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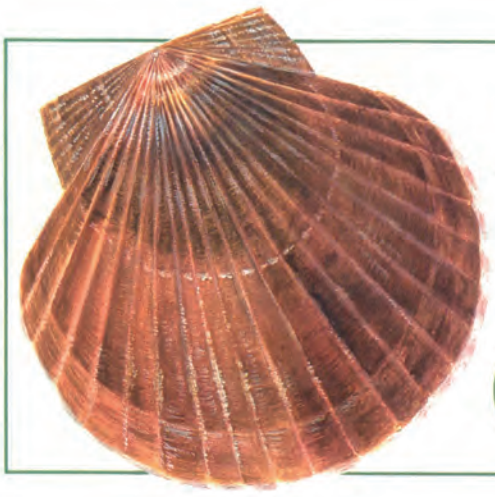


SCALLOP AQUA-CULTURE

Solving the mystery of good and poor harvests

——Developing a system of techniques suited to the mode of life of shellfish——

Scallop fisheries must be conducted with methods that fit the sea conditions and fishing ground characteristics in a way that sustains and propagates resources. Dredge net harvest of seabed sowing type culture, Sarufutsu, Hokkaido. (right) Hanging type culture using pearl culture nets, Mutsu Bay, Aomori Prefecture. (above)

The total Japanese production of saltwater and freshwater shellfish in 1988 was 861,000 tons, or about 7% of the country's fishery production. This clearly makes shellfish an important marine resource, following various types of fish. Of this shellfish production 833,000 tons were saltwater varieties and 28,000 tons freshwater, with the production of coastal water collection and aquaculture being especially important. Among the shellfish that are the object of fisheries, bivalves are far more important than sea snails, with scallop and oyster accounting for more than half of the total shellfish production. Two other bivalves that are important in the Japanese production for direct human consumption are short-necked clam and corbicula. By way of reference, the total world production of shellfish in 1987 was 4,840,000 tons (weight with shell).

Scallops belong to the family Pectinidae, and the species commonly known as "hotate-gai" in Japanese we will be dealing with in this issue is a boreal species *Patinopecten yessoensis*, and is called "giant ezo-scallop" or "common scallop" in common English.

Giant ezo-scallop is distributed along the coastal waters of the Okhotsk Sea, the Primorskiy coast, the East coast of the Korean peninsula and along the coasts of Hokkaido and Northern Honshu in Japan. This scallop inhabits only coastal waters with a depth of less than 40m, and prefers sandy bottom areas between depths of 10～30m with strong tidal flow. When the water temperature climbs to 6～9°C in the spring, the rise stimulates the scallop to commence all at once egg and sperm release, with fertilization taking place in the sea water. Five to seven days after fertilization the larvae reach a shell length of about 120 microns and enter a planktonic stage. Within 2 to 3 weeks, upon reaching a length of about 300 microns, they attach themselves to seaweeds or pebbles by means of a byssus. About 2 months after this, as they reach a shell length of 6～7mm, they cut their own byssus and fall to the seabed to begin benthic life on the bottom.

At the end of a full year the scallops will have reached a shell length of 5～6cm, by two years about 10cm, and after 3 years they will have grown to about 12cm. They mature at about two years old, and the span of life is said to be 10～12 years.

When viewed as a fishery, there are three ecological characteristics of giant ezo-scallop that are noteworthy: its great reproductive capacity, filter feeding and poor tolerance against changes in environment.

1) High reproductive capacity: A mature female will carry from 100 to 160 million eggs. Under natural conditions a female will release anywhere from 1/3 to 1/2 of the eggs it holds, but when all the environmental conditions are favourable a single female may release more than 100 million eggs in a season. However, it has been revealed that drastic reduction occurs during the planktonic stage 30～40 days after birth and again immediately after the beginning of the benthic life stage, resulting in a survival rate of less than 1% in most cases.

This high-reproduction/high-mortality rate of giant ezo-scallop is a primary factor accounting for the extreme fluctuations between good and poor harvests that have long been the pattern in scallop fishery.

2) Filter feeding: Bivalves feed by "filtering" planktons and organic suspended matters (detritus) originating from the decomposition of other organisms, by means of branchial respiration of the water taken into their mantle cavities. Therefore, the size of scallop population that can be sustained in a given water area is determined by the balance between the primary productive capacity of the sea and the feed consumption of the scallops and other competitor organisms.

3) Tolerance against environmental changes: Giant ezo-scallop is a bivalve that has a poor capacity to endure changes in environment such as water temperature, salinity and dissolved oxygen, etc. For example, the slightest increase in detritus in its waters leads to a serious drop in the filtering function of its gills. And in the case of aquaculture, rough handling in the culture process can easily lead to stunted growth or even death.

In Japan, the culture of giant ezo-scallop began on a large scale in the 1970s, and annual production has already reached a level of 300,000 tons. Several factors can be cited as contributing to this rapid and highly productive development. They include:

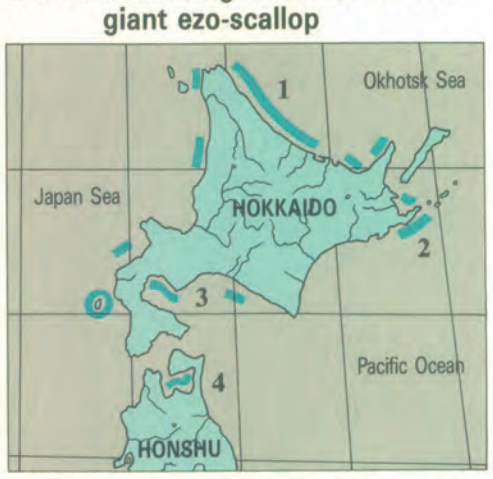
1) Along with dried shark fin and dried abalone, dried scallop adductor (muscle) has long been considered one of the three great delicacies of Chinese seafood cooking. Before World War II dried scallop adductor was exported in quantity to China, and since the War its export has continued to China and Southeast Asia via Hong Kong. Meanwhile, in Japan, fresh scallop adductor has been prized as a fresh shellfish delicacy in gourmet cuisine. And since the 1960s, the rising standard of living has led to an increasing demand in fresh scallop adductor for household consumption.

2) In Japan, the development of aquaculture industries for oyster and pearl oyster preceded the development of scallop culture. Both oyster and pearl oyster culture make use of a unique Japanese "hanging culture" method employing rafts. And the basic technology developed for these culture was to contribute greatly to the establishment of techniques for scallop aquaculture.

3) Concerned with the phenomenon of extreme fluctuations between good and poor harvests, a number of Japanese marine biologists began early on to study the biological characteristics, the mode of life and the environment of scallop. The results of this research added further reference material that played an important role in the development of scallop culture technology.

From dependence on nature to planned-production type aquaculture

FIG. 1: Producing areas for natural giant ezo-scallop



All types of scallop are cold-water shellfish found in waters above lat. 35° in both the Northern and Southern hemispheres. In Japan, the southern extent of their distribution is Tokyo Bay (35°10′ N) on the Pacific coast and Toyama Bay (36°50′ N) on the Japan Sea coast.

In the past, naturally occurring giant ezo-scallop abounded in the coastal waters of Hokkaido and Mutsu Bay of northernmost Honshu. The coastal breeding grounds for scallop in Hokkaido include **(1)** the Okhotsk Sea coast, **(2)** the Nemuro coast and **(3)** the Funka Bay coast. In addition to these areas, large harvests of scallop were also made in waters around offshore islands and certain coasts of the Japan Sea; although now production is quite limited. Today, the main scallop producing areas in Japan include the above **(1)**, **(2)** and **(3)**, plus **(4)** Mutsu Bay of northernmost Honshu. **(FIG. 1)**

The development of scallop production in Japan is shown in **FIG. 2**, while **FIG. 3** and **FIG. 4** show recent conditions in production by region.

The period of dependence on natural resources

Giant ezo-scallop fishery in Japan can be divided into two distinct periods; the period from the beginning of fisheries development in the late 19th century until 1970 which depended solely on the gathering of naturally occurring resources, and the period of planned production since the 1970s based on artificial propagation practices.

Scallop collecting in Hokkaido began around 1887, along the Okhotsk Sea coast. A fishing method using a hand-operated dredge net worked by a crew of 3～5 men from unmechanized boats of 11.5 m length and 2.4 m width, gradually spread and prospered throughout the island. Prior to this, records show enormous crops of scallop appearing in Mutsu Bay around 1860, followed by harvests exceeding 10,000 tons recorded at about 20-year intervals.

The period when scallop fishery depended completely on naturally occurring resources was characterized by extreme annual fluctuations between good and poor harvests. **FIG. 5** and **FIG. 6** show fluctuations in recorded harvests over periods of several decades between the time scallop gathering became a local industry around the turn of the century and 1970. This poor-and-plenty phenomenon can be explained by a peculiar 10～20 year cycle of abnormal bursts in abundance (exceptionally high survival rates among the scallop spats). Since a single female scallop carries from 100～160 million eggs, as a species it has an extremely high propagative potential. But the scallop spats generally incur extremely high mortality in their early stage as a combined result of various environmental obstacles. When a number of favorable factors happen to coincide in the environment, however, an exceptional number of spats survive and cause an especially large fishery harvest 2 or 3 years later.

Since the 1930s, though, natural resources of scallop clearly began to decrease in Hokkaido and Mutsu Bay. This reduction is not the result of natural cycles of population fluctuation, but rather of the increased fishing intensity.

In spite of the evident decrease in resources of natural scallop, in an attempt to increase food production and make up for the reduced labor force in Hokkaido during the World War II years, dredge net fishery for scallop using motorized boats was begun in 1942. And after the war, an influx of repatriates increased the fishing population, causing the continuation of uncontrolled overfishing for scallops. After the post-war confusion subsided, the initiative to return to orderly catching practices resulted in the adoption of communal operation systems in about 1952. By this time, however, it was already too late to reverse the deteriorating status of the natural scallop resources, and most areas were forced to put a halt to any scallop gathering whatsoever to allow the resources to recover to previous levels.

On the whole, however, the age of fishery for natural scallop was by no means an age without order or control in gathering practices. Within the long scalloping tradition in Japan, a number of conservation measures had been attempted on collecting practices to prevent depletion of resources. These included regulations on fishing gear, adoption of crop rotation systems, removal of natural enemies such as starfish and restrictions on the gathering season. Although these measures were unable to prevent the resource crisis that struck in the 1950s, they were to become the base on which production systems were built in the age of production based on resource propagation that ensured.

FIG. 5: Giant ezo-scallop production in Mutsu Bay

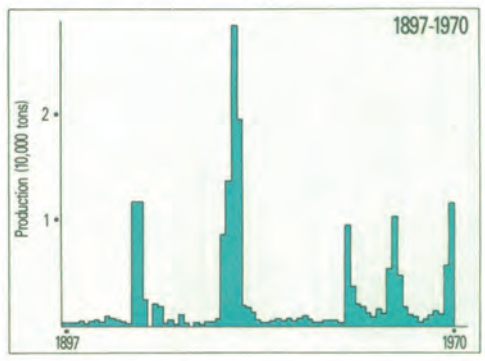


FIG. 6: Fluctuations in Hokkaido coastal scallop production

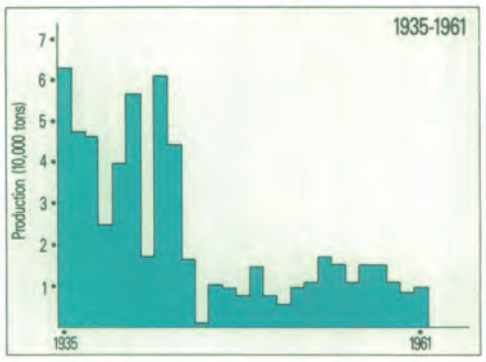
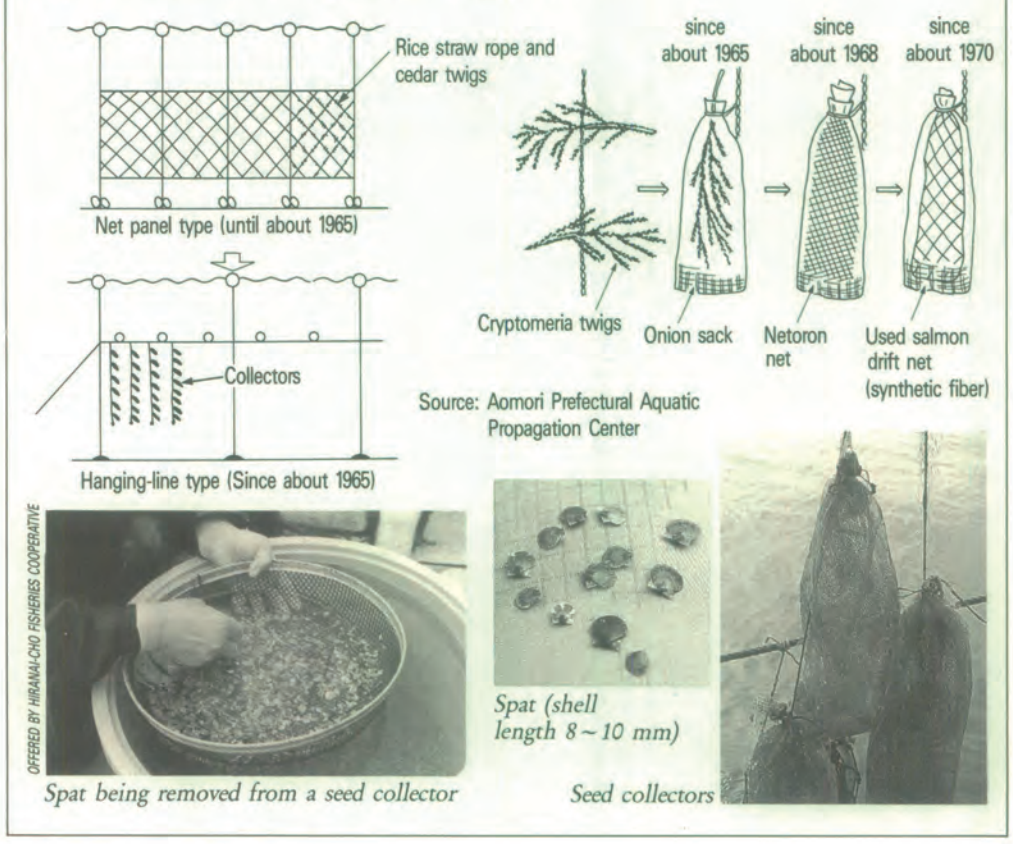


FIG. 7: Historical change in seed collectors



The age of planned production based on resource propagation

Research regarding the biological characteristics and the mode of life of giant ezo-scallop began in Japan in the 1930s, when the work of several researchers opened the way for the beginning of research into artificial propagation.

The gathering of natural seeds was first attempted in Hokkaido's Lake Saroma in 1934, and seeds were released in selected fishing grounds the next year. Then, from 1937～44 the Hokkaido Fisheries Experimental Station undertook environmental studies of scallop fishing grounds and surveys of potential sites for resource propagation.

After World War II, in 1951, a natural seed gathering project began once again in Lake Saroma, followed by the start of similar seed gathering in Hokkaido's Funka Bay and Aomori Prefecture's Mutsu Bay in the mid-50s. At first, scallop shells or twigs of cedar were used as collectors for the seeds to attach themselves to, along with hemp palm bark, plastic film, plastic trays, etc. These collectors were strung on ropes and hung in the water. In 1965, however, a fisherman in Mutsu Bay developed a revolutionary technique for gathering seeds. This involved placing cedar twigs or old fish net as attaching bases inside fine-meshed polyethylene net bags, and hanging the bags in the water. In this method, floating seeds were able to pass through the net bag and attach themselves to the base inside, but by the time they cut their byssi to drop to the sea bottom they had grown too large in shell size to pass through the bag mesh again. This caused a large number of spat to collect in the bottom of the bag. This method soon spread throughout Aomori and Hokkaido, hailing the beginning of the age of high-volume seed gathering. **(FIG. 7)**

In order for planned production based on propagation culture to begin in full-scale, the techniques for intermediate rearing of the seeds had to be added to those of large-scale collecting of natural seeds. This meant rearing large numbers of spat to a shell size of 3cm or more by artificial means. With the establishment of two such techniques, scallop aquaculture began to spread rapidly after about 1970. The course of its development has followed two different paths: that of hanging-type culture and that of seabed sowing type in fishing grounds. Details of these two methods will appear in the following pages in the form of regional reports.

In recent years, total Japanese production of giant ezo-scallop has been stable at between 300 and 340 thousand tons, with the harvest of natural scallop that are mainly the product of seabed sowing type culture at 150,000～160,000 and the produce of hanging type aquaculture at 150,000 to 180,000 tons. However, prior to this recent period of prosperity as an industry, the fishermen involved in scallop aquaculture had to endure many painful trials and sacrifices, such as the sudden mass death of seeds [Mutsu Bay in 1975, Funka Bay in 1977] and shellfish toxin [Mutsu Bay in 1978, Funka Bay in 1978～79]. The mass death turned out to be an incident which revealed the environmental strain and technological insufficiencies that resulted from the overly rapid development of scallop aquaculture. And the shellfish that caused food poisoning in the age of mass supply urged the fishermen to take better sanitary measures at the time of shipment.

FIG. 2: Scallop production in Japan

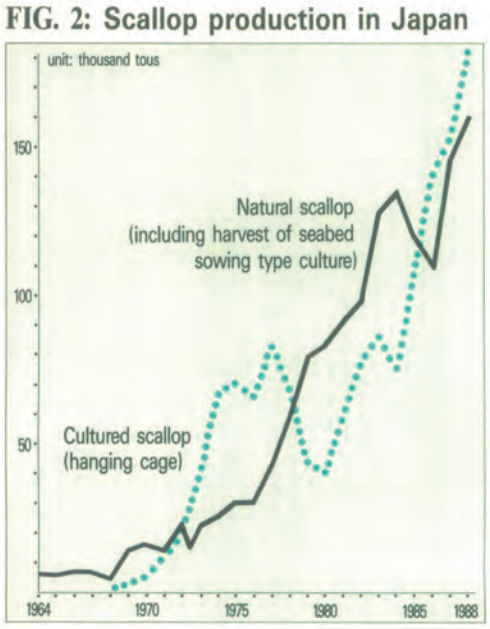


FIG. 3: Scallop production in Hokkaido (1988)

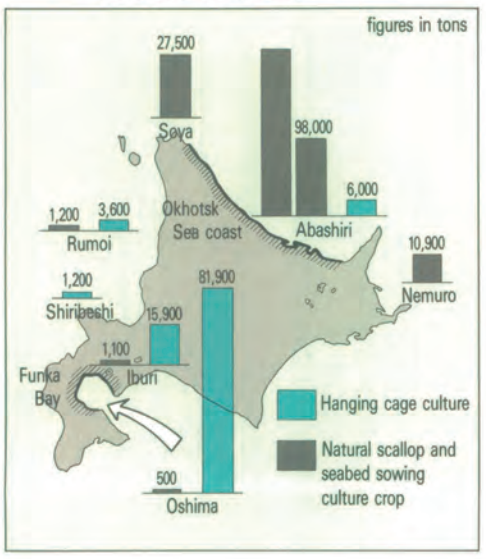
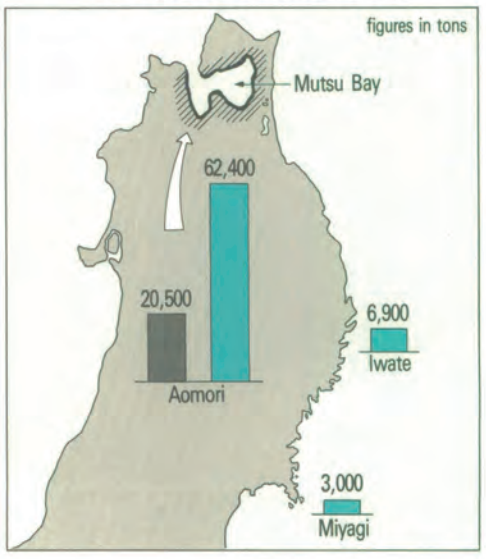


FIG. 4: Scallop production in Northern Honshu (1988)



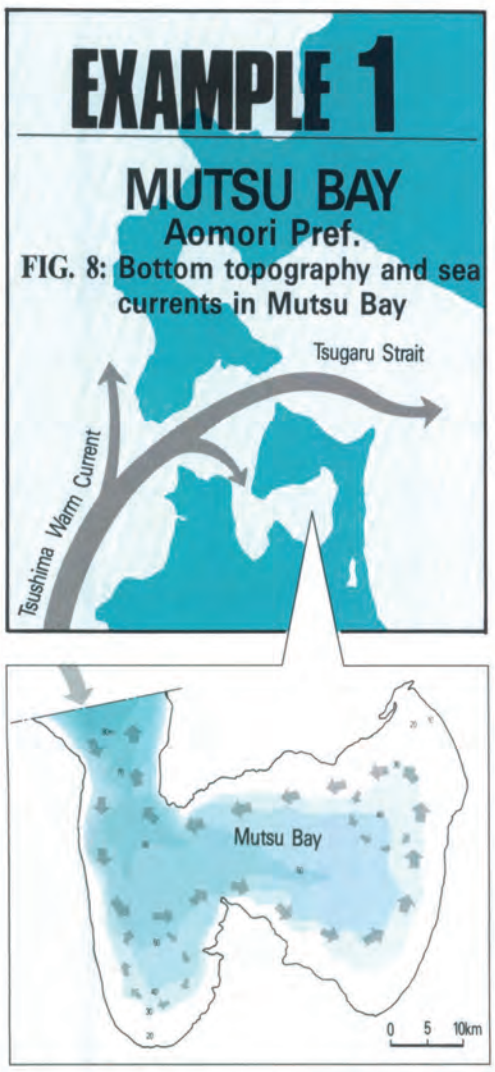


FIG. 8: Bottom topography and sea currents in Mutsu Bay

Making maximum use of the resources of a calm sea

As can be seen from **FIG. 8**, Mutsu Bay is formed by two peninsulas and opens on the northwest into the Tsugaru Strait. A smaller peninsula that sticks out into the central region of the Bay serves to divide it into the east and west parts, in terms of sea conditions. The sea bottom within the Bay is generally flat, with the east part in particular having a flat "basin" topography. A warm current enters Mutsu Bay from the Tsugaru Strait, moving south along the western peninsula then toward the east part in a counter clockwise course to form a large circular current. A smaller circular current is also known to be formed in the inner part of the Bay. The exchange of waters with the outer sea is relatively slow, and it is estimated to take at least 50 days for incoming waters to make a full sweep of the Bay and flow out again. The bottom type is not necessarily uniform, but with the exception of the steep section of the western part which is a gravel zone, almost all areas down to a depth of 30m are a sandy mud or sandy gravel bottom structure.

Originally, Mutsu Bay is an abundant natural breeding ground for the scallop. Every year large quantities of floating seeds are produced, and sea conditions make for easy collecting and rearing of them. This has made Mutsu Bay an ideal site for the development of a major scallop aquaculture industry. At present all types of scallop fisheries, including seabed sowing and hanging type culture are being conducted here. Let us, then, use Mutsu Bay as an example for outlining an overview of scallop fisheries.

Seed collection and intermediate rearing

Seed collection is a process that makes use of the habit of seeds to attach themselves to some object. In order to conduct effective seed collection, it is important to secure access to a water area with a good concentration of floating seeds. In addition to this, proper decisions regarding the timing of the gathering operation, the depth at which the collectors are hung and the number of collectors to be used, are also very important. If the collectors are put out too early, they will become dirty by the time seed attaching reaches its peak, thus interfering with attachment. If they are put out too late, they will miss catching the peak of the season's seed attaching. Also, to keep off starfish seeds that tend to attach themselves to the collecting apparatus in the same way, it is important to avoid waters where floating starfish seeds abound.

The prefectural fisheries experimentation and research agency, Aomori Prefectural Aquatic Propagation Center, aids fishermen in conducting more efficient and effective seed collection by supplying them with information acquired from their year-round surveys of parent scallop maturity and environmental conditions for seed rearing.

If the spat collected are released immediately into the seabed, or are left without special care, almost all will die because of their lack of environmental tolerance, by such means as malnutrition or oxygen insufficiency resulting from overcrowding, or excessive suspended mud or predatory loss. For this reason, spats that have cut their byssi and grown to a shell length of 8 ~ 10mm are removed from the collecting apparatus and dispersed to culture cages called "pearl nets" for hanging in the water for an intermediate rearing.

The density of spats in each cage of the pearl net is kept at about 50 ~ 100, and 10 cages are strung together into one unit. The units are hung at 1-meter intervals and they must be stabilized in the water to keep vibration to the spats and swaying to an absolute minimum. It was only after the techniques of this intermediate rearing were established that a stable supply of culture seeds was achieved.

The various types of culture

Scallop culture can be divided into two main types; seabed sowing type in which natural fishing grounds are stocked with seeds, and hanging type aquaculture. And the hanging type culture can further be divided into three types; ear-strung type, cylindrical cage type and pearl net type. **FIG. 9** and **FIG. 10** show the operating schedule and methods for aquaculture in Mutsu Bay. The process from seed collection through intermediate rearing is the same for all types of culture. The first thinning of rearing lots to reduce the culture density takes place in late September or early October when the young reach a shell length of about 30mm. After that the individual fisherman proceeds with the method that suits his own purposes best.

Seabed sowing culture: After an intermediate rearing stage in which the spats reach a shell length of 30 ~ 50mm, they are released in a natural fishing ground and harvested 2 ~ 3 years later by dredge net. In Mutsu Bay this culture is conducted on a 3-rotation crop basis.

Ear-strung culture: When the young are reared for an additional 3 ~ 4 months in pearl net cages, they reach a shell length of about 50mm. At this point they are landed and holes drilled in the ear of the shell and a string is put through the hole and then tied to a culture rope and hung vertically in the water.

Cylindrical cage culture: This is the most common method of hanging type culture. As the young grow, the batch of scallops in a cage is divided regularly to maintain the desired culture density. Finally the batch is placed in large cylindrical cages and reared to maturity over a period of about 2 years.

Pearl net cage culture: This method is a variation of the cylindrical cage method that is being used increasingly in Mutsu Bay in recent years. The spats continue to be reared in the pearl nets until they reach a shell length of 60 ~ 70mm, at which point they are harvested and shipped to market as a half-grown commercial product.

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FIG. 9: Scallop aquaculture and shipment calendar (Mutsu Bay, Aomori Pref.)

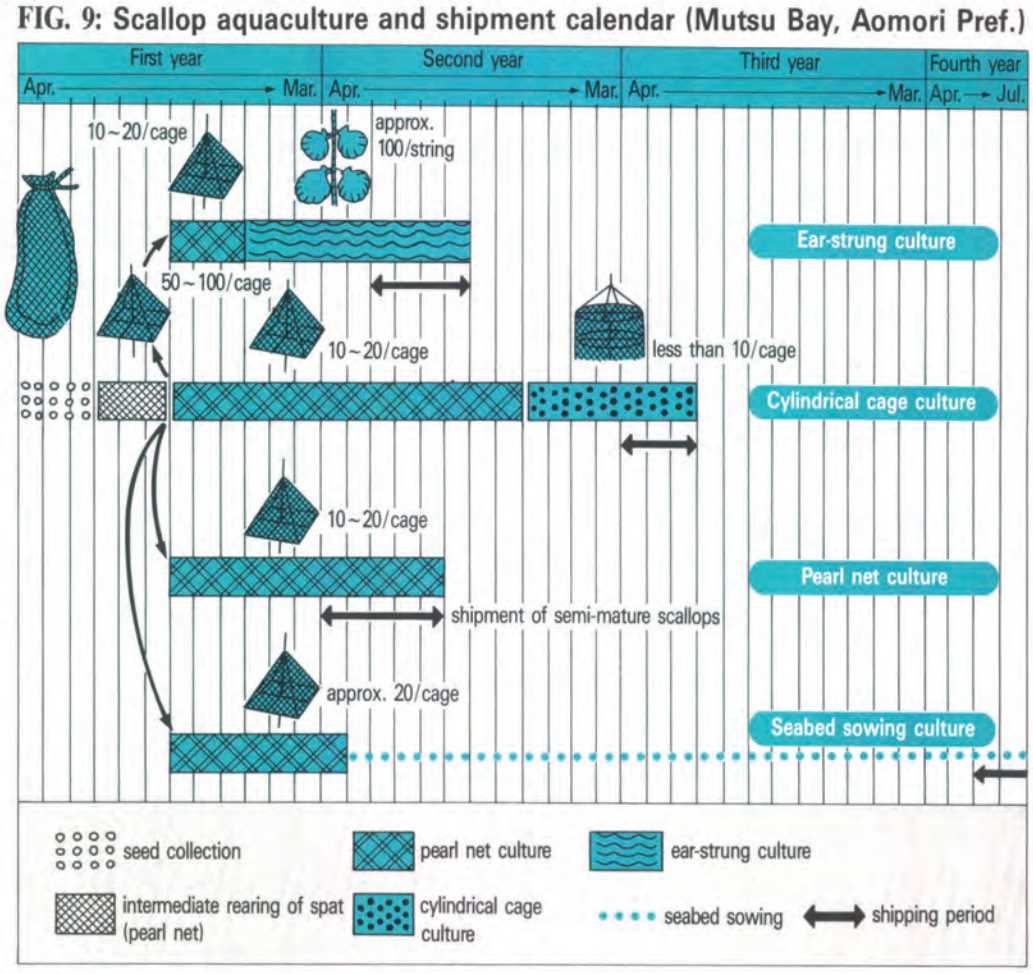
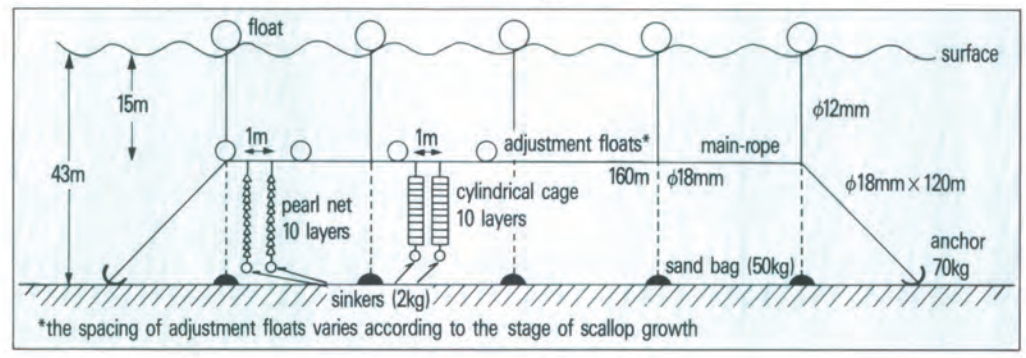


FIG. 10: Typical aquaculture facility set-up



The Aomori Prefectural Aquatic Propagation Center

An automatic sea-condition monitoring station (buoy)

A survey boat

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The background of aquaculture development

Let us consider some of the background factors that led to the development of the afore-mentioned variations of scallop culture in Mutsu Bay.

1) Seabed sowing type culture is dependent on characteristics of the sea bottom. Sand or gravel bottoms with a mud content of less than 30% are suitable for seabed sowing type culture. The species composing the benthos community inhabiting a given area also determines its suitability for this kind of culture. The areas suitable for seabed sowing type culture in Mutsu Bay are shown in **FIG. 11.**

2) Since hanging type culture is not restricted by bottom type, it can be conducted anywhere in the Bay. In order to prevent conflict with other kinds of fishery, however, scallop culture is confined only within the fishing grounds specified by the demarcated fishing rights in the Bay. **(FIG. 12)**

3) The growth of scallop in hanging type culture is faster than in seabed sowing type culture, and, since the hanging method uses the fishing ground in a 3-dimensional fashion, the hanging method is superior to seabed sowing type culture in terms of productivity per unit area. **TABLE 1**

4) Being a relatively calm sea that does not freeze over in the winter, Mutsu Bay is suitable for year-round culture operation. For this reason local fishermen began to undertake scallop aquaculture in increasing numbers. And as their investment capabilities have increased the scale of their culture operations have expanded. At present the produce from seabed sowing type culture accounts for no more than 1/4 of the total scallop production for the Bay.

Since it is the seabed sowing type culture activities that maintain the spawning stocks of scallop to produce aquaculture seeds, this fishery maintains an important place in the industry. Because scallops produced by hanging type culture are harvested about two years after birth, many of them fail to become sexually mature, resulting in insufficient spawners to replenish resources on their own. The fishery cooperative associations of the area organize local cooperative enterprises for aquaculture operators, and the members of these enterprises supply 50,000 ~ 100,000 spats of the post-intermediate stage for release in the seabed sowing type culture grounds each year. In order to prevent the senility of fishing grounds caused by excessive survival, it is necessary to reduce the no. of mature scallops regularly by dredge net. And roughly half of the fishermen take part in this work. The cooperative enterprises pay

FIG. 11: Areas suitable for seabed sowing culture

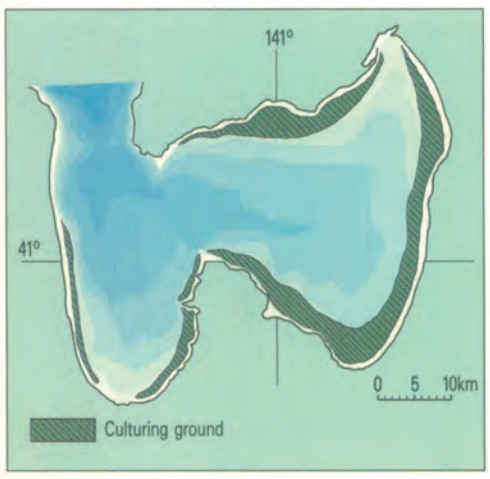


FIG. 12: Demarcated fishing right allocated to scallop culture

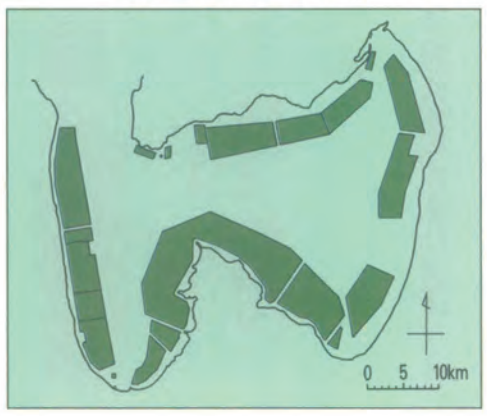
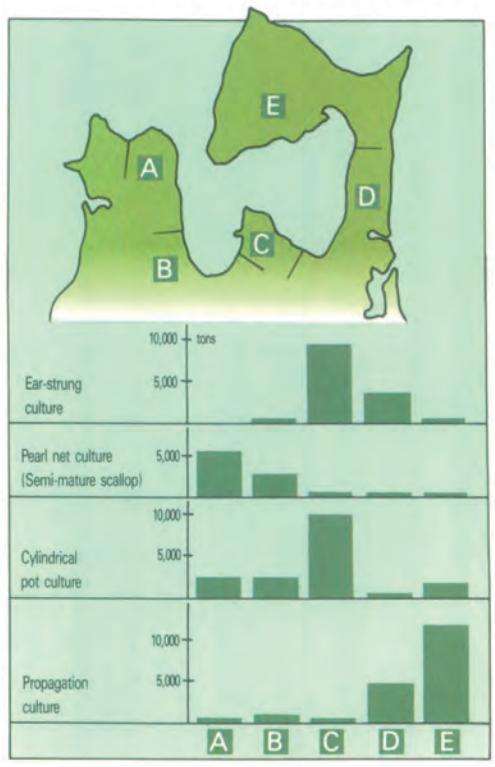


TABLE 1: Comparison of productivity of fishing grounds

	Area	production (1988)	production per area.
Mutsu Bay hanging cult.	52,000 ha.	62,400 tons	1.20 tons/ha
Mutsu Bay seabed sowing	23,000 ha.	20,600 tons	0.89 tons/ha
Sarufutsu, Hokkaido seabed sowing	38,000 ha.	29,000 tons	0.76 tons/ha

FIG. 13: Production by culture method and district (1989)



MUTSU BAY

A typical fishing port in Mutsu Bay

The office building of the Hiranai-cho Fisheries Cooperative Association

A scallop processing factory operated by Aomori Prefectural Union of Fisheries Cooperative Associations

DREDGE NET

Making use of a pulley on the mast and a side roller to a winch, the dredge portion is first heaved up and then the net portion and emptied on the deck.

The complete dredge net apparatus
width: 220 ~ 230cm
net length: approx. 270cm
net mesh: 106 ~ 120mm

EAR-STRU

Harvesting

A cutter cuts the nylon ties holdin the scallop as the string is heaved b means of a roller.

the costs of dredge net operations and divide the profits from its harvest among its members.

5) FIG. 13 shows the operating conditions of the different areas of the Bay in terms of volume of production. Seabed sowing type culture has developed most in districts E and D which contain the largest areas of suitable breeding grounds. Although cylindrical net culture became prosperous in district B around 1965, since 1970 it is district C which has shown the biggest growth in production, becoming the main producing district in the whole Bay. This exceptional development in district C is due to the large extent of the demarcated fishing right area granted to the local fishery cooperatives, the large number of fishermen in the district and the strength of the leadership within the cooperative encouraging the promotion of aquaculture.

In contrast to cylindrical cage culture which specializes in the long-term rearing of large-size scallop, ear-strung culture specializes in the short-term rearing of middle and small-size scallop. Compared to cylindrical cage culture, the financial outlay for materials is less with ear-strung culture but its operation requires more labor (**TABLE 2**). In deciding which of the two types will be better to undertake, a fisherman must consider his investment capabilities, the amount of labor available to him and the area of fishing ground he has the right to use. His decision should also take into consideration current market conditions with regard to the profitability of large, middle and small-size scallop respectively.

TABLE 2: Characteristics of the culture methods

Method	Size	# of scallops	Cost of materials	Years of use scallop	Cost per one per yr.	Labor involved in hanging
10-layer cylindrical pot	dia. −50cm length −2m	100/pot	¥1,500/pot	5~6yr.	Approx. ¥2.8	8,000~9,000 scallops/day for 1 laborer
Ear-strung	String −9m	100/string	Rope: ¥90/string Ties: ¥20/strong	Rope: 3~4yr. Ties: 1yr	Approx. ¥0.4	5,000 for 1 laborer scallops/day

6) In the past, half-grown scallop shipments from pearl net culture referred only to shipments of the scallop that were sorted out in the thinning process to maintain a desirable culture density. As of 6~7 years ago, however, sales in district A of half-grown scallop as a market product began to flourish, and a stable market for the product has been established. This market has been supported by demand from popular restaurants and catering services for smaller scallops, and special environmental factors in district A have also contributed to the decision to specialize in small-size scallop. This part of the Bay receives the strongest currents that cause losses in the culture crop when the culture period exceeds two years. Furthermore, summer water temperatures in the surface layer here are too high for scallop. These two factors have also encourage the policy of earlier shipping. More recently, an increasing number of fishermen are preferring early-stage shipment of produce as a means to speed up the rate of return on fishery investment, and this seems to be causing the spread of this practice to other regions, as well.

Note: Half-grown scallop is one with a shell length of 6~7cm.

An overview and points for consideration

At present, the areas of Mutsu Bay being used for scallop culture extend to almost all parts of the Bay with a depth of less than 40 meters. The combined annual production for seabed sowing type culture and hanging type culture in Mutsu Bay is 70,000~80,000 tons. Now the problems of finding the appropriate production scale and determining the maximum scallop production capacity for the Bay must be considered. The production capacity refers to the maximum number of cultured scallop that can be expected to undergo normal growth patterns in the Bay waters.

When calculating the production capacity of seabed sowing type culture, one must consider environmental deterioration through such phenomena as "auto-pollution" and "senility of the fishing grounds". In the case of scallop, however, the first problem becomes maintaining the food supply for the scallop during its peak growth period. Scallop become most active metabolically during the season of relatively high water temperatures from August to November. If the food supply is insufficient during this period, we see a concentrated occurrence of death among the weaker or slower-growth scallop.

Scallop feed on phytoplanktons and detritus (organic suspended matters). The total food supply is determined by the sum of the seawater production of phytoplanktons and the detritus consisting of animal excretions and effluence from rivers and seaweed beds. When calculating the food supply available for scallops in hanging culture, however, from this total you must subtract the amount consumed by zooplanktons and other filter feeders, as well as the amount that settles to the sea bottom. In the end, when deciding on limits for aquaculture activities one must take into consideration the overall profitability of the fishing grounds with regard to all the types of fisheries being conducted there.

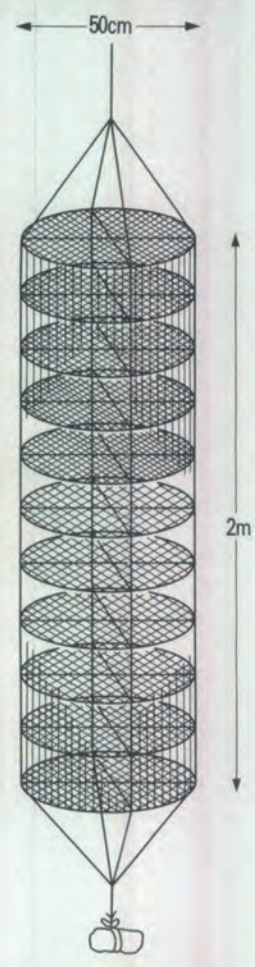
In Aomori Prefecture a total production limit has been adopted for maintaining a proper scale of scallop aquaculture activities. Culture operators here are instructed to maintain a culture crop not in excess of 1.4 billion shells as of October of each year.

CULTURE

A string of scallop for hanging

CYLINDRICAL POT CULTURE

A cylindrical cage made of 2~3cm mesh Hizex netting. A 2m tall cage is usually divided into 10 layers. An average of 10 harf-grown scallops of shells over 5cm are kept on each layer for rearing.



PEARL NET CULTURE

Harvesting. The main line is raised and hooked over hooks on the boat gunwale. Then the individual strings are raised by hand.

A pearl net. 34cm×34cm size

EXAMPLE 2

SARUFUTSU

Hokkaido

Working toward equalized income in a fishing village

The northeast coast of Japan's northernmost island, Hokkaido, is referred to as the Okhotsk coast. Sarufutsu is one of the small fishing villages that dot this long, straight coastline stretching from the Cape Soya to the Shiretoko Peninsula. Along the Okhotsk coast stormy weather continues in winter and starting from early December, drift sea-ice blocks transported by the easterly cold Okhotsk Gyre close in on the offshore area in January. Then, in the months of February and March the entire coast is blocked with sea ice. Thus, all fishing activities come to a complete halt for wintering from December through March. From the time the coast begins to clear of ice in April until November, fishermen here engage in such fisheries as horsehair crab and octopus traps, salmon set net and scallop dredge net.

The Okhotsk coast is relatively shallow with the 50-meter contour line running about 10km offshore. From a depth of 2 to 12 meters the sea bottom is mainly sand and mud, and from 12～13m to a depth of 60m the bottom is constituted mainly of gravel. The water temperature ranges from about 20°C in summer to a low of −1°C in winter.

The deterioration and subsequent rehabilitation of the fishing grounds.

Prior to World War II, the scallop production of Sarufutsu area made up a full 20 to 25% of the production for the whole of Hokkaido. After 1945, however, production dropped steadily, and with a harvest of only 369 tons in 1963, authorities were forced to put a ban on any further scallop fishery (FIG. 14). After that, the annual harvest consisted of only the few scallop that happened to be caught in the ongoing starfish clearing operations. This continuing failure of the scallop crop forced one resident after another to leave the village in search of a new livelihood.

In 1965 the Fisheries Cooperative Association of Sarufutsu conducted a resource survey on the sea bottom along its coast, and based on this survey drew up a plan for the rehabilitation of scallop resources. The fishermen strengthened their efforts at building up the fishing grounds, by intensifying their removal operations for starfish and other obstructive organisms. At the end of 1970 it was further decided to purchase seed spats from other regions and distribute them in large numbers primarily along the previously most productive fishing grounds. The following April, some 14 million seeds were released.

In exchange for a promise to deposit 5% of the its members' fishery income on a regular basis in a long-term account, the cooperative association was able to get a loan from a fisheries cooperative credit system. This loan along with a subsidy from the village government formed the investment capital for this project.

Of the 85,000 ha of fishing grounds for which the Sarufutsu Fisheries Cooperative Association held the common fishing right, it was decided that some 38,000 ha running along the coast at an offshore distance between the 1.5 and 8-mile lines would be designated for seabed sowing type culture. These fishing grounds were then divided into rectangular sectors and stocked annually according to a 5-year crop rotation schedule (FIG. 15). FIG. 16 shows the rotation of fishing grounds employed in the early stage of the project. The first clear results of the stocking operations were seen four years after the start in 1974, when a scallop crop of 1,674 tons was recorded. This was followed by 4,328 tons in 1975, 6,124 tons in '76 and 9,891 tons in '77, demonstrating that a definite rehabilitation of the scallop fishing grounds had been achieved.

FIG. 14: Changes in the catch of scallop fisheries in Sarufutsu area

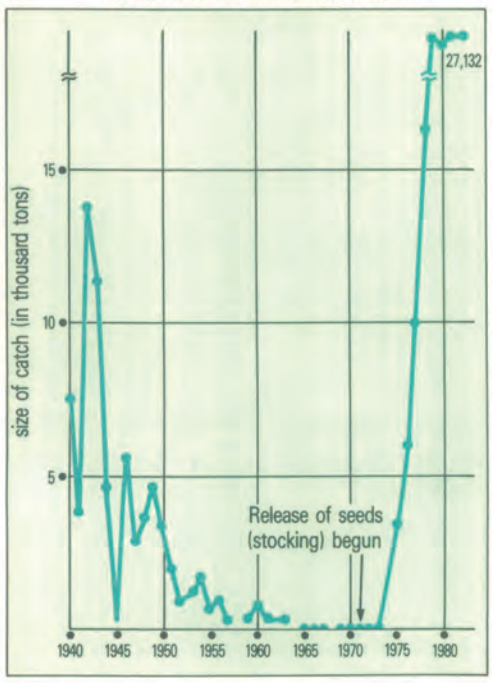


FIG. 15: The demarcated fishing grounds according to a 5-year crop rotation schedule

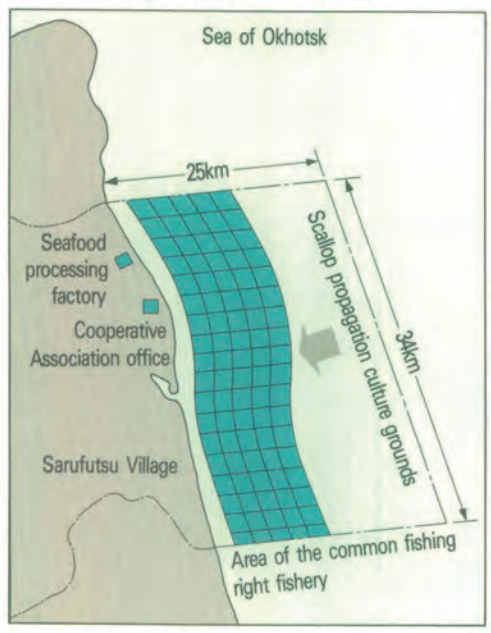
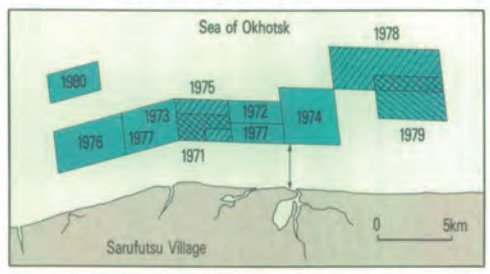


FIG. 16: Rotation of the fishing grounds employed in the early stage of the re-stocking project



The catch is loaded into a truck

The previously rich fishing grounds had been effectively revitalized. Also, as an important addition, under the leadership primarily of the local fisheries cooperative association, an improved system of fishing ground use, which had previously been left in the hands of the individual fishermen, was established.

Joint operations

At present, there are 164 full members and 21 associate members in the Sarufutsu Fisheries Cooperative Association. In its office there are 10 officers and 33 staff. The association's total catch for the year 1989 amounted to 31,000 tons with a wholesale value of ¥4.944 billion. Of this total, scallop fishery accounted for 3.79 billion (75%), horsehair crab fishery for ¥0.535 billion (11%) and set net operations catching salmon for ¥0.441 billion (9%).

Here, running of the horsehair crab fisheries, salmon set net fisheries and other assorted fisheries are all left up to the individual fishermen, while the scallop fishery alone is run as a joint business by all the cooperative members. To this end, in 1976 the cooperative convened a congress for the purpose of defining the cooperative's intentions regarding scallop fishery, and established "Scallop Fisheries Joint Enterprise Group" for the purpose of planning stocking and harvest operations and supervising the distribution of profits. Regarding the management of the Enterprise Group, a system was adopted in which the officers of the Fisheries Cooperative act as the board of directors and the auditor of the Cooperative also acts as the auditor of financial matters for the Enterprise Group. And, in addition, a distribution committee was established to preside over the distribution of profits from the scallop fishery. This committee is staffed by an appropriate number of members other than the above-stated Cooperative Association officers. At present there are 114 voting and 60 non-voting members in the Enterprise Group, bringing the total number of fishermen involved in scallop fishery here to about 180.

Every year the Joint Enterprise Group makes decisions regarding all basic matters such as fishing ground sectors to be operated, harvesting plans, amount of stocking to be done and the scheduling of these operations. The Enterprise Group owns no fishing boats or gear of its own but, rather, depends on the chartered boats owned by the individual members. At present the Group's scallop fishery activities are performed by means of 31 fishing boats of the 14-ton class owned by cooperative members and one 14-ton class seed gathering boat and 4 survey boats owned by the Cooperative.

The Enterprise Group places all scallop fishery income from all the boats into one pool, from which it pays out ① Labor costs ② Boat charter fees ③ Operating costs ④ Sales fees paid to the cooperative association ⑤ Seed costs ⑥ Fishing ground improvement costs ⑦ General management expenses.

Labor costs are paid in the form of a salary. The master fishermen (generally the owners of the boats chartered by the Enterprise Group) receive ¥330,000, boat engineers ¥310,000, deck hands ¥170,000 ～300,000 and on-shore laborers a salary of ¥200,000 a month for the ten months from March to December. (Work in March includes maintenance of the boats and fishing gear, and work in December includes dry-docking the boats and putting away the fishing gear and other materials.)

In addition to this, all workers receive bonuses, based on the year's production and profit dividends are paid to all Enterprise Group members. In recent years production has been so good that veteran members who do not own a boat may make as much as ¥10 million a year. The following shows the planned balance sheet for the Enterprise Group in 1990:

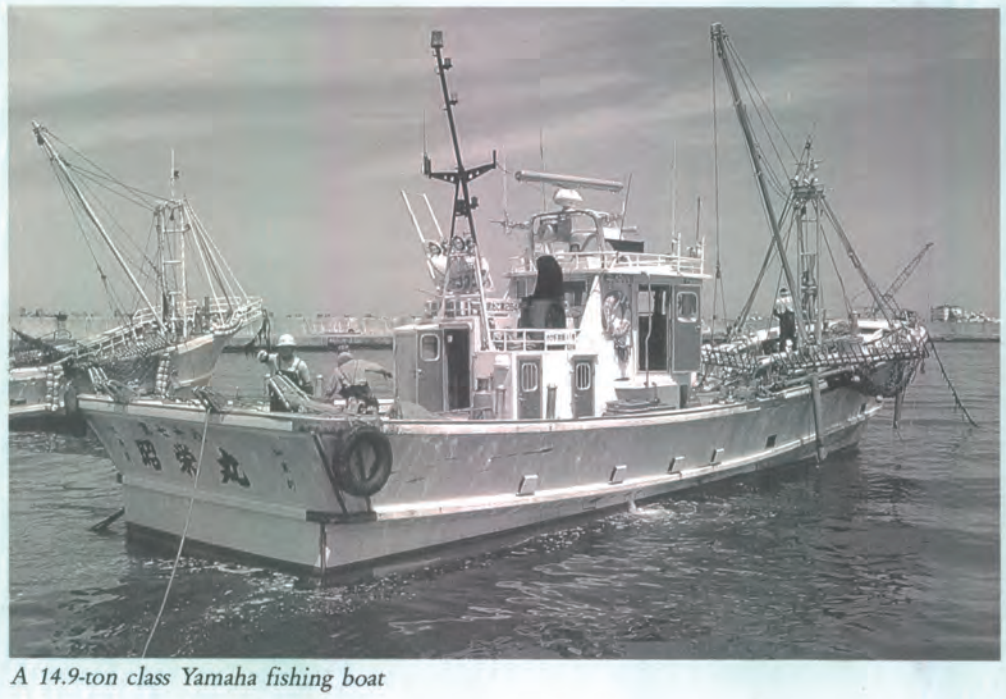
- Planned landing ..... 29,000 tons
- Income ..... ¥4.35 billion
- Expenses ..... ¥2.099 billion
- Net profit ..... ¥2.251 billion
- Net profit rate 51.7%

Propagation policies and fishing ground management

The transformation of this once devastated fishing ground into the leading scallop producing area in Hokkaido, can be explained by the following factors: First of all, the fishermen succeeded in artificial reformation of the benthic community in the

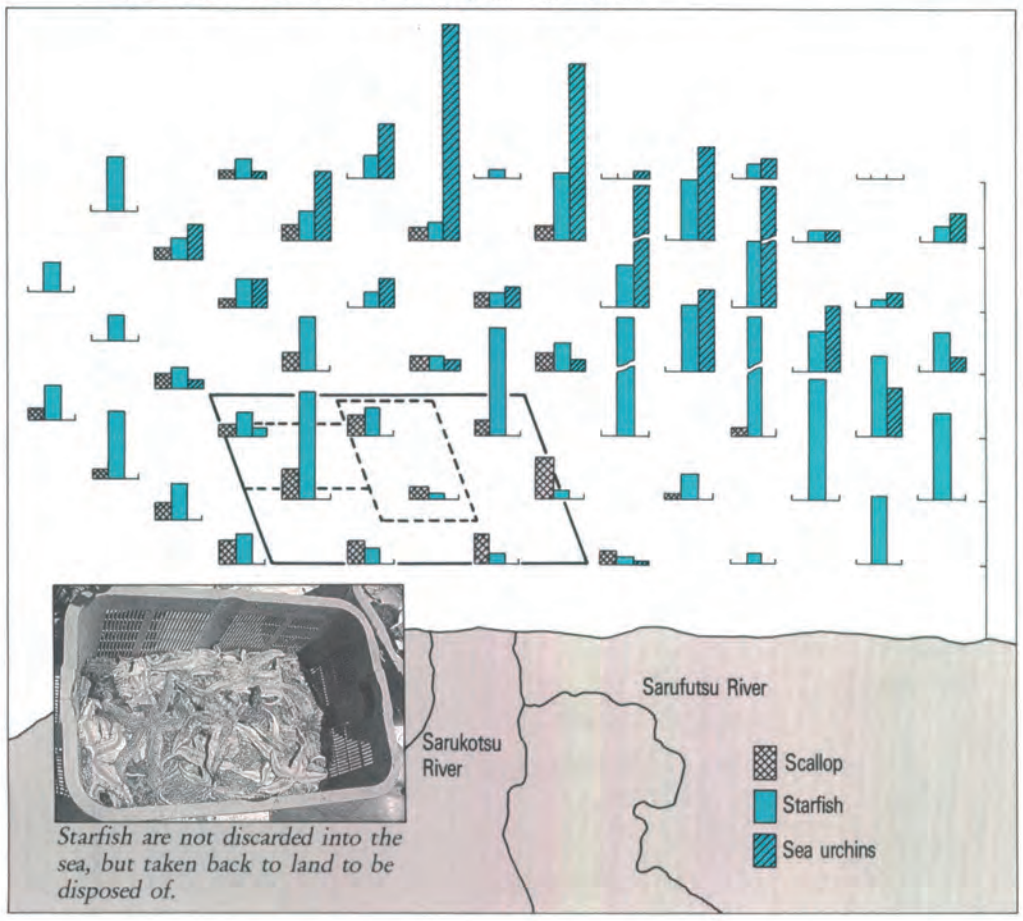
SCALLOP AQUACULTURE IN JAPAN

The fishing port and fisheries cooperative facilities at Sarufutsu



A 14.9-ton class Yamaha fishing boat

FIG. 17: Number of individuals of scallop, starfish and sea urchins inhabiting the Sarufutsu area in 1965 (number per 100m²)



Starfish are not discarded into the sea, but taken back to land to be disposed of.

region, and secondly, a profound resource propagation effect was achieved by releasing large numbers of seed spats. In a survey of the fishing ground performed in 1965 before the start of stocking operations, it was found that distribution of large-size benthos organisms in the Sarufutsu area was scallop 16%, starfish 62% and sea urchins 21%, with starfish and sea urchins being the dominant benthos over large areas of the fishing grounds (**FIG. 17**). Although some 0.05～1 million scallop seeds were released each year during the period when any scallop fishery was prohibited, scallop succeeded in dominating only in the areas of sand and gravel bottom. More than half of the scallop even in these areas were older shells with very few younger shells observed. Because the conditions over much of this area had become poor for scallop young to settle down, the scallop stock was unable to maintain enough reproductive potential to dominate.

Successful propagation of resources requires the simultaneous undertaking of two separate operations:

1) Formation of fishing ground condition: Starfish and sea urchins must be cleared continuously from sea bottom deemed to be suitable as scallop habitat.

2) Large-scale stocking with healthy seeds: Healthy scallop spats that have reached a shell length of over 3cm and acquired the ability to choose a favourable bottom type and withstand environmental stresses must be released in large numbers into well-cleared fishing grounds. However, stock density must not exceed 5 or 6 shells per square meter.

If the number of scallop is increased in the above way, and if they regain their function as a self-renewing stock, they can be expected to cause a large-scale succession to take place in the benthic community in the region, thereby bringing about an increase in scallop fishery production.

At this point, theory about resource propagation methods is divided into two courses:

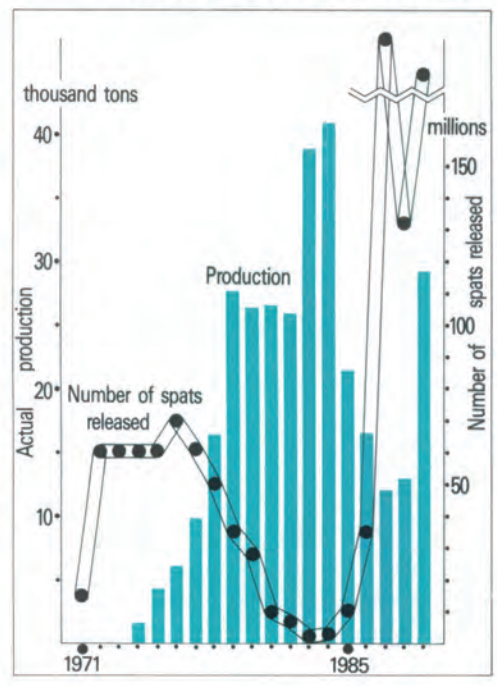
(1) The method of releasing spats in order to create a stock of mother shells with the aim of strengthening the reproductive capacity of the resources.

(2) The method of stocking well-cleared areas of fishing ground with large numbers of spats with the aim of raising a stock of mature shells that can be harvested completely without concern for reproduction.

From 1972 to 1977 the Sarufutsu Scallop Joint Enterprise Group continued to release about 60,000 scallop spats a year. But, by 1978 naturally occurring scallop had been found to be growing in all parts of the fishing ground. Consequently, the number of seeds released was reduced beginning in 1977, and, with the exception of a few experimental stocking areas, from 1981 to 1985 all stocking activities were brought to a halt. This measure was taken because it was decided that the female shells had recreated a sufficient cycle of natural reproduction. However, after two years of large harvests of mature scallop in 1983 and '84, two years of diminished catches followed in 1985 and '86. In response to this trend the Enterprise Group decided to conduct a complete harvest of the older scallops and to resume stocking the grounds with spats again as of 1986. After this the Group changed its propagation policy to one of stocking given areas of the fishing grounds every year with 200 million spots, the amount needed to yield an eventual crop of 20,000 tons, and to harvest the seeded areas completely after 5 years (**FIG. 18**). One of the leaders of the fisheries cooperative here analyses the situation in this way: "The fishing grounds available for resource propagation in Sarufutsu are large, and we know that the sea bottom is quite stable in terms of quality and that released seeds do not move any considerable distance. We believe this is why we experienced a natural occurrence of sudden population growth and the resulting disruption of production here. When deciding on one's propagation method, you should choose one of the two methods based on sea conditions and the characteristics of the fishing grounds of your area."

The Enterprise Group here in Sarufutsu conducts yearly surveys by collecting scallop, starfish, sea urchins and other benthic

FIG. 18: Number of spats released and actual production harvested



organisms at 116 stations around its fishing grounds to monitor the growth of the scallop crop and the ecological change in the community on the sea bottom.

Continued on next page

Mass Mortality

When conducted under favorable conditions the survival rate of seed spats reaching adulthood in hanging culture is considered to be 80～90%. When the mortality rate among shellfish in culture exceeds 30～40%, it is considered an outbreak of "mass mortality".

Such an outbreak of mass death among scallops in hanging culture in Honshu's Sanriku coast occurred in 1972～'73, but the cause was never identified. In 1975 when an outbreak of mass mortality occurred in Mutsu Bay, some 1.3 billion spats and half-grown scallop died, causing a fishery loss of about ¥1.7 billion. Then, in 1976 and again in 1977 mass mortality appeared in Hokkaido's Funka Bay. At this point, mass mortality in scallop culture came to be treated as a major problem.

Concerning its cause a number of theories emerged, including an abnormal sea conditions theory and a disease causing bacteria theory. As a result of government studies of the localities where mass death occurred, and studies by the Aomori Prefectural Aquatic Propagation Center using actual demonstrative experiments to determine proper culture intensity for fishing grounds, it is now believed that mass mortality occurs as a composite result of the following factors:

(1) A rearing environment with a stock density greatly exceeding that of the scallop's natural life would have caused biological disturbances on scallops. In combination with sudden changes in the sea conditions or high water temperature, the physiological devastation produced such phenomena as insufficient shell development, coloring of the inside of the shell, withering of the mantle, etc., that eventually lead to death.

(2) The sudden expansion of aquaculture activities and the resulting increase in the number of shellfish under culture would have caused the fishermen to become rough in their handling of the shellfish in culture, which resulted in a general deterioration in culture techniques. As a result a large number of unhealthy seed spats would have been introduced to the fishing grounds, increasing the danger of mass death.

Since 1978, the productivity of scallop culture in Mutsu Bay has begun to recover. This recovery is a result of the realization of the futility of overly-intense culture activities on the part of the fishermen, and the resulting substantial reduction in the number of shellfish they try to raise in one cage. Furthermore, they have become more careful in their handling of the shellfish, taking care not to cause them unnecessary shock at times of stock thinning or cage cleaning.

Continued from previous page

An overview and points for consideration

A form of fishery based on the combination of resource propagation and joint management can be thought of as one form of what is being championed in Japan today as "resource management oriented fisheries". Shellfish and crustaceans spend their lives in a fixed area, and for this reason they can be caught with a high degree of certainty. But, for this very reason, the pressure of overcatching can be acute. And this makes it one of a group of fisheries for demersal resources for which the above mentioned characteristics are often seen. In other fisheries cooperatives engaged in scallop fishery along this same Okhotsk coast besides Sarufutsu, we see similar types of fishery management formulas.

Fishery based on resource management has as its main concept the maintenance of marine resources while seeking to develop and expand local fisheries. And, as its basic goals, the following three objectives must be cited:

1) Establishment of an optimum operating system that is compatible with fishing grounds and resources.
2) Equalization of fishing family income based on a reasonable allocation of resources.
3) Rationalization of operations and management of fishing to provide a stable economic base for the fishing family.

In the case of Sarufutsu's scallop fisheries, what we see is a situation in which the fisheries cooperative association holds, by law, the fishing grounds of the Common Fishing Right fishery for scallop and has the responsibility for the management of those grounds and directly participates and at times intervenes in fishing rights it has legally granted to its members in order to coordinate and regulate fishing activities in line with the above three objectives.

Having faced the crisis of ruined fishing grounds together 20 years ago and the hardships that followed, surely instilled the fishermen of Sarufutsu with the cooperative spirit and sense of solidarity that has led to the present system of joint fishery operation. But, at the same time they have also been blessed with the following advantages that can not be ignored:

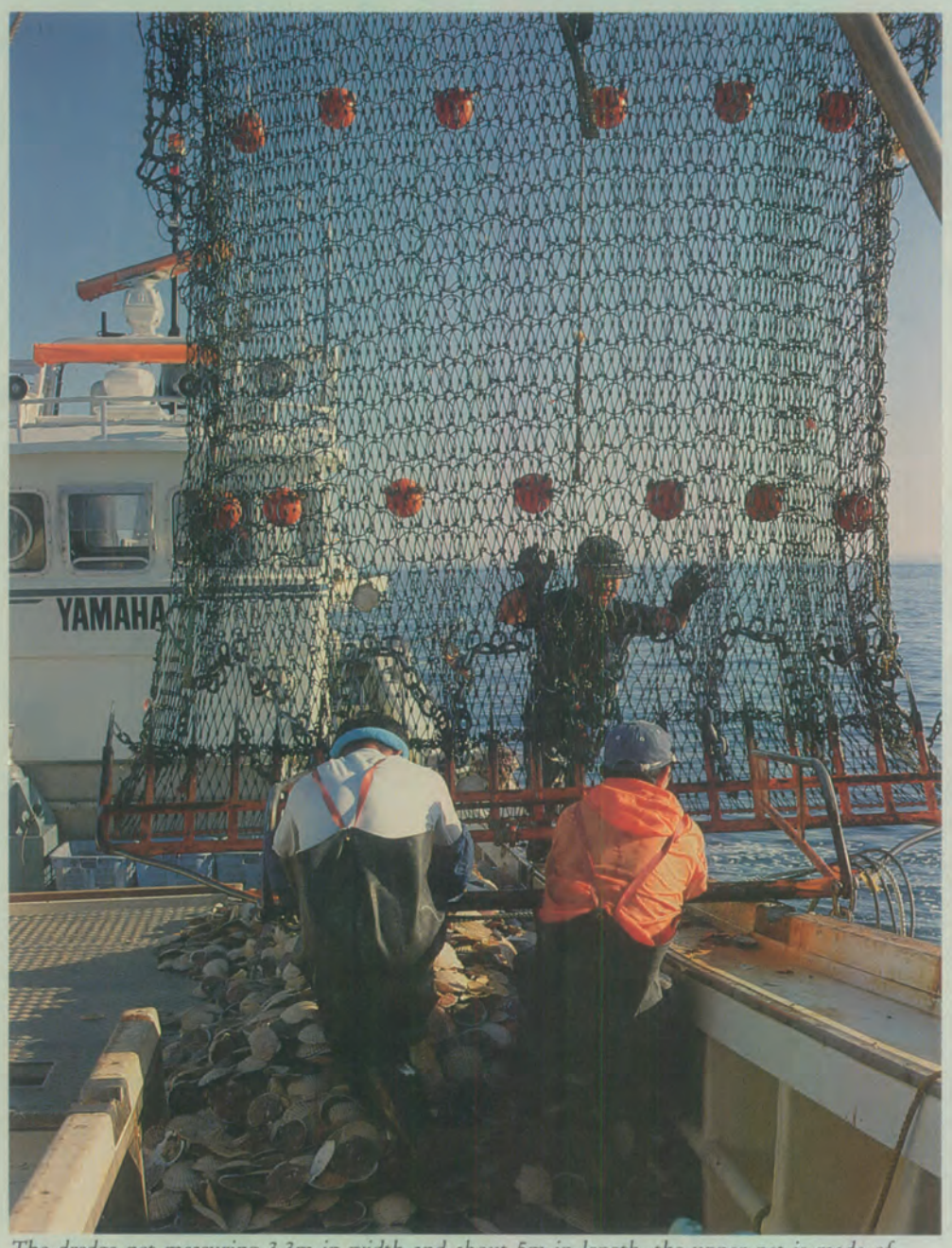
1) The Common Fishing Right granted here covers a large area, making the fishing ground per fisherman large.
2) They were blessed with scallop resources, a shellfish with especially good potential for propagation.
3) There was no complicated intricacy with the fishing rights of other existing types of fisheries, so the fishermen in different types of fisheries were able to segregate from each other in the fishing grounds to operate.
4) They were blessed with excellent leadership in their fisheries cooperative activities.

Up until now, the Sarufutsu Fisheries Cooperative has been able to promote the expansion of their scallop fisheries economy to the point where a "redistribution of profits" has been possible. And with this, they have been able to provide their members with fair and equal incomes while maintaining a "resource management oriented" approach in their fishing activities.

In the future, the following two subjects are the ones that will most likely become the focus of concern here in Sarufutsu:

1) Since 1986, the Enterprise Group has adopted a program based on a planned annual production of 20,000 tons. This decision is founded on the assumption that a decrease in shell size of mature scallop in recent years indicates that they are near the upper limit of the productive capacity of their fishing grounds. With this limit set, the group must now decide how they will deal with the anticipated drop in market prices as scallop becomes more of a "mass market commodity".
2) At present, qualifications for entering the Enterprise Group are extremely strict. With a planned production level set at 20,000 tons annually, the number of fishermen involved in scallop fishery has necessarily been limited to 180～200. Within this relatively closed framework, one of the biggest problems confronting the Enterprise Group is how it will train the next generation of fishermen and how it will keep a smooth turnover among the members in leadership positions.

DREDGE NET



The dredge net measuring 3.3m in width and about 5m in length, the upper net is made of nylon with a mesh of 13.5cm, while the lower net features chains strung to the mouth section of the net and a metal net made of interloped rings for the portion of the net that drags along the sea bottom.

The total weight of the fishing gear is about 350kg. With a 650hp engine the boat pulls two nets, one from each side of the boat.

The fish hold

Sorting is done by hand. Small scallops and empty shells are thrown out and large scallops are stored in the fish hold.

Landing the catch

A detailed survey of the growth conditions of scallop at the Sarufutsu Fisheries Cooperative. Specimens collected from 116 locations are measured for shell length, shell height, weight, inner yielding weight etc. to monitor the growth of the scallop resources in the fishing grounds.

Processing methods for scallop

Scallop is a seafood with taste of all its own. The secret of its delicious flavor lies in its high content of amino acids. As well as being eaten fresh, a variety of traditional processed products have evolved including dried scallop adductor, boiled scallop, canned, smoked, and other scallop delicacies. And more recently, a variety of other new local products have been developed, accompanied by an array of new marketing activities.

Uses of scallop and the distribution system

Scallop is a product with extremely good commodity value. It is sold commercially for various uses at all stages of its growth, from spats for tsukudani to half-grown and fully-grown scallop. In the days when only naturally occurring scallop were collected, those shipped to market were mainly large shellfish weighing more than 100g. Since the onset of scallop aquaculture, however, the sizes of scallop marketed have diversified considerably. In the case of Mutsu Bay, the make-up of scallop shipped to market can be summarized by culture type as in **TABLE 3.**

TABLE 3: Scallop products from Mutsu Bay

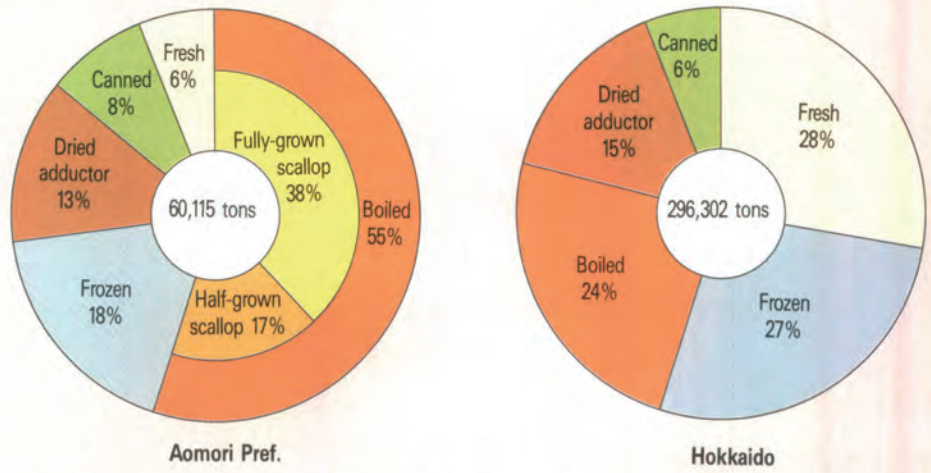
Culture type	Culture period	Shell length	Weight in shell	Price per kg in the producing area (1989)	Use of scallop
Seabed sowing	38 months	10 ~ 12cm	Approx. 100g	¥195	Fresh adductor, Dried adductor & Boiled scallop
Ear-strung	15 ~ 18 months	8 ~ 9cm	Approx. 70g	¥205	Canned scallop & Boiled scallop
Cylindrical pot	24 ~ 27 months	Approx. 12cm	170 ~ 200g	¥213	Fresh adductor & Dried adductor
Pearl net (Semi-mature shellfish)	12 ~ 16 months	6 ~ 7cm	Approx. 50g	¥174	Boild scallop

The ways in which scallop has been processed over the years has undergone considerable changes. Up until the 1960s, most of the scallop production was processed as dried scallop adductor. Entering the mass production age of the '70s we first of all see a growth in demand for fresh scallop adductor. Since the shellfish toxin problem occured in 1978, however, there has been a decrease in shipments of fresh scallop and an increase in boiled scallop.

In 1989 the combined scallop production of Aomori Pref. and Hokkaido was some 356,000 tons, and of this 87,000 tons (24%) were shipped as fresh scallop, 113,000 tons (32%) as frozen scallop, 82,000 tons (23%) as boiled scallop, 52,000 tons (15%) as dried scallop adductor and 22,000 tons (6%) as canned scallop. The frozen category includes both frozen boiled scallop and frozen raw scallop adductor. One of the major trends in the seafood industry as a whole is the recent increase in frozen products, and scallop is no exception to this rule. The increase in frozen products has also served to expanded the distribution network to include new regions. Until the mid-70s the distribution network extended no farther than Tokyo, but now it has spread to include the Kansai area and Northern Kyushu as well.

In the different producing areas of Hokkaido and Aomori we also see distinct patterns

FIG. 19: Uses of scallop (1989)



of scallop shipments. (**FIG. 19**) In addition to dried adductor, Hokkaido used to deliver mostly fresh products either raw in the shells or shucked, since the products were destined primarily for urban areas within Hokkaido including Sapporo, the largest consuming capital city of the region. With the increase in production since the '70s, however, sales routes were expanded to Honshu, a fact which was accompanied by an increasing proportion of frozen products. Now, 70% of the frozen products consumed in Japan come from Hokkaido.

In Aomori Prefecture, boiled products were traditionally the main form. With the popularization of shipments of half-grown scallop in recent years here, the proportion of boiled products has increased even further.

The onset of stable production of scallop on a large scale has also served to increase the mass market demand for scallop. In answer to this demand there has been a further growth in the scallop processing industries in the producing areas turning out frozen, boiled and dried products, etc. The result has been the formation of respective supply structures that fit the unique regional characteristics of Hokkaido and Aomori Prefecture.

* * *

Since the emergence of the shellfish toxin problem in Japan, the midgut gland where fat-soluble toxins accumulate is removed before shipping, not only from fresh scallop but also from boiled products. And in Hokkaido, there is a public health ordinance prohibiting the shipment of fresh scallop in the summer months when *Gonyaulax* sp., which is believed to be the origin of water soluble shellfish toxin, is most likely to proliferate.

* * *

Today, scallop ranks as one of Japan's important marine exports. Dried scallop adductor is exported to Hong Kong and other destinations like the U.S.A., Singapore and Taiwan at a rate of about 100 tons (product weight) per year. And about 6,000 tons of frozen scallop is exported to such countries as France, the U.S.A. and Canada. In the French market, in particular, the demand is for frozen adductor with ovarian eggs attached.

BOILED SCALLOP

Demand is growing for the product as a material for family-style restaurants and as a delicacy for household cooking. Middle size scallop are used, and the product yield recovery is 25 ~ 30% against the weight with shell.

1 BOILING

To make sure the meat is boiled to the very center, the scallops are kept in boiling water for about 10 minutes.

2 SEPARATING FROM THE SHELL

The meat is separated from the shell on a vibrating conveyer.

3 COOLING

The meat is washed in iced water and then cooled in cold water for about 30 minutes.

Boiled scallops. After this the midgut gland is removed and the meat frozen.

4 REMOVING THE MIDGUT GLAND

The midgut gland alone is removed by hand.

5 FREEZING AND GLAZING

After freezing the outer surface is glazed with ice to prevent changes in product quality during refrigeration storage.

6 PACKAGING

After sealing the scallop in plastic bags they are packed in boxes for shipping.

The product to be shipped

DRIED SCALLOP ADDUCTOR

Dried scallop adductor is used for various types of cuisine after it is made soft again by soaking in water.
The average yield recovery of dried products is, though variable by season, about 3% against raw material with shells.

The raw material

1 FIRST BOILING

The raw shellfish are washed in a warm water shower and then cooked in boiling water at a temperature of 90～100°C for 7～10 minutes. The cooking is continued just long enough to open the shells.

First boiling cauldron

2 REMOVING THE SHELLS

The shells are opened on a vibrating conveyer. The shucked meat of the scallop is then dropped through holes in the conveyer panel and separated from shells.

Separation from shells

4 SEPARATING OUT THE MEAT

On a work table the mantle and midgut gland are separated from the shucked meat, taking care not to damage the adductor meat while removing the membrane that surrounds it.

Picking up adductor meat

3 WASHING AND COOLING

The meat is cooled in a flow of cold water.

Cooling

Washing

5 SECOND BOILING

The second boiling determines the quality of the final product. The meat pieces are placed in baskets, then put in a boiling pot, and after the water reaches a boil again they are boiled for 5～10 minutes depending on the size of the adductors. With successive boilings the salt density in the boiling pot dilutes, so salt must be added periodically.

After second boiling

6 COOLING AND BROILING

To ensure prompt removal of moisture from the inner part of the meat and promote contraction, the adductors, placed on drying screens and stacked on carts and taken to a drying room where they are broil-dried by means of a hot-air drying device at 90°～100°C for 40～60 minutes.

Broil-drying

Drying adductors

7 NATURAL SUN DRYING

The scallop adductors are next dried under the sun until moisture content reaches about 16%. Care must be taken of the fact that direct sunlight with high temperatures can cause a darkening of the meat colour.

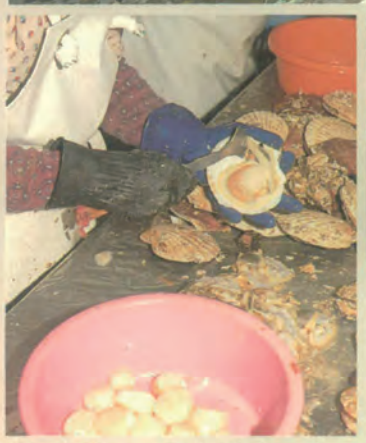
Natural sun drying ground for producing dried adductor

8 SORTING

The scallops are sorted according to size and boxed.

FRESH SCALLOP ADDUCTOR

Large size scallop are used as a high-quality material for raw "sashimi" or "sushi".
The fresh scallop adductor meat is shipped in ice or refrigeration.



The shelling work for fresh scallop

Extracting the meat

1 SHUCKING

The shell is opened by hand, the mantle and midgut gland removed and the adductor meat extracted.

Portioning by weight

2 COOLING

The meat is washed in iced water and cooled in cold water for 10～15 minutes.

Washing and cooling

Packaging

3 PACKAGING

After weighing and sealing in plastic bags the product is placed in ice and shipped by isothermal carrier truck.

Packing in ice

Shipping

(Note) The mantle of the scallop is used as a material for "tsukudani", assorted pickled seafood, "shiokara" and other delicacy items.