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ABALONE AQUA-CULTURE

Tradition and Innovation

A female releasing eggs

Photo courtesy of Nagasaki City Fishery Center

Abalone is a type of conch belonging to the family Haliotidae of the class Gastropoda. It makes its habitat in rocky reef areas of coasts facing the outer sea, feeding primarily on seaweeds and demonstrating rather limited mobility. Approximately 100 species of abalone are found around the world, inhabiting both the northern and southern hemispheres. Most cold water and tropical zone species tend to be small in body size and distributed in small numbers. The larger species that are useful for commercial fishery are found in the temperate zone. The countries that catch abalone commercially include Japan, Korea, the Pacific coast countries of North America, South Africa, Australia and New Zealand, etc., and in recent years the annual worldwide catch totals 13,000 ~ 15,000 tons. **(TABLE 1)**

TABLE 1: World Production of Abalone Species

(in tons)

	1986	1987	1988	1989
Japan	4,511	4,189	3,913	3,571
South Africa	683	680	676	562
Australia	7,100	6,700	6,800	5,500
Korea	466	319	278	282
Canada	52	49	48	43
Mexico	1,262	1,502	1,992	1,914
U.S.A.	368	500	1,308	1,287
New Zealand	830	700	267	319

(FAO statistics)

In Japan, the annual catch of abalone is around 4,000 tons, making it second largest of conch catches after top shell (turbo). At present Japan imports about 1,000 tons of fresh, frozen and refrigerated abalone annually from China, Korea and New Zealand, and about 1,000 tons of canned abalone and several hundred tons of processed (cooked) abalone from Australia. In addition, Japan exports several dozen tons of dried abalone to Hong Kong and Taiwan.

Mankind has used shellfish as a food source since prehistoric times. In the case of Japan, it is believed that hunting and gathering began to be replaced by agriculture in the Yayoi Period (*circa* 300 B.C. ~ 300 A.D.). There is evidence that from this period man engaged not only in gathering shellfish and seaweeds along shores and tidelands, but also developed fishing techniques and boat-building techniques that enabled him to venture into offshore waters to catch fish and shellfish. In a Chinese historical document dating from around 300 A.D., we find mention of a region of Western Japan which says, "The inhabitants chose to make their living by catching fish and abalone. They dive in any part of the sea, shallow or deep, to make catches of these seafoods."

Of all shellfish, abalone is regarded as the greatest delicacy in Japan, and thus draws the highest market price. In Europe and America abalone is usually prepared by pounding the meat to soften it before grilling or deep fat frying. But in Japan, abalone is preferred in the raw state as sashimi or the marterial for sushi. Since olden times there has also been a tradition of processing abalone by boiling and then heat-drying it. Furthermore, the shells of abalone have been traditionally used as a material for craft articles or for processing into buttons. As an example of the special value the Japanese attach to abalone, we must mention its traditional use as "noshiawabi." Since olden times, abalone has been cut into long, thin strips and dried to make "noshiawabi" as a sacred offering made to shrines at festival times. Later, abalone came to be used as a greeting symbol to be added to the gifts of special significance to be given at celebrations such as weddings, much as one might send a greeting card today. Thus, the abalone came to be associated in Japanese culture with felicitous occasions.

In China, as well, abalone has long been a highly prized delicacy. Dried abalone, like dried sea cucumber and shark's fin, is an irreplaceable ingredient in many Chinese gourmet dishes. In the Edo Period of Japanese history (17th ~ 19th centuries), abalone was one of the most important seafoods exported by Japan to China, and this export was one of the main markets supporting the abalone fishery industry in Japan at the time. Today, the traditional fishery techniques for abalone and the special value that the Japanese attach to the abalone reminds us of the anthropological culture that has spread widely throughout the East Asia.

Abalone is caught in all the coastal prefectures of Japan with the exception of subtropical Okinawa. For many generations, the fishermen of the different regions of the country have formulated policies to govern the preservation of abalone resources in their waters. Following World War II, we have seen large-scale efforts in Japan to transplant the cold water species "ezo abalone" to temperate zone waters. Also, in recent years, artificial production of abalone seeds and release in the natural sea environment are being practiced in all regions of the country. With these efforts, the shift has begun from traditional gathering-type fishery to aquaculture-based fishery.

Within about 30 hours after hatching, the abalone young transform from tocolophore to veliger, and by about the sixth day begin to crawl around on the sea bottom. Young abalone are induced to attach themselves to spat collection vessels in which appropriate diatoms have been grown that are placed in the tanks 3 ~ 4 days after hatching. The young feed on the attaching diatoms until reaching a shell length of 4 ~ 5mm. After this they are fed either soft seaweeds or composite feeds recently developed especially for abalone culture.

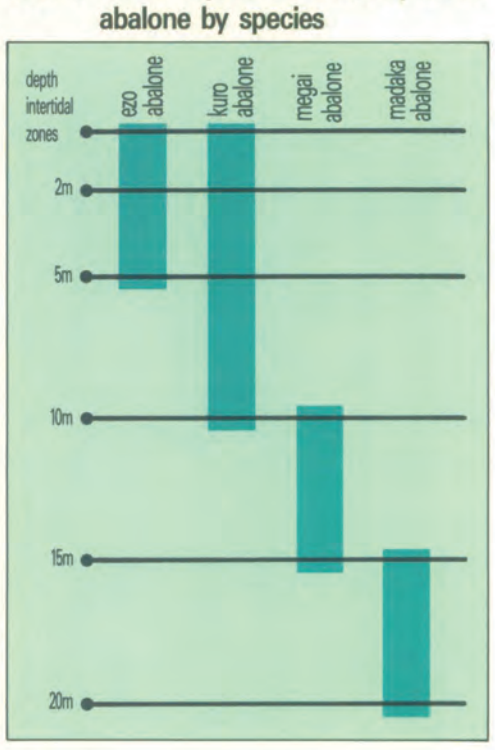
A mode of life well suited to reefy coast areas

Ezo abalone and sea urchin on the sea bottom. Ezo abalone is the only species of abalone inhabiting the cold water regions of Japan. Bottom areas deeper than five meters or more are the habitat of sea urchin, but in some areas abalone and sea urchin coexist.

There are ten species of abalone inhabiting the coastal waters of Japan. Of these, the four species of primary commercial value include the three temperate zone species "kuro abalone", *Haliotis discus*, "megai abalone", *Haliotis sieboldii* and "madaka abalone", *Haliotis gigantea* and the cold water species "ezo abalone", *Haliotis discus hannai*. Among these, ezo abalone is thought to be a regional variety of the kuro abalone. Two other temperate zone species inhabiting shallow rocky reef areas, "tokobushi", *Haliotis diversicolor supetexta* and "futokobushi", *Haliotis diversicolor*, are also caught commercially, but the small size of the shell and the limited amount of resources make them less important commercially than the abovementioned four species.

In the abalone genus, different species tend to make their habitats at different depths. **(FIG. 1)** The four species, ezo abalone, kuro abalone, madaka abalone and megai abalone inhabit successively deeper waters in the order listed here. Ezo abalone are distributed primarily at a depth of 4～5 meters, while the habitat of madaka abalone reaches depths of 30～50 m. For ezo abalone, a method by which a long hook and glass-bottom box are used to catch them from on board a small boat has been developed. But the temperate zone species living in deeper waters are caught exclusively by diving methods.

FIG. 1: Water depths inhabited by adult abalone by species



In the abalone genus, there is dioecism (sexual differentiation individually between male and female) and fertilization occurs externally. After hatching, the young float in the water for 3～4 days before descending and attaching at the sea bottom where they take up benthic life. The spawning period for abalone differs by species and even within the same species depending on habitat and sea conditions. In the case of ezo abalone, the spawning period varies considerably, from late July to early October or from mid-September to late November. But, in either case, the water temperature at peak spawning time is about 20°C.

Abalone make their habitat in rough waters with rocky reef bottoms, and their flattish, fan-shaped shells that are thick and strong, are well suited to such an environment. Nocturnal by habit, abalone spend the daytime firmly attached in the crevices of rock formations or to the sides of rocks, but at night they begin to move about in search of food. Generally speaking, abalone are strongly sedentary, and if food is abundant they tend to move about very little.

After entering their benthic life, the young feed on diatoms growing on the rocks and stones. Upon reaching a shell length of 4～5mm, they begin to feed on small, soft seaweeds. Adult abalone feed on a variety of seaweeds including kelps, wakame, sea oak, thick-haired codium, sea lettuce, etc. However, abalone do display preference and are selective to some degree in the types of seaweeds they eat. Feeding experiments in which abalone are given a variety of seaweeds show them to be strongly selective in an order from brown seaweeds to green seaweeds and finally red seaweeds.

The abalone's growth is subject to seasonal changes. First of all, feeding activity and growth are closely related to water temperature. And in the case of ezo abalone, movement becomes extremely slow and feeding virtually stops when the water temperature drops below 7°C. A temperature range of 15～20° is best suited for growth. Besides water temperature, such biological factors as gonad maturity and spawing also have a big effect on growth. During periods of sexual maturation and spawning there is a drastic drop in the amount of food consumed. And when spawning ends, the abalone's appetite quickly returns, accompanied by an increasing rate of weight gain.

Generally speaking, growth rate for abalone is slower in the higher latitudes. In the case of ezo abalone, for an individual to grow to sexual maturity in Hokkaido requires 5～7 years, while in Miyagi Prefecture it requires 4～5 years, in Ibaraki Pref. 4～6 years and in Mie Pref. 4～5 years.

The main factors influencing the abalone's life environment are water quality, tidal flow, rock quality, sea bottom topography, seaweed makeup and presence of predators. The areas where the floating abalone larvae first descend to the sea bottom are always shore areas facing the outer sea with relatively mild tidal currents and where eddies tend to form. Young abalone of one to two years are most often found in crevices or indentations in rocks at a depth of 0.5～1 meter. In areas where the stones on the bottom tend to roll, they are found attached to the sides of stones. As they grow, the abalone move offshore to areas with rough waves and strong currents where seaweeds proliferate. Concerning the rock quality of the habitats they choose, it seems that smooth, soft-surfaced aqueous rocks are more suitable than rough, hard-surfaced igneous rocks.

Among the external factors inhibiting the growth of abalone populations, predator species that feed on the abalone have a particularly large effect. Octopuses are the primary predator, but young abalone are also fed upon by such fish as rays, sharks, sea bream, moray, surf perch and flatfish. When making attempts to transplant or engage in aquaculture of abalone in natural sea areas, it is essential to first study the makeup of the given ecosystem and take measures to eliminate potentially harmful predator species.

Abalone dried to a bright yellow or reddish color. After removing from the shell, the meat is placed in saltwater and kneaded clean to remove wastes and mucous before being rinsed in fresh water and boiled for about 20 minutes. The boiled abalone meat is then either sun-dried or dried in a oven under low heat.

Photo courtesy of Iwate Prefectural Union of Fishery Cooperatives

In search of a resource-management type fishery

The adoption of 200-mile national jurisdiction in the world's oceans during the 1980s has served to make the Japanese fishery industry aware of the importance of establishing "resource-management type fishery."

In order to put into effect a system of resource-management oriented fishery, it is first necessary to identify the biological mechanism of reproduction for the marine resource that is the object of the fishery. It must also be taken into account, however, that there is a complicated interrelationship between the organisms in the food chain of any particular ecosystem. Also, it must be known that great differences exist between species concerning the conditions of their life environment and/or their life cycle from birth through growth and spawning. Generally speaking, fishery resources can be divided into three main categories; 1) marine animals and plants such as shellfish, seaweeds and other sedentary, bottom-dwelling organisms like sea urchine that inhabit shore areas; 2) semi-sedentary (territorial) bottom-dwelling fishes that grow while repeating limited deep-shallow migrations between the shore and offshore waters; and 3) migratory pelagic fishes whose migrations cover wide areas of offshore and ocean waters. When creating a model for resource-management type fishery, each of these three categories must be approached differently.

In Japan, abalone species are one of the main fishery resources of shore areas. In this issue we will review the tradition of abalone fishery and look at innovative new techniques now being tried, as we consider the direction along which the abalone industry is moving in search of an effective form of resource-management type fishery.

Of course, long before the term resource-management type fishery came into use, Japanese fishermen had learned about the importance of resource management by experience. And, with this need in mind, they have made efforts since long ago to establish a sustainable basis for their own fishing operations. These efforts have been especially conscientious in the case of shore fisheries centered around abalone gathering. The history of these efforts leading up to present day resource-management fishery can best be viewed in terms of three stages;

(1) the stage of seeking stability
(2) the stage of seeking development
(3) the stage of overcoming the conflicting factors in the conditions required for stability and for development.

At present, abalone fishery is in stage (3), with fishermen adopting fishery plans aimed at solving the conflicts involved in achieving stability and development.

The stage of seeking stability

Abalone, which attach themselves to rocks in reefy coast habitats, are sometimes caught in bottom gill nets used to catch bottom-dwelling fishes. But the two main fishing methods by which they are usually caught are the diving method and the hooking method. **FIG. 2** shows the coastal abalone fishery areas in Japan. Although there are some exceptions, in general the hooking method is used in the ezo abalone zones of Hokkaido and the Tohoku region, while the diving method is used in the kuro abalone zones of the Kanto region and Central and Western Japan. And, with regard to any one region, the fishing method is unified so that all the fishermen use the same method. Although this choice takes

FIG. 2: Abalone producing areas and major sea currents around Japan

into account the fact that ezo abalone are found in shallow waters and kuro abalone and other temperate zone species in deeper waters, it is usually a reflection of the regional traditions of fishing techniques.
In the ancient social system, the job of the fisherman was a hereditary one passed on from father to son within certain families and under the authority of the Imperial court. In the latter part of the middle ages, as the feudal system became established, fishery became integrated into the agrarian social system. From this point on, fishery became a specialized profession and fishermen began to gradually increase their productivity. Depending on a region's fishery resources, separate communities of fishing families specializing in either hook-and-line fishery, net fishery or shore gathering were formed.
Under this system the right to catch or gather marine resources of the shore waters such as sedentary fishes, shellfish, seaweeds, etc., was a collective right and source of livelihood given to the communities by the feudal lord. Thus, with regard to fishing ground use, the communities began to function naturally as communal units in which all members of the fishing community took part. This principle was later reflected in the first modern fishing laws laid down in the latter part of the 19th century. And today, the responsibility for controlling the use of shore fishing grounds rests with the fishery cooperative associations set up in each locality of the country. It is the job of the fishery cooperatives to establish fishery regulations and control the fishing grounds in order to protect the fishery resources of their waters and maintain the natural productivity of the environment for the future. With regard to abalone fishery, this involves the following measures:

•Regulating fishing season and fishing hours

Gathering operations outside the days and hours agreed upon by the cooperatives are prohibited.

•Limiting or prohibiting the use of fishing gear

① The use of wet suits has become accepted in diving fishery throughout the country, but the use of scuba equipment is prohibited.
② The use of harpoons or spears with firing mechanisms is prohibited, as is the use of instruments which produce electric currents or sparks.

•Regulation of body size of abalone caught

Gathering of young or immature abalone below a specified size is prohibited.

•System of communal sales

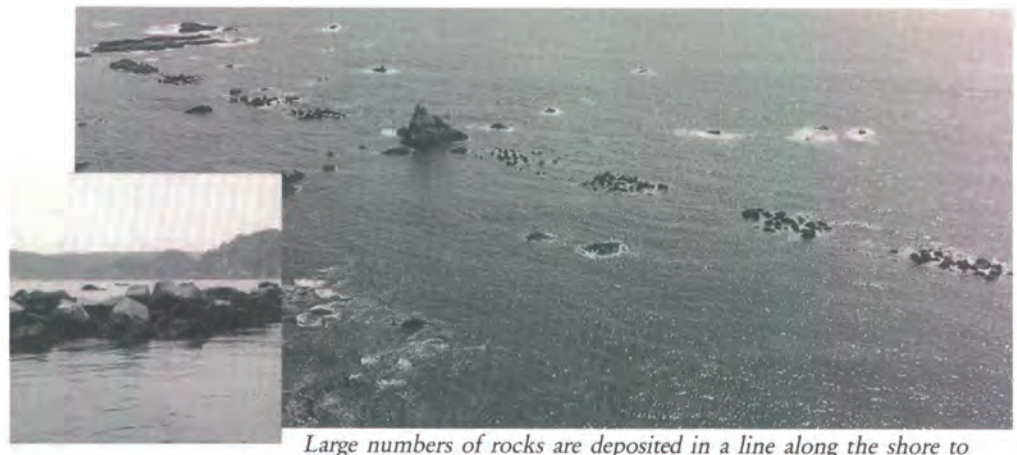
Catch must be certified by the cooperative and sold only through the cooperative sales mechanism.

•Prohibited fishing areas

Certain areas are set aside as rearing grounds for young abalone, and gathering is prohibited in these areas.

•Fishing ground structuring

In order to expand abalone habitats or improve reef beds the abalone attach to, natural rocks or artificial reefs are laid out.



Large numbers of rocks are deposited in a line along the shore to create a breakwall. By breaking wave action, it helps seaweeds grow and creates a favorable place for abalone spat to settle down.

An extensive culture ground for abalone: Troughs are dug through a tidal flat exposed at low tide to bring in sea water from off shore. Concrete blocks are placed in the troughs to encourage the grow of kelp and thus create a rearing ground for abalone.

Photo courtesy of the Fisheries Promotion Dept. of the Iwate Prefectural Government

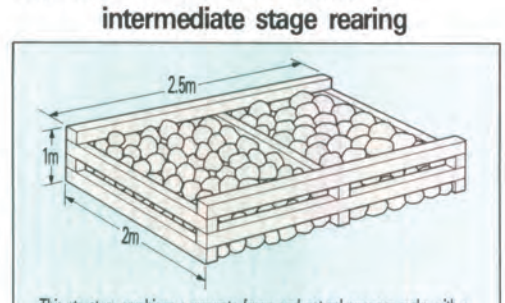
•Transplanting

To make up for depletion of the natural resources, abalone young are purchased from other regions and transplanted to the local waters.
All of these resource management activities are based on the fishermen's experience of the natural conditions within which the abalone live, and are carried out according to methods also acquired by experience. In short, their efforts are aimed at maintaining a balance between their fishing activities and the reproductive capacity of the resources while relying completely on the productive capacity of the natural environment. And this balance also becomes the basis for maintaining the economic aspect of their fishery business.

The stage of seeking development

When techniques like artificially increasing the supply of fry or young and maintaining a favorable environment during the infant stage are used to encourage the proliferation of a specific species, resource-management type fishery enters a new, more active stage of development. Generally speaking, resource proliferation (extensive aquaculture) activities can be pursued on a full-scale basis once the techniques of artificial seed production have been perfected. In the case of abalone, transplanting of natural fry was begun from the island of Okushiri off Hokkaido which had been designated as a national abalone preserve in 1954. Up until 1985, some one million fry a year were transplanted to prefectures like Ibaraki and Fukushima on Japan's main island.
The history of artificial seed production for abalone began in 1952, when Dr. Takashi Ino succeeded in the insemination and hatching of kuro abalone (*Haliotis discus*) eggs and raising the young for a period of 13 months. Through this process he was able to clearify the abalone's life history almost completely. The techniques for mass production of seeds were developed in 1970, after which the production of kuro abalone and ezo abalone seeds was begun as a fishery resource with great promise at fishfarming centers set up in prefectures throughout the country. Since about 1983, an annual production of over 20 million seeds have been released in fishing grounds nationwide. The total production of abalone seeds for the year 1989 was 22 million, of which 13 million were ezo abalone, seven million kuro abalone and two million megai abalone.
Abalone seed production takes place in water tanks at the fishfarming centers. Seed gathering in the natural sea environment, of the type performed for scallop, is not used in the case of abalone. In contrast to the scallop, which releases some 100 million eggs from one parent, a single abalone parent releases only about 600,000 eggs. This makes it almost impossible to conduct seed gathering commercially under natural conditions due to the extreme low probability in collecting natural spat.
In order to undertake successful extensive aquaculture (fishfarming in the natural environment), it is very important that seed release be accompanied by measures to maintain a favorable life environment for these resources in the natural sea area in question. These measures include; (1) creating favorable places for the spat to descend and attach to the sea bottom in the initial stage after release; (2) creating favorable nursery grounds for the young to grow; (3) creating seaweed beds in the growth environment suitable as a food source for the abalone; and (4) removal of predator species that feed on the abalone.

FIG. 3: An underwater block for intermediate stage rearing



This structure combines a concrete frame and natural aqueous rocks with a diameter of 30~50cm. Placed at a depth of about one meter, it serves as an intermediate rearing ground for abalone spat.

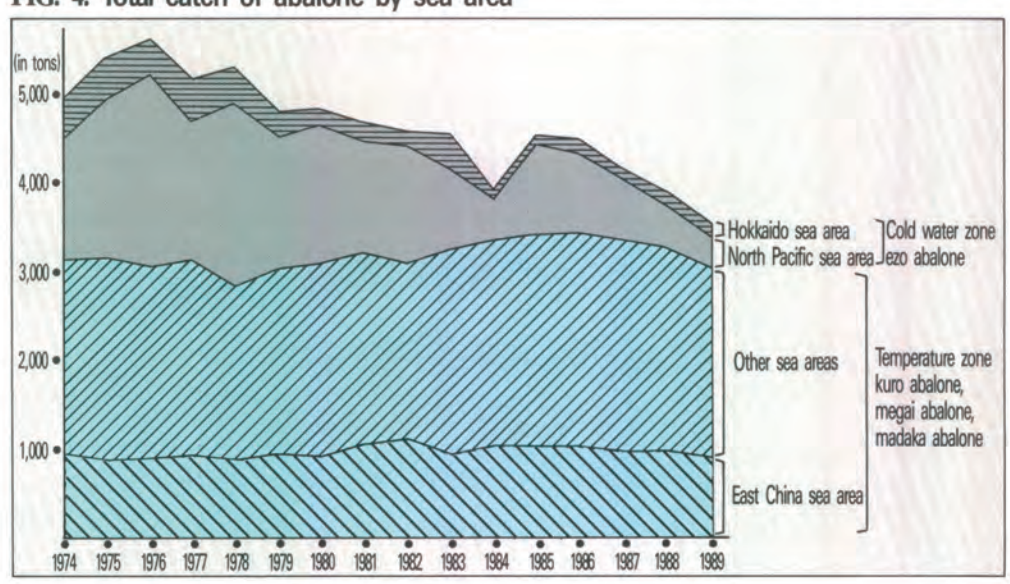
The stage of overcoming the conflicts between stability and development

In 1989, the total catch of abalone in Japan was 3,571 tons. It is estimated that in recent years 10% of the total catch originates from artificial seeds. In actuality, natural resources of abalone are on the decrease, and release of artificial seeds is serving only to fill in for this decrease. Thus, as yet it cannot be said that the release of artificial seeds is having any significant effect in terms of actual proliferation of resources.
FIG. 4 shows changes in the total national catch of abalone in recent years. The abalone catch shown here is divided into two regional groups; ① the ezo abalone zone (Hokkaido and the North Pacific sea areas) and ② the kuro abalone, megai abalone and madaka abalone zone (East China Sea and other sea areas). Whereas the catch of the temperate zone abalone species has maintained a steady horizontal line on the graph, that of ezo abalone has been gradually falling since the latter part of the 1970s. There are several theories explaining the decrease in ezo abalone resources, including the over-catching theory and the deterioration of water quality theory. The most widely accepted theory, however, concerns changes in sea conditions. According to this theory, the effect of the Oyashio Current (cold current) has increased in recent years along the North Pacific coasts of Japan, lowering the overall water temperature and thus inhibiting the propagation of abalone young. In general, the young of a given species hatch when the cummulative water temperature (water temp. multiplied by the number of days) reaches a certain value. When water temperatures are low, the period from egg release and insemination to hatching is lengthened. This causes the usual summer-into-autumn birth period of abalone to be delayed until later in the year. As a result of this delay, the newly hatched fry are immediately forced to endure the low water temperatures and rough sea conditions of the winter season. According to this theory, rough wave conditions cause the young abalone to be knocked off their attaching rocks and die or be eaten by predators due to insufficient development of their self-defense mechanisms, thus resulting in a high winter mortality rate. With regard to the Sanriku Coast of the North Pacific region, surveys by fishery experimental stations have shown that there is a definite correlation between winter water temperature and the following year's survival rate for abalone.
How about the case of temperate zone abalone species? It has been shown that, with regard to catching conditions in the various localities, an increase in the overall catching effort for kuro abalone in shallow waters has led to a decrease in catch and a decrease in body size of the abalone caught. However, this decrease in the kuro abalone catch has been accompanied by increased catches of megai and madaka abalone that serve to keep the overall abalone catch at a constant volume.
We can define two types of models for resource-management type fishery based on resource proliferation by artificial means.

[Model I] A model aimed at getting the largest possible catch out of the seeds released in the given fishing ground: By catching the fish or shellfish while still young, you lose the chance to realize a substantial gain in catch volume. But, on the other hand, restricting catching operations too much leads to a loss of resources due to natural mortality or dispersion.

Continued on next pages

FIG. 4: Total catch of abalone by sea area



[Model II] A model in which the artificial seeds released are allowed to work themselves into the natural reproductive pool of the resource, thus increasing the parent population that will propagate the next generation:

Up to a certain point, there is a direct relationship between increases in the parent population and the birth rate of the next generation, but after that point is reached it becomes harder to establish a clear relationship. It is very difficult to determine the size of a parent population that will ensure a suitable reproductive capacity. Also, in order to increase the capacity of the natural reproductive mechanism, there are an endless number of problems that must be dealt with besides that of securing a sufficiently large spawning population. These include; securing a juvenile population; environmental control aimed at securing sufficient plants and organisms to feed the population; and protecting the ecosystem that will support a proper life environment for the shellfish to grow to maturity. In the case of abalone, research in these areas has only just begun. In 1991, the Fishery Agency began a project to research the reproductive mechanism for ezo abalone. Depending on the characteristics of the species involved, there are cases such as those of salmon aquaculture and kuruma prawn aquaculture where the Model I type 'one generation harvesting' is stressed. Then again, there are cases such as that of sea bream aquaculture that stress a Model II type.

However, in resource-management type fishery, basically, the two methods are in a mutually complementing relationship.

It can be said that abalone fishery in Japan today is still undecided as to which model should be given priority. Those who are in a position where they want to see immediate returns on the investments made in seed production and creation of fishing grounds, naturally want priority to be given to Model I, because of the immediate economic results it offers. In this case, the subjects of immediate attention are; ① reducing the costs of seed production; ② improving the survival rate of seeds; and ③ increasing the recatching rate. With regard to problem ①, the Iwate Prefectural Fishfarming Center has developed a new type of water tank that recycles the culture water in an attempt to reduce labor costs in the seed production process. Regarding ②, the fishfarming centers of Toyama, Ishikawa and Saga Prefectures, among others, are trying to achieve more stable mass production of seeds by adopting ezo abalone seed production, even though these prefectures lie in the temperate zone. This is because ezo abalone seeds are easier to handle and less susceptible to viruses in the warm summer period. As for ③, the introduction of gathering methods such as scuba diving that leave fewer abalone uncollected and increase recatching rate, are most effective. However, the adoption of such methods would represent a tremendous uprooting of the traditional fishing methods employed by the shore fishery communities up until now. In recent years, such methods have in fact been put into use by a very limited number of fishery cooperatives in the Tohoku district for certain fishing grounds under their direct jurisdiction where extensive aquaculture is being practiced.

* * * *

Although there are some examples of abalone being cultured in cages or other containers hung vertically in sea water in Hokkaido and the Tohoku and Kanto regions of the main island, as yet their production is so small it does not constitute an industry of any significance in these localities. Meanwhile, there are one or two examples of enterprizes that are involved in raising abalone all the way from the spat stage to adulthood in large-scale water tanks on land. In spite of the high running costs and labor costs involved in this kind of long-term culture operation, it seems that the present high price of abalone, at as much as ¥10,000 per kilo, resulting from the gourmet comsumer market is sufficient to support such enterprizes.

Energy-efficient seed prod

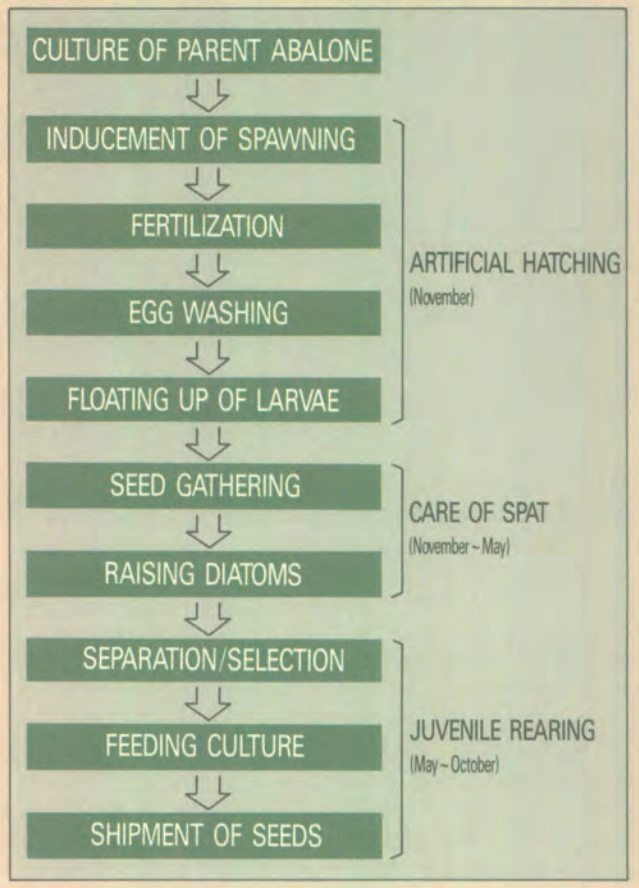
Abalone culture seeds are produced by the process shown in **FIG. 5**. Seed production is usually conducted with the entire process from the culture of parent abalone to spat and juvenile rearing in a single facility. The method we will introduce here, however, is one used by the Nagasaki City Fishery Center which involves seed gathering and a six-month period of spat-juvenile care conducted in facilities set up in the surface waters of the sea. As for the juvenile rearing stage, it is also quite different from usual methods, using water tanks with natural stones as the attaching surfaces instead of the plastic corrugated boards usually used.

This Center is built on the shore of a bay. This means it does not have access to a large supply of clean outer sea water. Therefore, it uses the bay water after filtration with gauze. In order to overcome the disadvantages of its location, the Center has developed its own production process which combines the use of surface waters of the sea in the larvae-spat care stage and a low water-consumption on-land tank with aeration to preserve water quality for the juvenile rearing stage.

One of the unique qualities of this Center's production technology is the way it makes full use of the stable environment of the bay waters and their cyclic nature. As a result, the Center was able to build a facility that did not require a large capital investment, and to create a seed production system that is highly energy-efficient.

The Center's production record for the five-year period from 1987 to '91 was a total of 390,000 seeds, with a spat culture capacity of 5,500 individuals per square meter and a survival rate of 83%. This record is by no means inferior to that of other facilities.

FIG. 5: The seed production process for abalone



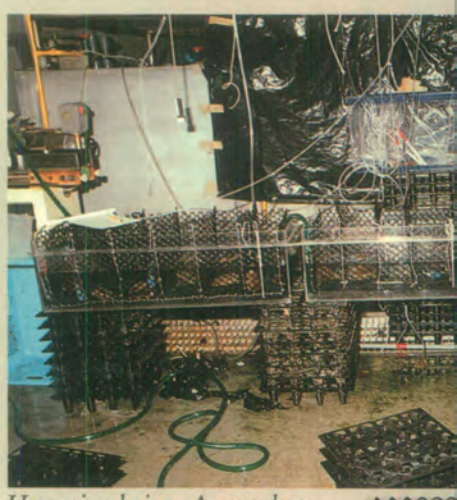
Sea-surface facil

SEED PRODUCTION (clock-wise, from top left)

Selecting parent abalone

Female with mature gonad

Male with mature gonad



Heat stimulation: As another method for inducing spawning, water in the tank is heated.

Air-exposure stimulation: In order to induce spawning, the parent abalone is exposed to the air for 20 or 30 minutes.

When the juveniles in the sea-surface facilities reach a shell length of 5 ~ 8mm they are moved to the on-land tanks. Round rocks are spread on the bottom as shelter for the young abalone.

In the juvenile rearing stage, salt-pre wakame, fresh wakame, fresh kajim used as feed. The photo shows juve have reached a shipping size of 30m are shipped as they are, attached to stones.

*On-land juvenile rearing tanks (See **FIG. 7**)*

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Detail of the facility

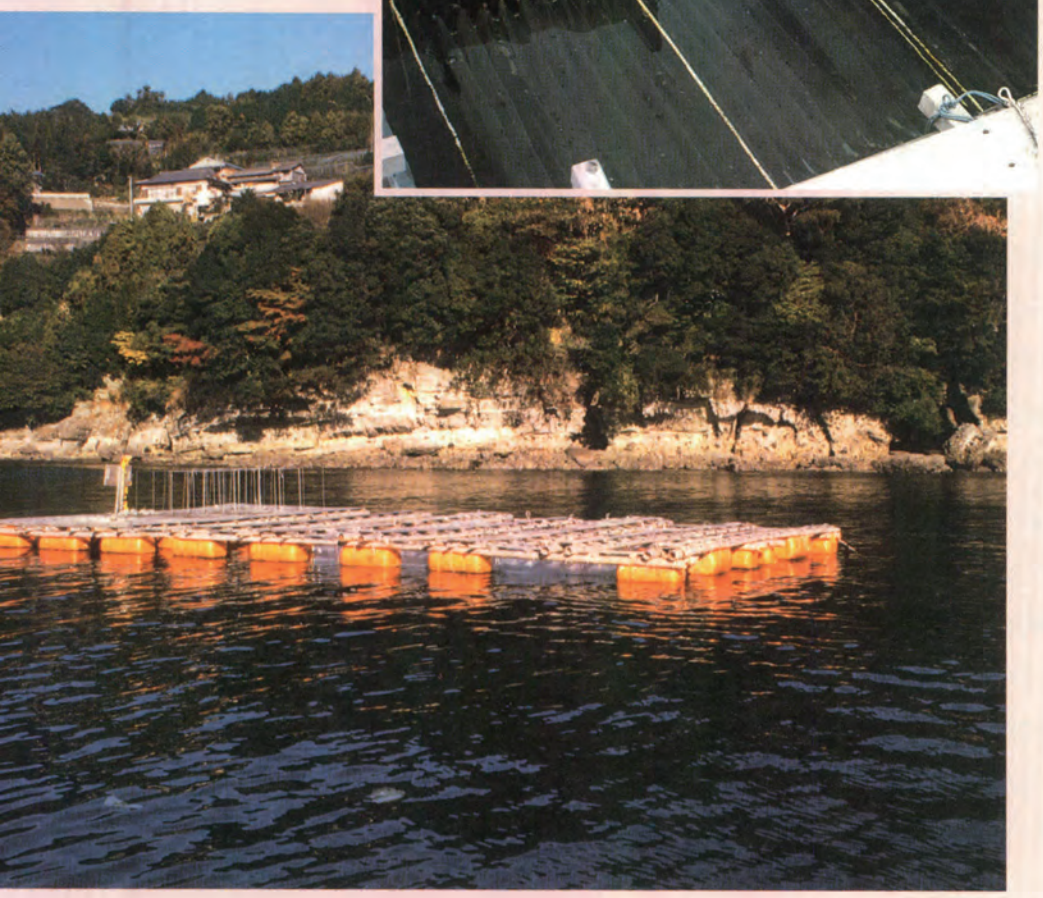


FIG. 6: Diagram of a sea-surface abalone seed gathering facility

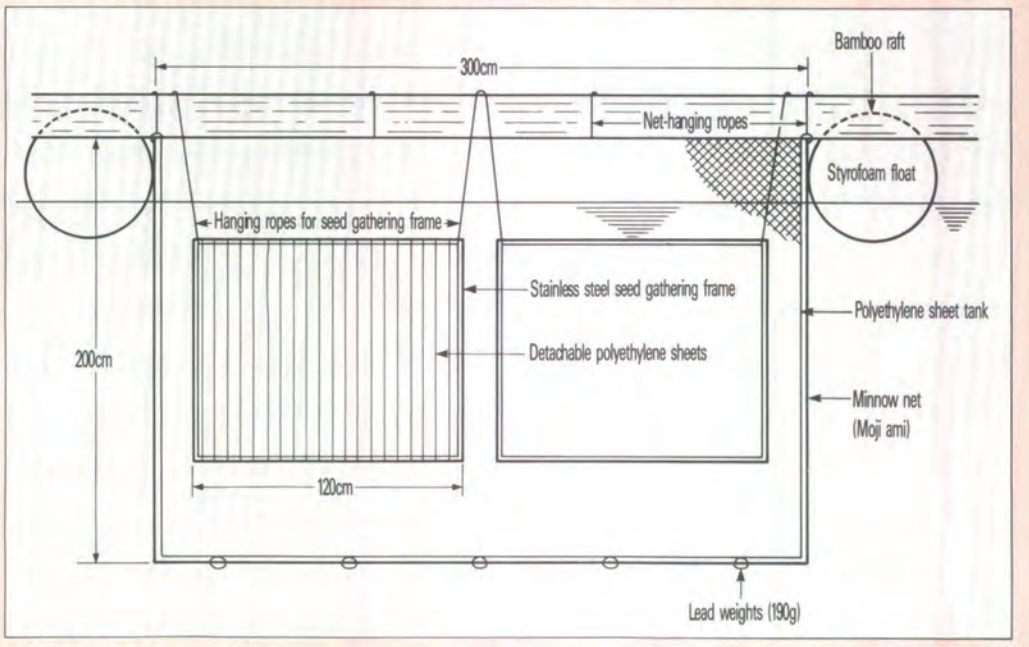
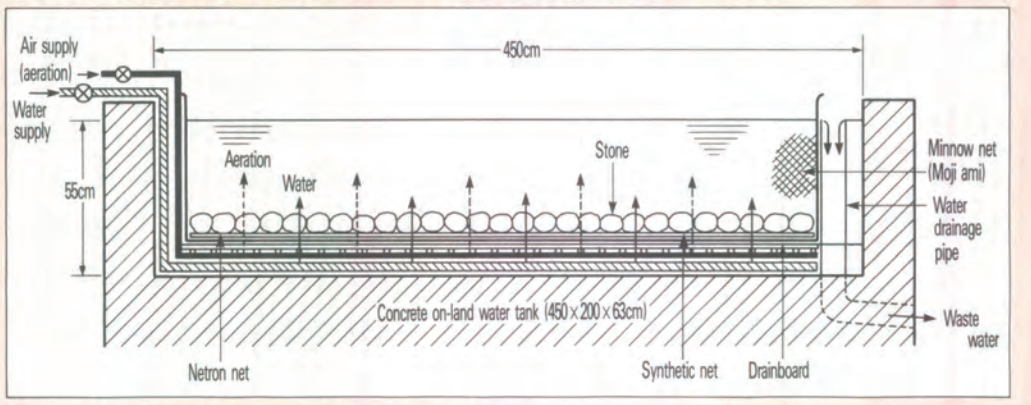
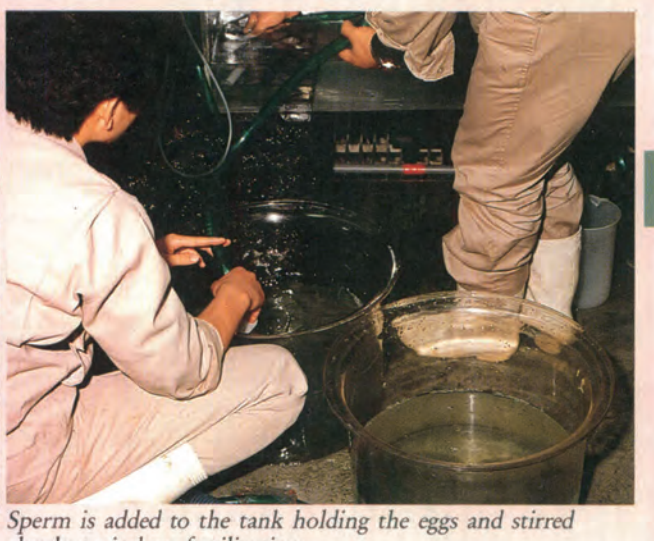


FIG. 7: Diagram of an on-land culture tank for juvenile abalone



(Photos courtesy of the Nagasaki City Fishery Center)

A female releasing eggs



Sperm is added to the tank holding the eggs and stirred slowly to induce fertilization.

Egg washing: After fertilization, time is allowed for the eggs to sink to the bottom of the tank, and then the surface water containing excess sperm is drawn off and fresh sea water added.

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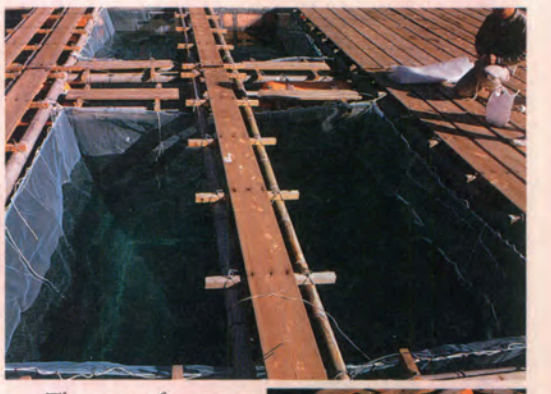
Transferring fertilized eggs

Collectors for the spat to attach to (polyethylene sheets) are hung in the cages.



The sea-surface cages (two-layer walls of minnow net [moji ami] and polyethylene sheeting) are filled with filtered sea water.

Releasing fertilized eggs gently into a sea-surface cage. After the spat have attached themselves stably to the collector sheets, the polyethylene sheet tank that lines the inside of the cage wall (moji ami) is cut out into strips to allow sea water to circulate through the cages. The spat feed on diatoms that grow naturally on the collectors. No artificial feeding is done.

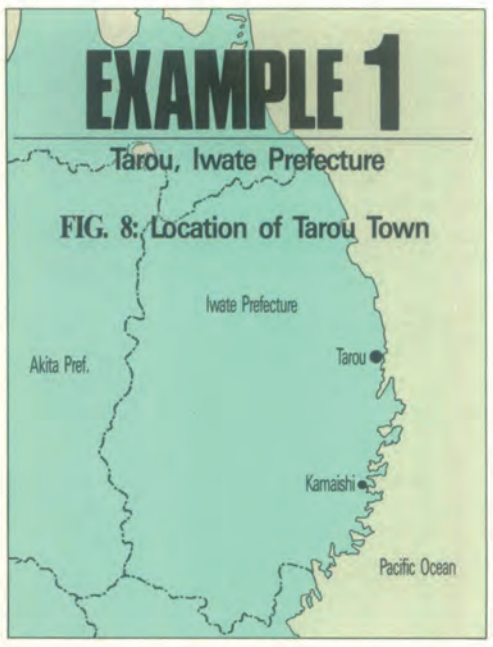


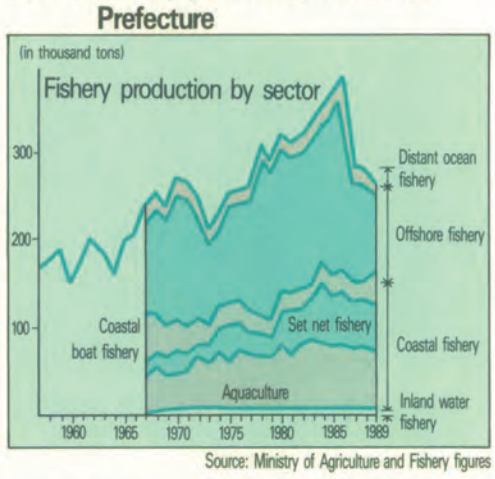
FIG. 8: Location of Tarou Town

Toward larger-scale seed releases and a higher recatching rate

Iwate Prefecture is situated on the Pacific coast of the Japanese archipelago between 39°0′ and 40°25′ latitude North. Almost all of the prefecture's total coastline of 300km is a Rias type coast with countless deep inlets and a complicated bottom topography. Furthermore, three sea currents intermingle in the waters off the eastern coast of the prefecture; the cold Oyashio Current coming down from the north, the warm Kuroshio Current coming up from the south and the warm Tsugaru Current flowing east from the Japan Sea. Both the coastal and offshore waters here are extremely rich fishing grounds, with set net and various types of boat fisheries being actively conducted in the coastal waters and migratory fishes like mackerel, sardine and saury being caught in abundance by surrounding net and dip net fisheries in the offshore waters. There are also several ports in the prefecture that are home bases for long-distance ocean-going fleets that fish for skipjack and tunas.

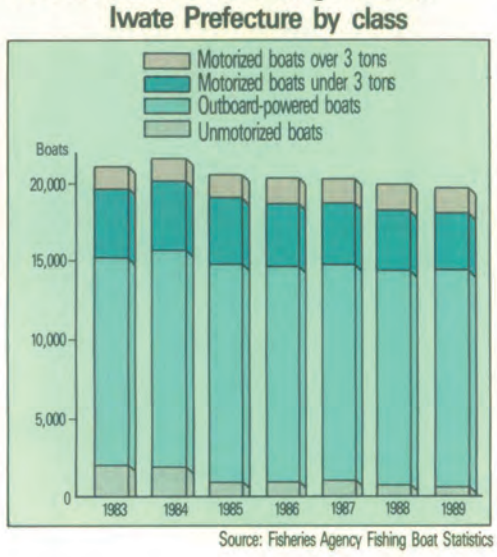
As shown in **FIG. 9**, coastal fisheries account for roughly half of Iwate's fishery production in recent years, thus constituting a major local industry. About 20,000 fishing boats operate out of Iwate, the vast majority of which are small-size boats of under three tons. Another characteristic of the Iwate fishing fleet is the large number of boats powered by outboard motors. These boats are used primarily for bay area aquaculture (fishfarming) of various fishes, shellfish and seaweeds, as well as for a shore fishing technique called "mi-tsuki" (spot-and-hook/spear) fishery. **(FIG. 10. See also FIG. 18)**

FIG. 9: Fishery production for Iwate Prefecture



Source: Ministry of Agriculture and Fishery figures

FIG. 10: Number of fishing boats in Iwate Prefecture by class



Source: Fisheries Agency Fishing Boat Statistics

Iwate Prefecture is the largest producing area for abalone in Northern Japan, the area consisting of the Tohoku region of the main island and the northern island, Hokkaido. In the 1960s, Iwate boasted the largest production in the country, with an annual ezo abalone catch of about 1,000 tons. Beginning in the latter half of the 1970s, however, the catch began to decrease dramatically, causing a serious problem for coastal fishermen whose income depended to a large degree on abalone. **(FIG. 11)**

FIG. 11: Abalone fishery production for Iwate Prefecture

Recognizing the seriousness of the problem, the Prefectural Fishery Authority drew up a plan for increasing abalone resources, which was introduced in July, 1982. The plan called for efforts to restore the abalone resources based on a three-point policy: ① greater efforts in abalone seed release, ② securing a sufficient supply of kelp suitable as food for the abalone. and ③ preventing illegal or unauthorized catching of abalone resources. This policy has been continued until the present day, but unfortunately has failed to raise the level of abalone resources in the prefecture's waters. At the same time, however, the system of abalone fishfarming in Iwate has gradually been strengthened, and a number of technical developments have produced important results.

1) Between 1979 and 1982, the prefecture's Fishfarming Center facilities were expanded as part of the government's fishfarming program, and production of abalone seeds was begun in 1981. Since then, the Center has produced a total of about six million abalone spat annually for supply to the prefecture's fishery cooperatives. Furthermore, most of the cooperatives in the prefecture have created facilities for the intermediate rearing of abalone. This has enabled a system by which the Center raises the spat to a shell length of 15mm and ships them to the local fishery cooperatives where they undergo intermediate rearing to a shell length of 30mm before being released.

2) Surveys of catches show the recatching rate of abalone originating from artificial seeds to be from 15 to 17%, and that the volume of their catch within the total is gradually rising. Through the release efforts it has gradually become clear what the most suitable shell size and time of year for releases are. It has also become clear that, rather than releasing the young in the autumn, releasing larger young the following spring results in a better survival rate and higher recatching rate. As a result of this finding, it has been decided to change the existing system to one in which the Center will use low-cost recirculation-type water tanks to raise the spat to a shell length of 20mm before shipping to the local cooperatives where they will be reared to a length of 40mm and then released.

The Tarou Fishery Cooperative, located in the central part of the Iwate coast, has the largest abalone production of any of the Prefecture's 38 cooperatives. With an annual catch of 30～50 tons, abalone fishery alone accounts for some 10% of the cooperative's total fishery sales of about ¥2 billion . This cooperative has 700 members and 1,200 registered fishing boats. Of these. 1,100 are outboard motor-powered boats of less than one ton that are used for wakame and kelp aquaculture as well as gathering of abalone, sea urchin and natural wakame and kelp. In this way Tarou is a typical shore fishing community.

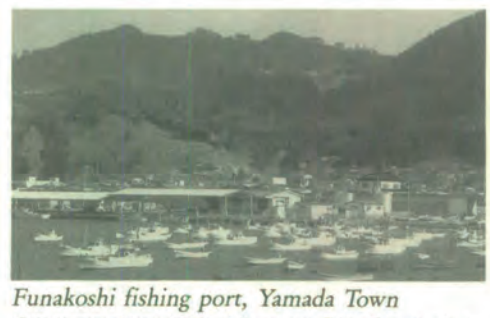
The Tarou Fishery Cooperative began the practice of releasing abalone seeds in 1981, and in recent years they release an average of 650,000～700,000 seeds annually. Seeds with a shell length of 30 mm are released and then recaught two years later after reaching a length of over 90mm.

Of the cooperative's total abalone catch of 178,613 individuals with a combined weight of 27,732 kg for the year 1991, abalone originating from artificial seeds made up 38.1% of the total by number and 38.2% by weight. The estimated recatching rate for the 670,000 seeds released two years before this catch (in 1989) is 10.2%. And, the ¥109 million market value of the catch originating from released seeds represents a 170% return on that year's seed investment of ¥64.5 million.

Although the Prefecture has set a two-month season of November and December for the gathering of abalone, in fact, the cooperatives only permit their members to gather abalone for a period of three or five days per season. What is more, gathering is only permitted for a three-hour period on these days, starting at dawn. On these days all the members of the cooperative engage in abalone gathering, with a further restriction that only one person per household be allowed to gather. Although the cooperative makes sure that all its members have equal opportunity to gather abalone during the allotted time, there is no limit set on the amount any one fisherman can gather during this time. As a result, depending on the skill of the gatherer, individual catches can vary greatly, with averages of 3～5kg and individual highs of up to 30kg.

In this cooperative, the members contribute their efforts together in the jobs of ① supplying kelp for feed, ② removing predatory species, ③ removing unwanted seaweeds, and ④ patrolling for illegal poaching.

The Tarou Fishery Cooperative has set as its present objectives the increase of seed release from the present level of 650,000～700,000 seeds to an almost double amount of 1.2 million and raising the recatching rate from its present 10% to about 15%. To achieve these aims, they plan to build a new seed production facility in 1993. This plan calls for the use of solar energy for a heated-water rearing system. The Tarou Fisheries Cooperative's goal is to raise their production level to 50 tons annually; 20 tons of which will be natural abalone and 30 tons from cultured seeds.



Funakoshi fishing port, Yamada Town
Photo courtesy of Iwate Prefectural Government, Fishery Promotion Dept.

FIG. 12: Major districts for Abalone production

Fishery based on catch quotas

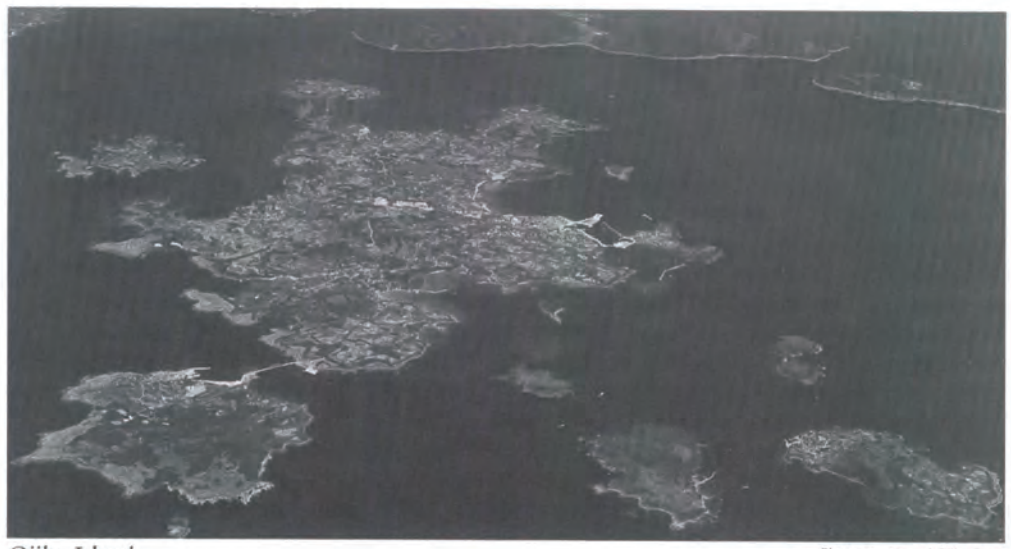
The total abalone production for Nagasaki Prefecture in 1990 was 462 tons. Broken down by district, the Tsushima district produced 165 tons, the Iki district 47 tons, the Kitamatsuura district 169 tons, the Tachibana Bay district 13 tons and the Goto Islands 68 tons. Thus we see that 83% of the prefecture's production is concentrated in the northern districts of Tsushima, Iki and Kitamatsuura. **(FIG. 12)** Ojika Island, which we will introduce here, is in the Kitamatsuura district.

As shown in **FIG. 12**, the northern part of Nagasaki Prefecture is an area of many islands that is visited by the Tsushima Warm Current. The two main factors determining the suitability of an area for abalone growth are the availability of outer sea type water quality and sea conditions, and the presence of suitable seaweeds, particularly brown algae. This region is well endowed with both of these vital elements.

Ojika Island and the small surrounding islands that make up Ojika Town, have a population of 4,600 people. The residents of these islands make their living by a combination of farming and fishing. In the past, farming made up the larger part of the people's living, but in recent years fishery has surpassed farming in importance. At present, agricultural production on the islands is valued at about ¥500 million, while the fishery production ranges from ¥2.0 to 2.2 billion.

There are 1,050 members in the Ojika Fisheries Cooperative, of which 300 are full-time fishermen. Some 100 motorized boats of the 5～6 ton class make up the cooperative's main fishing fleet. In addition to these are twenty motorized boats of the 19 ton class and some 600 outboard powered boats of less than one ton. The 5～6 ton class boats are used for longline fishery for swellfish and pole-and-line and bottom gillnet fishery for grunt, while the 19-ton class boats are used for swellfish longline fishery and surrounding net fishery for dorado. The outboard-powered boats are used primarily for diving fishery for abalone and turbo, with other uses including wakame and hijiki (a kind of brown algae) gathering. Because there are few suitable bay areas with shallow, reefy waters, aquaculture is not conducted here.

The Island's total fishery production for



Ojika Island

Photo courtesy of Ojika Town

1990 was valued at ¥2.09 billion, of which fishes accounted for ¥1.68 billion, shellfishes ¥281 million, sea urchin ¥54 million and seaweeds ¥77 million. The two individual products with the largest market value are "tora" swellfish and abalone, with abalone accounting for 10% of the Island's total fishery sales.

About 300 fishermen here are involved in diving fishery for abalone.

Ojika has had a steady annual abalone catch of 60~70 tons. This represents the largest per capita abalone catch, as well as the largest catch for a single cooperative, in the prefecture. The Ojika Fisheries Cooperative allows gathering of abalone by its members only during two roughly one-week periods a year, in May and September, for a yearly total of about 15 fishing days. Fishing hours are from 8:30 a.m. to 4:00 p.m.

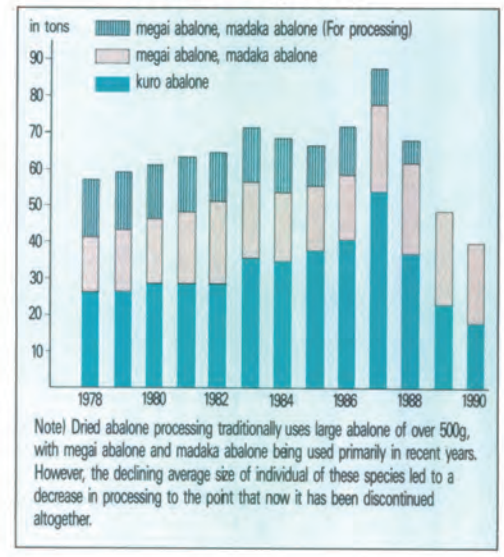
The individual fishermen are allowed to choose their fishing grounds freely, but they must be sure to return to port by 5:00 p.m. on fishing days. The cooperative also sets a limit on the minimum size for abalone that may be gathered, which is one centimeter stricter than that set by prefectural law. Namely, 11cm for kuro abalone and 12cm for megai and madaka abalone.

One of the primary reasons why this district has been able to maintain a stable abalone production, is that for the past 30 years, the cooperative members have met every year to discuss and reach agreement on the amount of abalone they will catch that year. Then they strictly enforce the quotas they have agreed upon. In setting these annual quotas, the previous year's catch is first reviewed and then an appropriate quota is set for the coming season. According to this system, when the agreed quotas have been reached, cooperative members immediately cease all gathering operations. The framework used by the cooperative for setting their annual quotas derives from a survey of the Island's fishing grounds by a fishery researcher, which concluded the optimum catch level for abalone in these grounds to be around 65 tons annually.

It happened, however, that certain organized crime elements, recognizing the high market value of abalone, conspired to use these resources as a means to raise money. Entering the Ojika Fisheries Cooperative's fishing grounds at night by means of high-speed boats and shining search lights on the water, they poached on the cooperative's abalone with teams of scuba divers. In response to this, the cooperative members attempted to patrol the fishing grounds using their own boats, but were unable to stop the poaching activities completely. Frustrated by these efforts, the members finally decided that gathering the abalone resources themselves was better than seeing them carried off by poachers. So, from 1987 into 1988, they raised their annual quotas all the way to the 100 ton range. However, within one or two years the adverse effects of this over-catching began to show in the form of decreased average size of the abalone. Sensing the danger of continuing catches at that level, the cooperative and its members decided to restrain themselves and return to their previous catch levels. Now, they are in the process of reestablishing a sound resource-management type fishery program. **(FIG. 13)**

Every year, the Ojika Fisheries Cooperative releases 10,000~30,000 kuro abalone juveniles in its fishing grounds. The cooperative has also continued efforts to create new abalone fishing grounds by depositing natural rocks of about one-ton size in waters with a depth of 5~6 meters. These efforts come from the belief of the cooperative leaders that, in order to keep the abalone resources from declining, they must create hiding places for a portion of the abalone population where even the fishermen can not get at them.

FIG. 13: Abalone catches of the Ojika Fisheries Cooperative



Note) Dried abalone processing traditionally uses large abalone of over 500g, with megai abalone and madaka abalone being used primarily in recent years. However, the declining average size of individual of these species led to a decrease in processing to the point that now it has been discontinued altogether.

The fact that the fishermen of this cooperative have been able to maintain a strict system of catch quotas in abalone fishery, can be attributed to the following social factors:

1) Fishery holds an important position in the Island's economy.

2) Being an isolated island group, the cooperative plays an important role in selling the fishery catches.

3) For the above reasons, the cooperative exerts strong leadership and control over its members.

4) Due to the development of fish-catching operations using 5~6 ton boats in recent years, abalone gathering has become only a secondary source of income for many of the fishing households.

5) Being an isolated island group with a long tradition of fishing community ethics, none of the cooperative members violate the fishing rules etc. set by the cooperative.

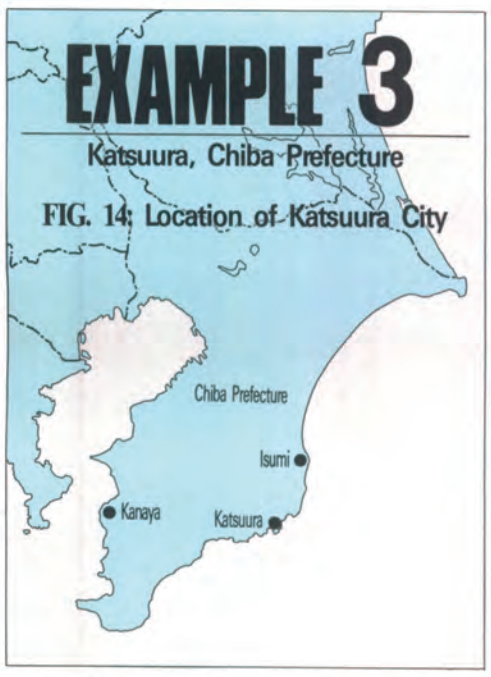


FIG. 14: Location of Katsuura City

Encouraging the next generation of diving fishermen

Chiba Prefecture's Boso Peninsula is a natural habitat for temperate zone abalone species. Since olden times, diving fishery for abalone has been conducted in the reefy coast areas on the Pacific Ocean side of the peninsula. And today, the fishery cooperatives of this area engage in the practices of abalone seed release and fishing ground management in an effort to maintain and propagate their shore area resources.

As an experimental enterprize, the Western Katsuura Fisheries Cooperative began, in 1987, an abalone aquaculture operation under the cooperative's direct management using a hanging-type method. This experimental aquaculture is still in operation today.

The aquaculture method is a longline type, as shown in **FIG. 15** and **FIG. 16**, with about 40 cages hung from each line. At present, eight of these longlines are strung out in suitable water areas. In June of each year, spat with a shell length of 40mm are placed in cages at a density of about 90 spat per cage and hung in the sea. Three or four times a month sea trumpet (kajime) is added to the cages and the cages are periodically cleaned as the abalone grow. Two-hundred days after the start of culture (shell size: 50~60 mm) and again at four-hundred days (shell size: 60~70 mm) the abalone are sorted according to size and the number in each cage reduced, first to 60 and then to 30 per cage to maintain a suitable culture density.

Seven-hundred days after the start of culture, the abalone reach a shell length of 70~80mm and a weight of 60g, at which time they are sold on a limited basis to local hotels. **(FIG. 17)**

Each year about 10,000 abalone spat are introduced to culture, and the survival rate is 70%. The operation's yearly sales of about ¥9 million, less estimated initial costs of ¥4 million for culture facilities and seeds and running costs of ¥2 million for labor, fuel for boats and material supplies, leave an estimated profit of ¥3 million.

Presently, this aquaculture operation is being run directly by the cooperative, using the full-time labor of one or two cooperative members.

This scale of operation is one that can be managed with family labor alone, and is meant to serve as a model for future operations to be run by the cooperative's members on an individual basis.

There are two factors which motivated the Western Katsuura Fisheries Cooperative to undertake this experiment in hanging-type aquaculture of abalone.

1) During the period of high economic growth in the '60s and '70s, many young people left the region to find jobs in urban industries, leaving few younger generation interested in taking up the profession of a diving fisherman, thus resulting in a gradual aging of the local diver population.

2) The catch of natural abalone has failed to show any substantial growth, and, in spite of efforts to increase resources through the release of artificially produced seeds, the recatching rate has remained low.

If the technology for abalone aquaculture can be put effectively into practice, a fisherman with a small-size fishing boat can use this aquaculture in combination with other angling or trolling type fisheries to strengthen his fishery income. However, successful operation of abalone aquaculture requires, ① a water area with good inflow from the outer sea, ② a site without ocean waves, and ③ a site with no inflow of freshwater (river water). Waters that satisfy these three conditions are usually quite limited in area. Thus, it is expected that there will be great difficulty in establishing hanging-type abalone aquaculture as a local industry. As a result, the cooperative is now considering beginning research on a new sunken-type sea bottom cage method as an alternative to the hanging cage method.

A piece of plastic pipe cut into a half cylinder is inserted in the cage as a means to increase the attaching surface area available to the abalone.

FIG. 17: The growth of abalone in cage aquaculture

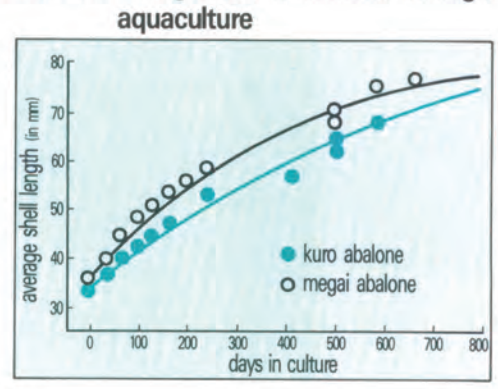


FIG. 15: A longline type aquaculture facility

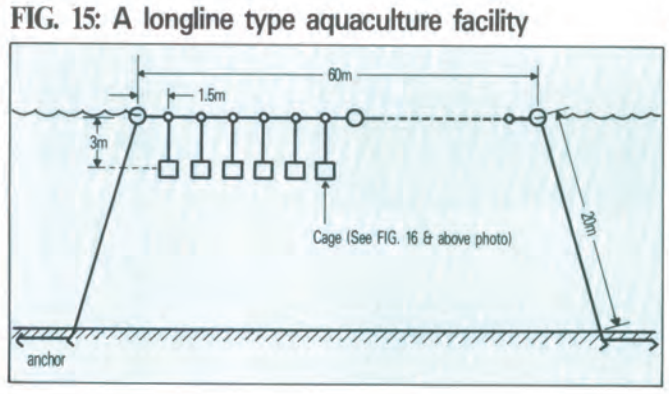
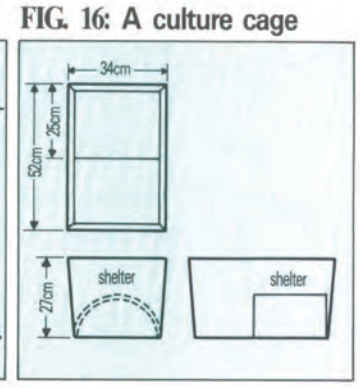


FIG. 16: A culture cage



Abalone Fishery

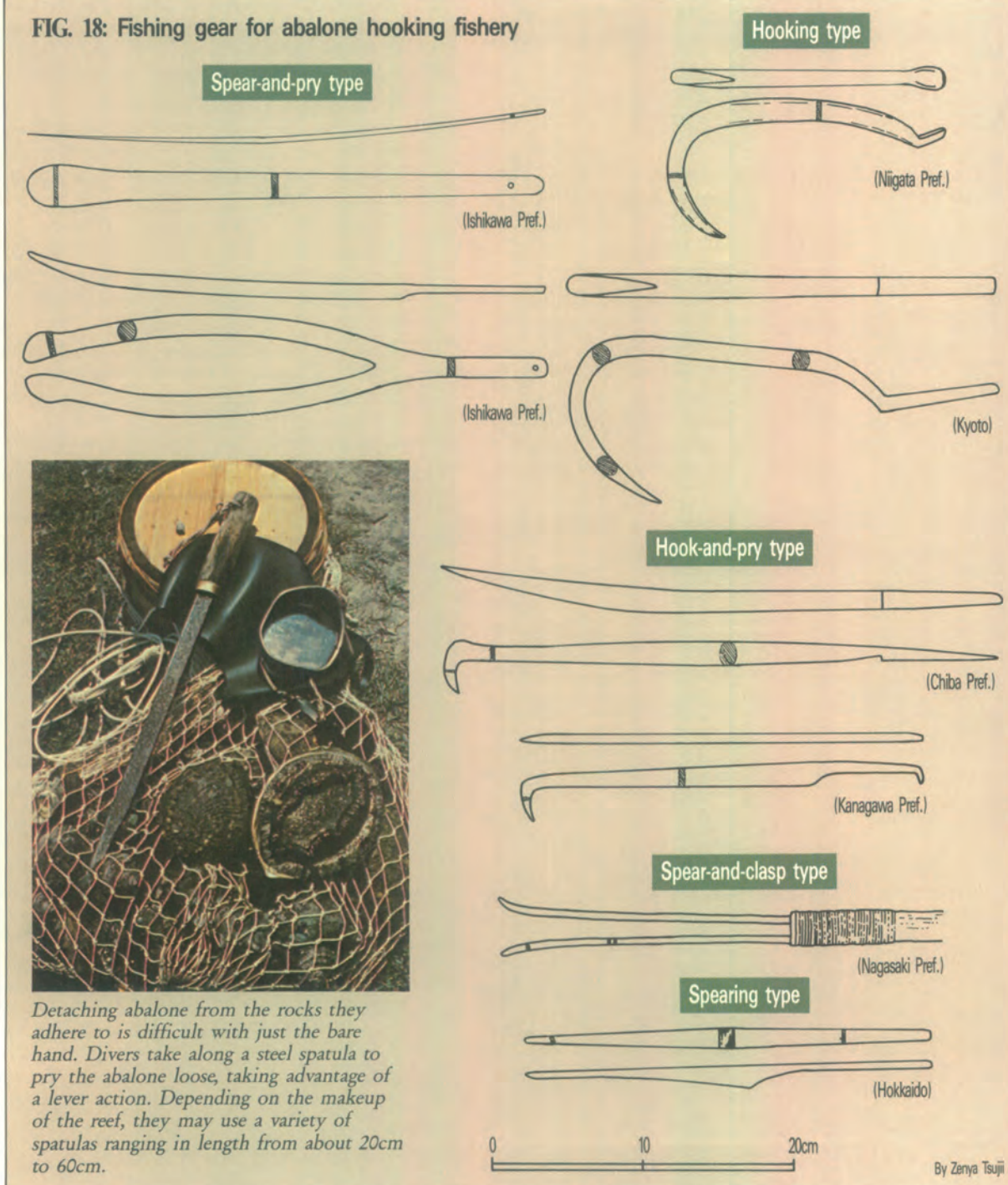
The fishing season for temperate zone species of abalone caught by the diving method, runs from April to September. The early part of the season is devoted to catching kuro abalone that live in the shallower waters.
Later in the summer, fishing efforts shift farther off shore to catch megai and madaka abalone living in deeper waters. After the end of the abalone season, the fishermen switch to other types of fishery such as angling or longline that use small-size boats.

The diving method and hooking method of abalone fishery are both methods that require considerable practice and experience. The fisherman must learn to read the sea bottom topography and distribution of seaweed types in order to search out the abalone's habitat. He must also learn the technique for prying the abalone from his rock in one quick motion. Abalone fishery is a profession that has been carried on within specific sub-communities within the coastal fishing society. And its techniques tend to be passed on from one generation to the next within certain families. In recent years, however, fewer and fewer young people are inclined to take up the profession of an abalone fisherman. As a result, we see a continuing aging of the work force in this branch of fishery.

Diving fishery is performed in some regions by men and in others by women. In areas near the shore, women float a wooden tub on the surface to hold their catch and dive with a long rope connecting themselves to the tub. In addition to abalone, they gather turbo and certain seaweeds at the same time.

Photo courtesy of Mie Prefecture

FIG. 18: Fishing gear for abalone hooking fishery



By Zenya Tsujii

Detaching abalone from the rocks they adhere to is difficult with just the bare hand. Divers take along a steel spatula to pry the abalone loose, taking advantage of a lever action. Depending on the makeup of the reef, they may use a variety of spatulas ranging in length from about 20cm to 60cm.

Hooking fishery involves leaning over the side of a small boat with the face close to the water to search for the desired shellfish, etc. This type of fishery can only be conducted on calm days during seasons when the water has good transparency. In the past, fishermen used small amounts of vegetable oil poured on the water to create an oil slick that removed small ripples and increased visibility. Around the year 1900, the invention of a simple "looking glass" box with a glass bottom improved the effectiveness of this technique tremendously. According to Mr. Zenya Tsujii, a researcher of folk tools, the fishing gear used in hooking fishery can be divided into five categories according to function: ones that ① spear, ② spear and clasp, ③ spear and pry off, ④ ones that hook, and ⑤ spear and hook. In the different regions of the country, variations on these five types have been created in assorted sizes and shapes.
Traditionally, the hooking fishery method has been used for shellfish like abalone and turbo, as well as for seaweeds, sea urchin and octopus.

Photo courtesy of Iwate Prefecture