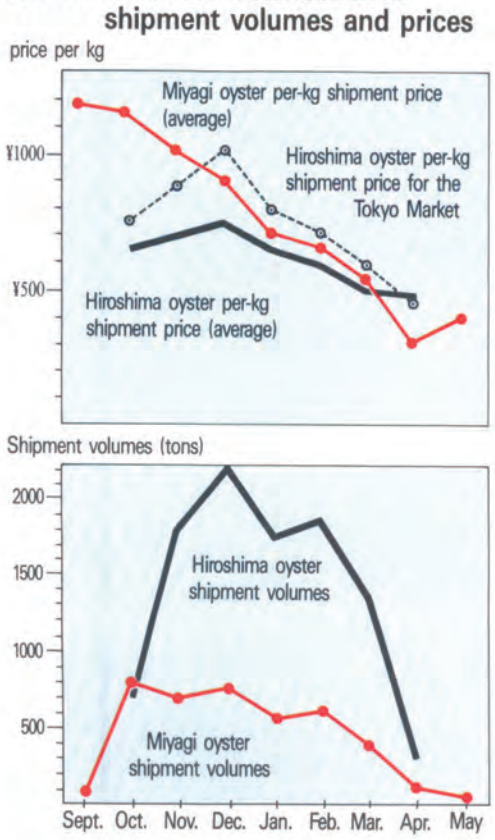
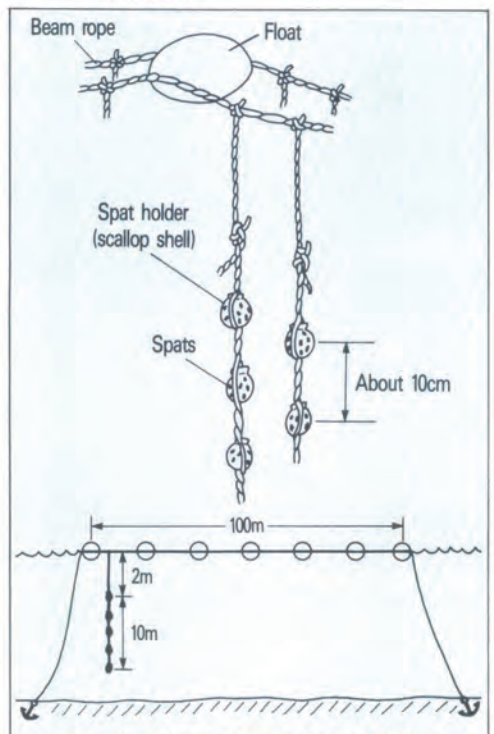


FIG. 16 Long-line type hanging culture



Note: 40 to 42 spat holders (scallop shells) are held by a hanging string about 10 meters long.

Culture management based on one-family labor

Here in Oshika, the culture work, harvesting and shucking are all conducted by means of family labor. Since the entire yearly production must be harvested within a limited season, culture operators here decide the volume of culture they will undertake based on the amount of family labor they can commit to the shucking operation.

Oysters that have been shucked are washed in filtered and sterilized sea water, put in polyurethane buckets and placed in the Fisheries Cooperative Association's refrigeration facility (5°C) until evening. That same evening the entire daily produce of the local members is loaded into an association-owned refrigerator truck and transported to a collective marketplace under the management of the Prefectural Federation of Fisheries Cooperative Associations. Miyagi Prefecture operates 3 such collective marketplaces for oysters at which each day's production is sold to local middlemen at an auction held the following morning.

Management of culture operations in combination with fishing boat fisheries

In Miyagi Prefecture the scale of oyster culture operations varies with the size of the fishing grounds and number of fishing families in the different regions. In the area governed by the Eastern Sector Fisheries Cooperative a limit has been set at a total of ten spat-collecting and culture long-lines per fishing family. In Fuki-ura the annual income for family-operated oyster culture is about 6 million yen. But all of these families are also engaged in other forms of fisheries, such as gillnet, small-scale set net or squid jigging, to fill out their yearly household income. The average income figures for a fishing family in the Eastern Sector Cooperative in 1987 was as follows;

- Oyster culture ..... ¥579 million
- Launce square net fishery ..... ¥284 million
- Small-scale set net fishery ..... ¥21 million
- Squid jigging ..... ¥110 million
- Gillnet fishery ..... ¥35 million

Total: ..... ¥1,029 million

For the past ten years this Fisheries Cooperative has also engaged in efforts to maintain the productivity of their culture grounds by cultivating the location of culture grounds every June before the start of the oyster culture operations.

TABLE 2. Economic situation of fishing families engaged in oyster culture (1986)

	Northeast (Miyagi & Iwate)	Seto Inland Sea (Hiroshima & Okayama)
Culturing ground area (hectare)	0.2	0.4
Number of days worked	135	223
Number of hours worked	461	2,364
Hours worked by family members	429	836
Hours worked by employees	32	1,528
Culture fishery income (¥1,000)	2,876	25,504
Culture fishery expenditures (¥1,000)	1,551	20,001
Wages	149	8,052
Facility, boat & fishing gear	136	2,145
Fuel & oil	126	508
Seed oysters	48	12
Depreciation	580	4,388

Source: Statistics by the Ministry of Agriculture, Forestry and Fishery

Note: While in the Northeast culture management is based on family labor, in the Seto Inland Sea areas the culture work is conducted mainly by means of hired labor due to its much larger scale. 3 to 5 men are hired as regular employees for the culture operations on the sea and 5 to 20 shuckers are hired for the shucking period. In the case of the Seto Inland Sea culture fishing family, wages, depreciation and repair expenses of facility, fishing boat and gear account for about 75% of the total expenditure.

Bidding at a collective marketplace in the Miyagi Prefectural Federation of Fisheries Cooperative Associations

Culture workboats in use here are around 5 tons. The foredeck is equipped with a line hauler, a shell grinder and a rotating washer.

EXAMPLE 3

Mangoku-ura, Miyagi Prefecture

Seed oyster culture

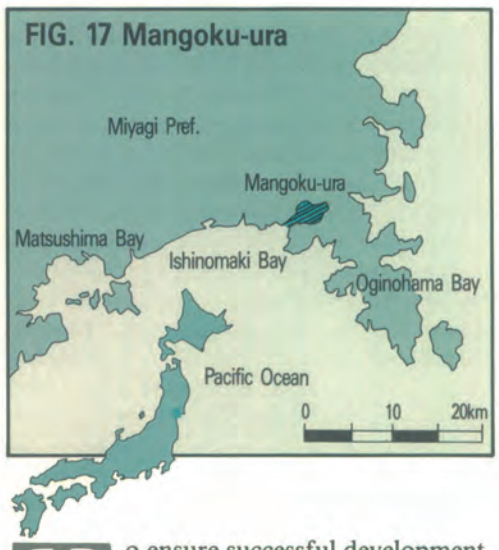


FIG. 17 Mangoku-ura

To ensure successful development of oyster culture as an industry, a stable supply of seed oysters is an absolute necessity.

However, achieving a large stock of seed oysters by natural means requires a delicate combination of certain biological characteristics of the oyster and ocean environmental conditions. For this reason, traditionally, the only places that a profitable production of seed oysters could be carried out were the shores of Sendai Bay in Miyagi Pref., the Hiroshima area of the Seto Inland Sea and Matoya Bay in Mie Prefecture.

According to statistics of the Ministry of Agriculture, Forestry and Fishery, in 1986, there were 685,000 strings of seed oysters sold in Japan (note: one string consists of 70 spat-holders). This is the number of strings produced for sale, and does not include strings produced by individual culture operators for their own use. Broken down by Prefecture, we find the Miyagi sells 506,000 strings, or 74% of the total national production.

Seed oysters produced in Miyagi are sold throughout the country from Hokkaido to Kyushu, and, with the exception of the Hiroshima and Mie areas, all of the nation's oyster culture industries depend heavily on Miyagi seed oysters. Sales are not limited to Japan, either. Since the 1920s, Miyagi has also exported a considerable production of seed oysters to the U. S. and France as well. However, as the transplanted seeds have formed parent shell groups and acclimated themselves to these new foreign environments, the export has decreased as of the 1970s. Still, a significant quantity of export continues to the present.


Seed oysters being hardened


Hardening shelves at high neap-tide


Mangoku-ura. The average depth of water is about 5 meters. Within this bay, besides oyster culture, gillnet and short-necked clam collecting fisheries are also operated. During the period from 1977 to 1988 the Fisheries Cooperative improved culturing conditions by constructing a waterway 80 meters in width, 2 meters in depth and 3.6 km in length for a smoother exchange of tidal currents.

Fishing grounds that provide all the necessary conditions for excellent growth

The producing grounds for seed oysters in Miyagi Prefecture include Mangoku-ura, Matsushima Bay and Ogihama Bay. These water areas provide all the necessary conditions for seed oyster production; including **1)** a sufficient stock of parent shells, **2)** sufficient water temperature rise in summer, **3)** the essential feeding environment for good larva growth, **4)** proper tidal flow patterns to ensure the separation and distribution of the larvae, **5)** a water boundary in the outer sea where a stock of larvae forms, **6)** suitable coast areas for spat collecting, **7)** shallow water surfaces suitable for hardening operations.

For example, in Matsushima Bay and Mangoku-ura, a dense growth of "amamo" (Zostera marine) grows over a large area of the bay waters. The growth and flowering of this amamo in spring and the dropping and decaying of the leaves in summer play an important role in providing a suitable environment for oyster seed production by influencing the water pH in the bay, the amount of available oxygen and the yearly fluctuations in available nutrient salts.

In the past, spat collecting in Mangoku-ura was done in the bay waters, but as the number of inner-bay facilities increased, the collecting efficiency began to decrease. At the same time, research concerning the life pattern of oyster larvae progressed and it was learned that spats could be gathered in large quantities in offshore waters by means of movable rafts. As a result, spat collecting operations are now conducted in suitable waters outside the bay.


Under 3-ton class workboats are used for smallscale culturing operations. Pictured here is a Yamaha drive boat, YDW-27 (1.3 tons) designed specifically for small-scale culturing. Seen on deck are a simple manual winch and a shell grinder.

With a maximum tidal difference of 1.5 meters Mangoku-ura is an ideal place for conducting hardening operations. The area of the bay mouth with its fast tidal flow is used as the hardening grounds. The strings of shells that have gathered spats during July and August are moved to the hardening grounds for several months of hardening. Then they are packaged one after another and shipped to the various culture areas before June of the following year. There are about 100 families engaged in this type of culture fishery here in Mangoku-ura, each of which produces about 2000 strings of seed oysters per year. Their total industry production sells for about ¥300 million. Besides seed oyster production, families involved in oyster culture fishery here in Mangoku-ura also engage in the production of mature oysters, using the simple-type hanging method in the inner bay waters and long-line method in the outer sea type waters of Ishinomaki Bay.

Health supervision in the Hiroshima oyster industry

In order to maintain health standards for fresh oysters, Hiroshima Prefecture has set the following guidelines by which to instruct its oyster producers and distributors.

1. Designating sea areas for use as culture grounds

Every year the Department of Health of Hiroshima Prefecture conducts bacteriological studies of the waters of the culture grounds, and approves as clean sea areas only those waters which show a colon bacilli reading of less than 70 per 100 milliliters of sea water. And only these "clean sea" waters can be used to produce "oysters for raw consumption". Waters which do not receive this rating can sell their fresh oysters for "cooking purposes" only.

2. Health standards at the packing and distribution stages

Regarding the producers

1. Producers are instructed to thoroughly wash the harvested oysters with saltwater;
2. to leave the harvested oysters in a trough of filtered and sterilized sea water for about 24 hours before shucking to allow them to flush out impurities through their own natural waste-emission processes;
3. to wash the shucked oysters in a flow of chilled, clean sea water with a salinity of over 2% which has been filtered and sterilized;
4. to refrigerate the shucked oysters at a temperature of 5°C or less until shipment.

Regarding the distributors

1. Distributors are instructed to never sell oysters that have been designated "for cooking purposes" as products "for raw consumption";
2. to wash shucked oysters in chilled sea water with a salinity of over 2%;
3. to be sure that the oysters are kept refrigerated at 5°C or less until they reach the consuming area;
4. to make it a rule to process and ship fresh oysters on the same day they are received from the producers.

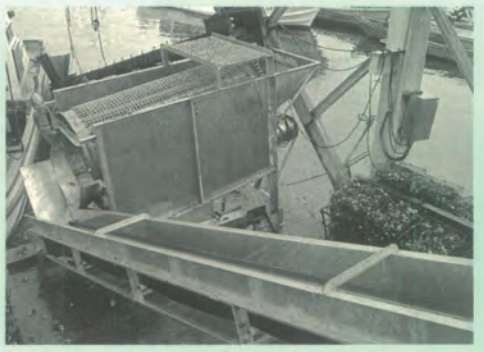
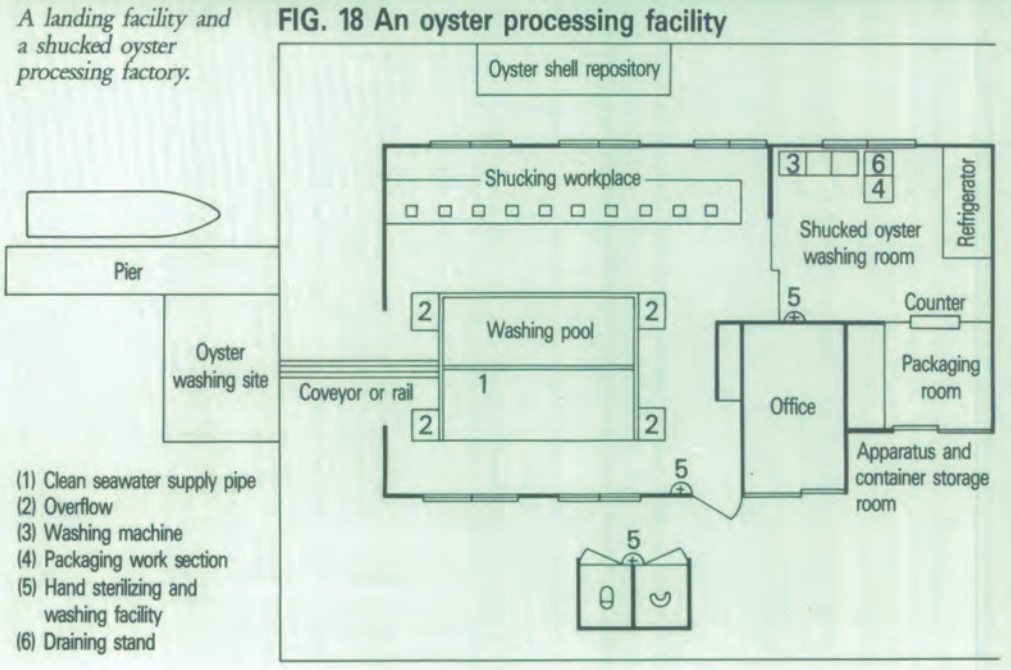

A landing facility and a shucked oyster processing factory.

FIG. 18 An oyster processing facility



Development and evolution of distribution systems

In France virtually all oysters are delivered to the consumer in the shell. In America, the ratio of oysters in the shell and shucked oysters delivered to the market is about half and half. In Japan, on the other hand almost all of the oysters are sold shucked. As of 10 years ago some operators began shipping particularly well "fattened" oysters in the shell under the product name "single oysters". But all such shipments are destined for hotels or high-class restaurants, so they remain no more than a small quantity, specialized commodity group.

In Japan, oysters are mainly handled as a shucked product in the raw state and their price is based primarily on the freshness of the meat from the standpoint of raw consumption. This is how the basic market situation has stood ever since the rapid growth of oyster culture shortly after World War II, and even today it shows no signs of changing. In recent years there has been no noticeable growth in the demand for oysters, and, furthermore, there is increasing competition from imported oysters. So, if there is going to be a new development in the Japanese oyster industry it will probably have to be as a restructuring of the handling routes for oysters intended for raw consumption.

The production and sales regions for oysters in Japan can be divided roughly into 3 regional groups:

1. **Products of the Seto Inland Sea**
   (Hiroshima & Okayama)
   Sold throughout the country (with exception of Hokkaido and the Northeast)
2. **Products of the Sanriku region**
   (Miyagi & Iwate)
   Sold to the Tokyo area, the Northeast and Hokkaido
3. **Products of Central Japan**
   (Mie & Ishikawa)
   Sold to the Nagoya area, Central Japan and Tokyo

The recent shipping statistics for Hiroshima oysters, which have the greatest market influence, are shown in **Table 3.** One half of the total production is shipped as fresh oysters. Another characteristic of this group is that an exceptionally high percentage of the shipments are bound for urban consumers. As shown in **Table 5,** about 70% of the shipments of fresh oysters go to cities with a population of over one million.

TABLE 3 Oyster shipments from Hiroshima (1987)

Total production 31,500 tons
Shipments of fresh oysters 15,500 tons
- About 1,000 tons for central wholesale markets of major cities
- About 5,000 tons for supermarkets

Shipments for processing 16,000 tons

TABLE 4 Processed Hiroshima-oyster products (1987)

Canning:	Smoked	29,000 cases
	Boiled	206,000 cases
Freezing:	Freeze-processed food	8,894 tons
	Frozen block	813 tons
	Frozen pieces	4,535 tons
Total		14,242 tons

Tsukudani 41 tons
Dried 292 tons

TABLE 5 Hiroshima-oyster shipments by destination (major city) (1987)

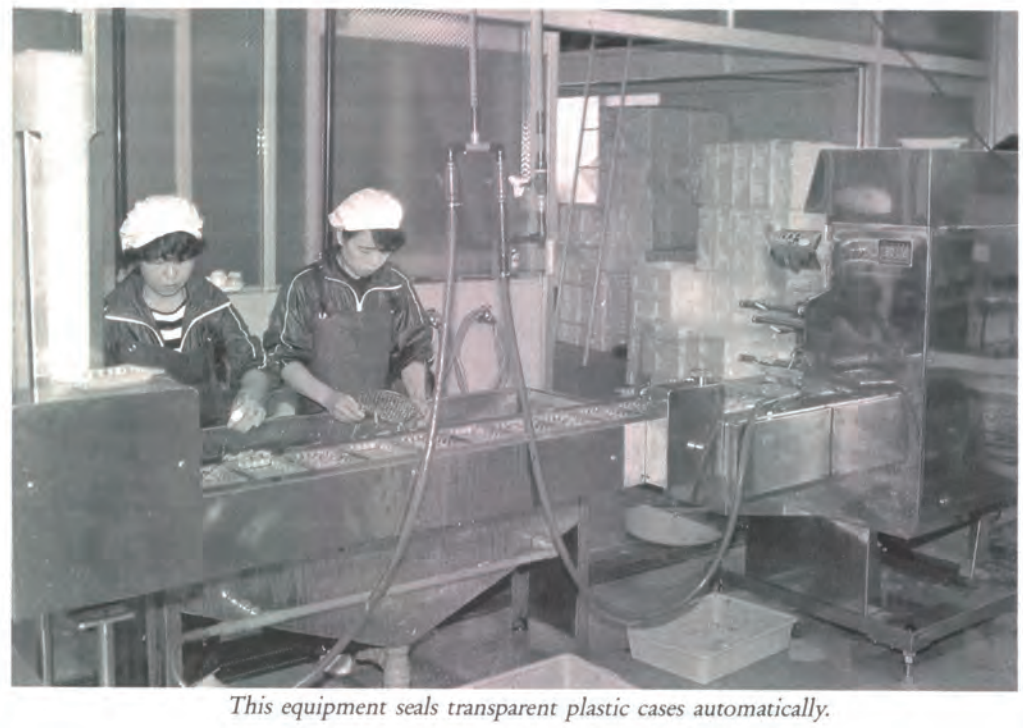
Tokyo	2,216 tons
Yokohama	435 tons
Nagoya	1,817 tons
Kyoto	637 tons
Osaka (districts other than city)	574 tons
Osaka (city)	1,670 tons
Kobe	625 tons
Amagasaki	81 tons
Himeji	180 tons
Wakayama	392 tons
Northern Kyushu (Fukuoka & Kita Kyushu)	1,057 tons
Hiroshima	296 tons
Total	9,980 tons

One of the factors behind the development of the Hiroshima oyster industry is a history of efforts to develop sales routes outside of the prefecture. In fact, even before modern times, the largest consuming market for Hiroshima oysters was the economic center of Western Japan, Osaka, more than 300km away. This fact was a direct result of a Hiroshima merchant who got permission to moor his oyster boat on the canals of the city and offer Osaka residents a variety of oyster dishes in the middle of the 17th century. These floating oyster restaurants became an established part of Osaka life and gave rise to a group of culture operators who contracted to supply oysters specifically to these restauranteurs. Such oyster boat restaurants continued to do business in Osaka until as recently as 1950.

As the post-war revolution in oyster culture technology led to dramatic increase in production, a similar development was also occurring in the distribution routes. In the 1950s, Hiroshima oyster producers got together to successfully open a sales route to Japan's largest marine product market, the Tsukiji Market in Tokyo. In the 1960s the urban central wholesale market system developed at a good pace, enabling a steady development of sales routes. This, in turn, allowed the Hiroshima oyster culture operators to increase their scale of business.

Entering the '70s, a group of local middlemen was established in the producing area. To avoid competition with shipments made directly to the wholesale markets of Tokyo and Osaka by the producers, these middlemen made a policy of placing emphasis on shipments to small and mid-size cities. Aided by the development of railway refrigerated shipping facilities and the national highway system, the sales routes for Hiroshima oysters spread in this way throughout the country.

Moving into the '80s, large supermarkets began to engage in fresh oyster distribution operations, making it a much larger business. As these supermarkets established their influence, they brought a major change to the oyster distribution system. This change took the form of a "packaging revolution". The conventional method prior to this revolution was for the producers to ship their shucked oysters in 20kg containers. However, because supermarkets rely on small packages, oysters began to be sold in small transparent plastic packs containing 150g, 200g or 250g each. As the producers were unable to meet such needs, it became the job of the middlemen to invest in packaging equipment that could automate the packaging process and produce large volumes of "oyster packs".



This equipment seals transparent plastic cases automatically.

A fresh oyster packaging factory which is run by local middlemen in the producing area. Oysters which are supplied by producers are washed and grouped into three size classes, small, medium and large, with the exception of 'Mizugaki' and egg-bearing oysters before they are automatically sealed into small transparent plastic packs. These packs are ice-packed in styrofoam boxes for shipment.

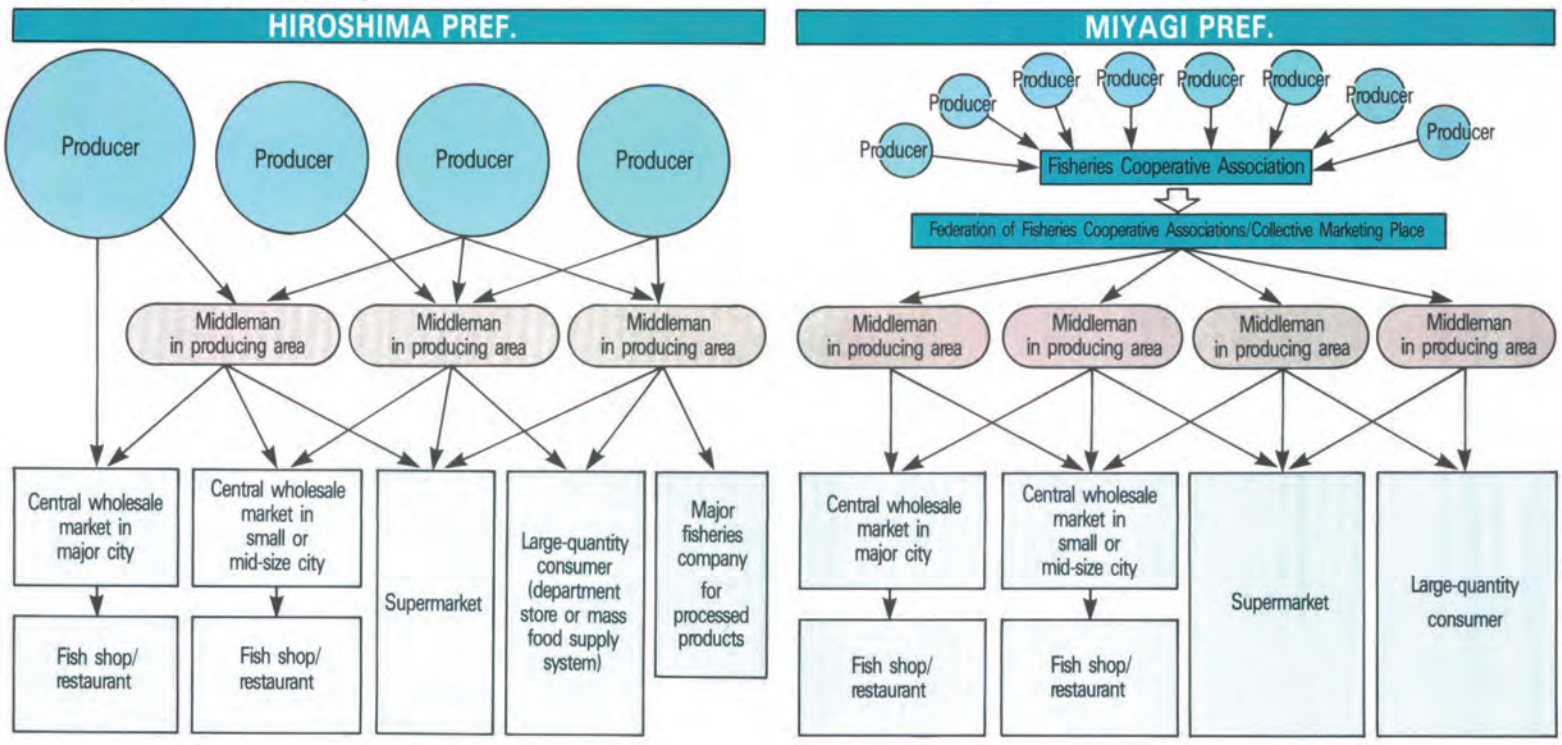
The distribution process for fresh oysters is shown roughly in **Fig. 19.**

The distribution system is divided into two major routes. One that goes through the central wholesale markets of major cities and another in which middlemen in the producing areas deal directly with supermarkets.

Some 30% of the fresh oysters produced in Hiroshima go to supermarkets, while in the Sanriku area, 50% of the production finds its way to supermarket shelves. These trends have reduced the power of central wholesale markets in the major urban areas to set prices, and have given more of that power to the middlemen in the producing areas. These middlemen are also aided in their business by such things as excellent refrigerated shipping methods, developments in equipment for the processing industries, and the introduction of high level information and communication services. Today, producers and middlemen in Hiroshima can receive detailed information about bidding prices at the Tsukiji Market 900 km away in Tokyo by Facsimile in less than one hour's time.

Processing operations involving either canning or freezing begin with the end of the fresh oyster season in mid-March and continue through the end of May. Shipments of these products to the markets begin, then, in June. Most of the oyster canning is done at canning factories that engage in the canning of a wide range of food products, while primary freeze processing is carried out at freeze facilities owned and operated by the mliddlemen in the producing area.

Fig. 19 Oyster distribution system



Oyster Dishes & Processed Foods

Oysters are an easily digestible food that contains an excellent balance of the basic nutrients required by the human body. They also contain a high percentage of glycogen, taurine, minerals, amino acids and other important trace nutrients that make them an increasingly valued food from a nutritional standpoint. And, of course, they have unique flavor which have made them a preferred delicacy throughout the world since ancient times. In particular, oysters contain an especially large amount of glycogen. Because of the fact that, in the human body, complex sugars in the bloodstream must be broken down first into glycogen by enzymes secreted by the pancreas and stored temporarily in the liver, glycogen from oysters makes an excellent source of energy that reduces the work load on the pancreas and enters smoothly into our systems.

There are said to be about 600 species of oyster dishes enjoyed in the world today. In Japan many oysters are consumed fresh, and many people prefer to eat them raw as a vinegar flavored or dressed dish. In winter oyster stews and soup dishes are also favorite delicacies. Also, as Japanese eating habits have become more westernized year by year, we are recently seeing an increase in the popularity of fried oysters, oyster gratins, chawders and oyster grilled in the shell.

The primary processed oyster products are canned oysters (boiled, smoked or oiled), frozen block oysters, freeze-processed (for fry cooking), tsukudani (boiled in soy sauce with other seasonings), dried oysters, and oyster sauce. Among these, dried oysters are an important ingredient in many Chinese dishes.

TABLE 6 Comparison of nutritional contents (per 100g portion)

Food	Energy (Kcal)	Protein (g)	Fat (g)	Sugar (g)	Minerals (mg)		Vitamins			
					Calcium	Iron	A (IU)	B_1 (mg)	B_2 (mg)	C (mg)
Oyster (raw)	78	9.7	1.8	5.0	55	3.6	55	0.16	0.32	4
Eggs	162	12.3	11.2	0.9	55	1.8	640	0.08	0.48	0
Milk	59	2.9	3.2	4.5	100	0.1	110	0.03	0.15	ϕ

Source: Revised Standard Nutritional Contents List of Japanese Foodstuffs

OYSTER DISHES

A full course meal consisting of a variety of oyster dishes.

One of the most popular oyster dishes is nothing more than squeezing a little lemon over fresh raw oysters and enjoying them straight out of the shell.

PROCESSED OYSTER FOODS

Freeze-processed oysters for fry cooking

Cocktail

Marinated

Oyster sauce

Frozen pieces

Salted innards

Cream soup

Stew

Smoked, oiled and canned oysters