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Fish attracting techniques in Japan

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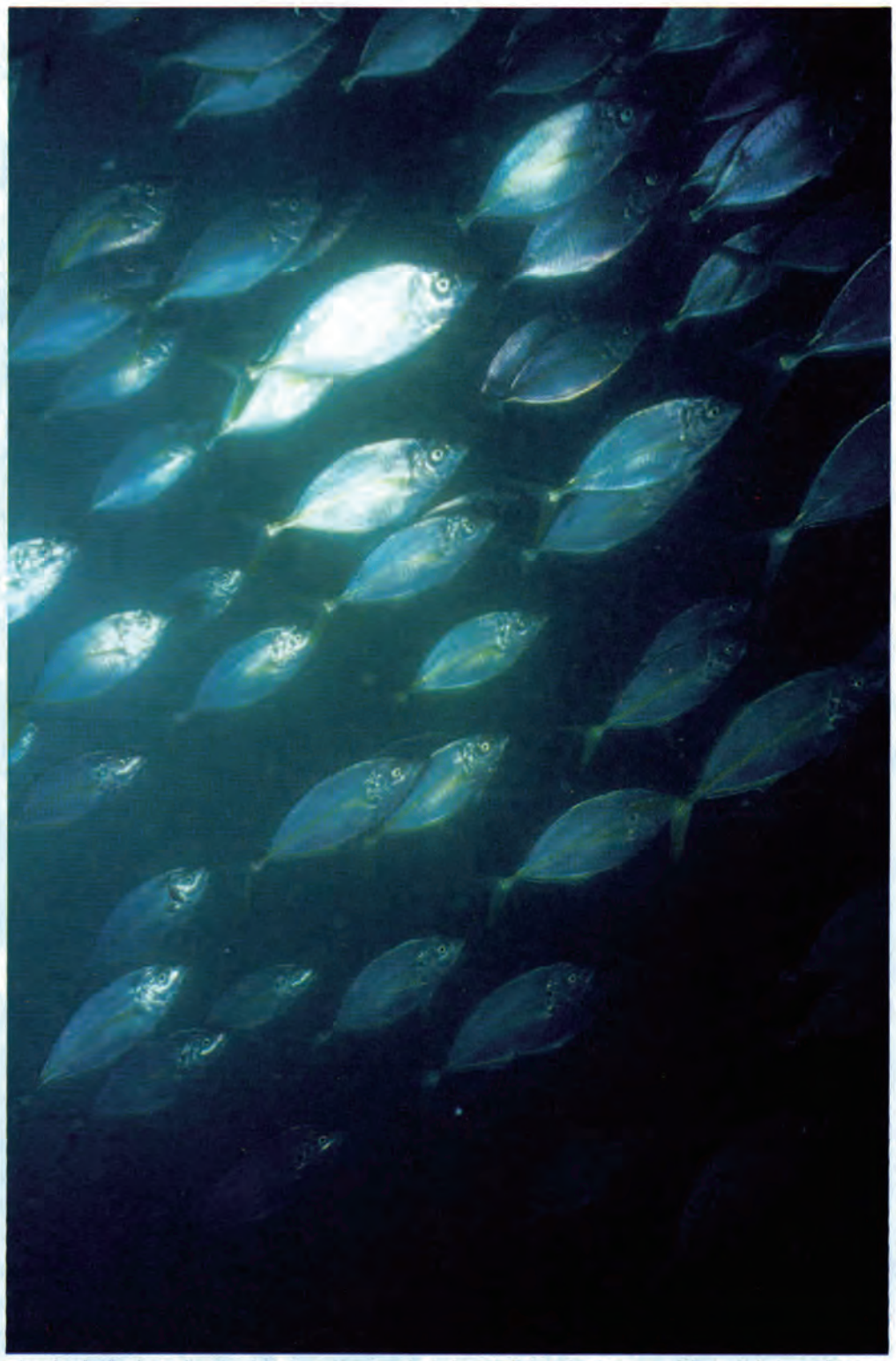
The first necessity of any commercial fishing business is the ability of the fishermen to consistently catch a certain volume of marketable fish. In order to do this, the fishermen must do one of two things: they must either consistently find places where large numbers of fish are living, or use some methods to gather into one place a large number of fish originally scattered over a large area of water. These two techniques, fish finding and fish attracting, become the first techniques that fishermen must develop when undertaking fishery in a given natural environment. The various fish-finding and fish-attracting techniques that have been developed for each kind of fish are also major factors determining the nature of the fishing gear and methods used, and thus can be said to be at the very base of all fishing technology.

Fish finding

(1) Sighting: This is the method in which fishermen find fish by means of visual sightings after arriving at the fishing ground. It is a method that has been used since olden times in whaling and marlin fishery. In these fisheries the whale's blow and the marlin's jump become the sign the fishermen look for. Larger fish or marine animals like these migrate over large areas of sea in search of waters with a preferable temperature. The fishermen know the seasonal migrations of these species extremely well and have the experience to be able to judge from the water temperature or the color of the tide just where the best fishing grounds will be on any given day.

(2) Secondary indicators: There are other fish-finding methods that rely on recognizing certain secondary indicators for locating large schools of fish. For example, skipjack, in their migrations over large areas of sea, tend to congregate at certain recognizable points, such as around drifting timber or drifting seaweed flows or gatherings of large fish or sea animals like whales, sharks, pilot whales or dolphins. When fishermen sight such signs, they know there is a good possibility that schools of skipjack will be found in the surrounding waters. At times, skipjack will also follow large schools of small fish like sardine, feeding on them heavily. When this happens, the sardine chased to the surface by the pursuing skipjack will attract large flocks of sea birds. Experienced fishermen are able to observe the movements of these flocks of birds from afar and judge the size and density of the skipjack schools swimming below them.

(3) "Yamatate": Demersal species of fish, shellfish and other marine animals like octopus and sea urchin, can be divided into types that inhabit rocky bottom areas and types that prefer sand or mud bottoms. But, in either case, these animals find the most suitable habitat and repeat migrations between shallow waters and deep waters in accordance with seasonal changes in water temperature. From their long years of experience, the fishermen come to know when the best fishing seasons will be and where the best fishing grounds will be for each species. In order to confirm the exact locations of their boats at sea, fishermen have long used a technique called "yamatate," or mountain sighting. This technique involves lining up a number of landmarks like mountains, points of land or buildings in order to position their boats exactly over the desired fishing ground.



A school of released striped jack swim directly below a fish culturing pen. These fish have become permanent residents of the culture grounds as they have learned to feed on the excess feed that falls through the preserve netting. They react with great sensitivity to the sound of the feeding machine on the culture operator's boat. Second and third year adults have been identified in this school. (Refer to pp. 7 and 8)
(Photo courtesy of: Ehime Prefectural Fisheries Experimental Station)

(4) Scientific methods: Besides the above traditional methods which have been developed over long years of experience, modern scientific and technical advancements have led to the development of a new generation of fish-finding instruments that greatly improve the fish-finding effectiveness of fishermen today. First among these is certainly the echo sounder. Based on the sonar technology developed for military purposes in World War II, these devices send pulses of ultrasonic waves down into the water and register the echos reflected back from the sea bottom and other objects in the water on a screen similar to radar. Thus, fishermen are able to get not only a picture of the topography of the sea bottom but also identify schools of fish in the deep, middle or surface water layers. From the blips that appear on the echo sounder screen, fishermen are able to distinguish both the type of fish and the size of the school. Today fishermen in almost all types of fishery, and regardless of the size of their boats, are using echo sounders in some way to improve their fish-finding capability.

Modern equipment for determining the position of the fishing boat on the sea have also come into common use in recent years. With the LORAN position-finding system, fishermen tune in to a signal broadcast by the regional shortwave station and are automatically given a digital readout of their boat's position in longitude and latitude. Since the use of LORAN has now spread to many small fishing boats, the traditional "yamatate" technique seems to be going out of use.

Recently, the appearance of satellite transmission has brought another big change in fish-finding technology thanks to its ability to gather information about temperature distribution over large areas of ocean. Ultrared cameras on satellites can gather data about surface water temperatures that is then processed to create maps of water temperature distribution. These maps, which show the courses of warm and cold currents and the location of warm- and cold-water pockets, have become indispensable information sources for offshore fisheries such as large-scale seine fishery and tuna fisheries.

Fish attracting

(1) Guiding: Since olden times fishermen have used techniques to lead fish into their catching devices. In the case of set nets in the sea or fish weirs in inland waters, the fence net serves this purpose.

(2) Startling: The ground rope on a bottom trawl net or the long wing nets of a boat seine have the effect of startling the fish and driving them toward the center of the net, either by the sound they make in the water or the flashing of the fibers in the net cord. In one variation of the bottom trawl net called the otter trawl, the trawl door serves the dual purpose of a spreader to hold the mouth of the net open and also a rake to drag along the sea bottom and stir up clouds of silt that startle the fish schools.

(3) Fish attracting lights: The technique of using lights to gather fish is used widely throughout the world. This technique will be explored in detail on pages 2 and 3.

(4) Artificial fish reefs: Fishermen have long known, and made use of the knowledge, that floating man-made reefs in the water or setting them up on the sea bottom is an effective way to attract fish and other marine animals. These man-made structures that function to gather fish can be called artificial fish reefs. In the case of entrapping type fishing gear like octopus pots, baskets and bamboo tubes, it can be said that the gear itself functions as a kind of artificial fish reef.

As to why fish gather around artificial fish reefs, there are a number of theories. These include the shelter theory, which says that fish choose places where shadows are formed as their hiding places; the feeding theory, which says the fish feed on the smaller creatures that attach themselves to the reef; the thigmotaxis theory that says fish like to make physical contact with stationary objects; and the eddy theory, which says that fish are attracted to the eddies that form around artificial reef structures. Professor Makoto Inoue suggests that it is actually combinations of these various factors that function to produce the fish-attracting effect depending on the species and the specific conditions that exist.

Since the latter half of the 1950s, Japan's Fishery Agency has continued a program of building artificial fish reefs around the country as part of its coastal fishery facilities development program. During this time a variety of artificial reef structures of varying sizes and built of a number of durable materials such as concrete, steel,

rubber and plastic have been developed. In recent years there has also been a growth in research and development of floating fish reefs aimed at pelagic fish species, and in accordance with this trend, the Fishery Agency has now adopted a subsidy system to further promote such development. We will take a closer look at examples of such floating reefs on pages 4 to 6.

(5) Bait: In addition to attaching bait to the hook in angling fishery, there is also a technique in which live bait is used to attract fish. For example, in skipjack pole-and-line fishery live sardine or anchovy are chummed into the water to keep a school of skipjack in the vicinity of the boat. An example of one variation of this, called "Kaitsuke" (domestication) that has been practiced in some regions of the country since olden times, will be presented on pages 7 and 8.

(6) Sound conditioning: Fish demonstrate sensitivity to a certain range of sound frequencies. In recent years efforts have been undertaken to raise fry that are conditioned to respond to a sound signal generated in the water, thus forming the basis for a new kind of conditioned-response fish farming. The initial research with this technique has involved red sea bream. First, red sea bream fry are raised in a culturing cage where they are exposed to the same frequency signal at every feeding in order to condition them to associate the sound with feeding.
After the young are thoroughly trained to gather at the sound of the signal, they are released to the open sea where they grow but still retain the learned response to gather at the source of an underwater sound transmission of the same frequency. At present this tecnique is being used on an experimental basis at only a few sites along the coasts of West Japan, but as research progresses it is likely that this method will spread to other regions as well.

Fish-attracting lights – The principles and practical uses

The word "isaribi (fishing fire)" is often found in the ancient songs and poetry of Japan. From this we can surmise that the technique of using light to gather fish was already common in the 8th century AD. But it is also very possible that the technique's roots go back much further in human history. For example, cormorant fishery, in which the diving birds are used to catch sweetfish in rivers, is a night fishery that depends on a large flame suspended out over the water from the boat to attract the fish. This fishery came to Japan from China, where it originated in regions south of the Yangtze River. One scholar maintains that the cormorant fishing technique was introduced to Japan about the same time as the paddy rice cultivation technique. This seems to be a logical assumption, and if it is true, would place the importation of this fishery closer to seventeen or eighteen hundred years ago.
The use of light in fishery is not unique to Japan, either. Fishing methods using fire or other forms of light have existed in all parts of the world since olden times, and today they continue to be a feature of contemporary commercial fisheries in many countries.
In the Mediterranean countries lights are used to attract pelagic fish like anchovy, mackerel and jacks to be caught by nets. In Egypt's Gulf of Suez there are boat seine and gillnet fisheries in which boats with lamps are used to lure sardine and other fish into the nets. In France's Bay of Lyon there is a fishing method in which lamp boats are used to guide fish schools into floating gillnets. In Russia there are seine and scoop net fisheries that use fish-attracting lights, as well as a fishery that uses underwater lights to attract fish to be sucked up with a pump, and another that uses lights to catch fish with a "ship-side pursed net" that combines the qualities of both a purse net and boat seine. The two-boat trawl net fisheries catching herring and cod off the coasts of Sweden and Germany shine spotlights on the water just ahead of the net mouth in order to lure fish into it.
Seine fisheries in Norway use both on-board and underwater lights to attract fish. In America there is a fishery for Pacific squid that uses lights in combination with a suction pump. In Latin America we find fisheries using lights to catch anchovy.
Meanwhile, in Asia there are examples such as the Philippine laswag scoop seine, a kind of lift net fishery that uses fish lamps, and in Korea there is a scoop net fishery that also uses fish-attracting lamps. In Thailand there is a lift net fishery using fish lights to catch squid. Among all the different kinds of fish-attracting techniques, the use of light is the most widely adopted, contributing greatly to mass catching of pelagic fish species.
Among Japan's modern, scientifically advanced fisheries, the three that rely heavily on fish-attracting lights are purse seine fisheries, stick-held dip net fisheries and squid jigging fisheries. Although all three of these fisheries use high-powered lights, the way the light is used is unique with each of the three, creating subtle differences in effect.

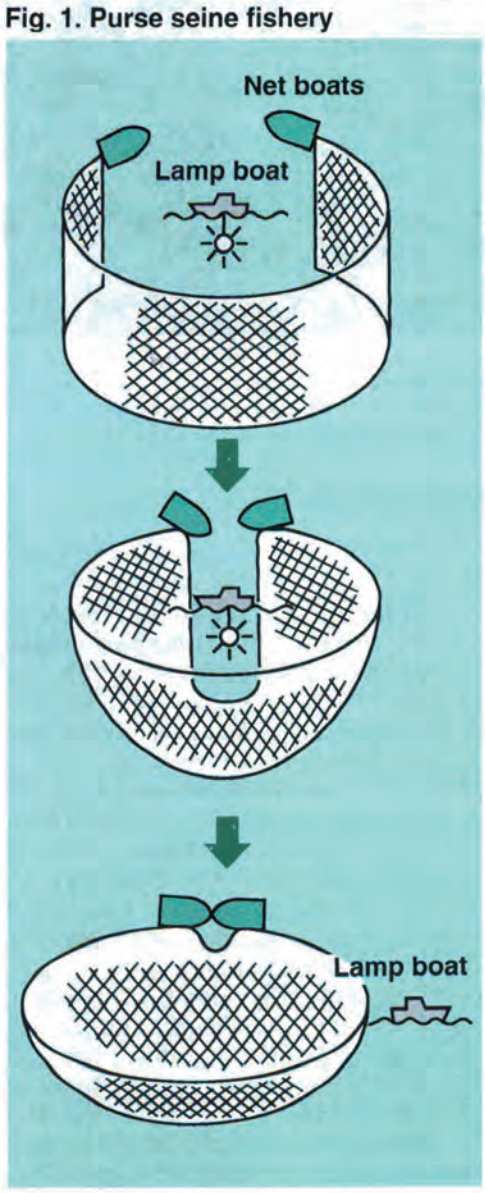
Purse seine fishery

Purse seine fishery is conducted by a fleet of boats including the net boats (main boats), a fish-finding boat, lamp boat and transport boat. When the fish-finding boat locates a school of fish, the lamp boat proceeds directly to the middle of the school and begins the fish-attracting operation using both on-board lights and underwater lights. The function of this operation is to bring the schools up from the middle layer to the surface waters and also to stablize the movements of the schools. The net boats then proceed to cast the net in a large arch with the lamp boat as its central point. The lamp boat remains stationary in that spot with its lights on until the net boats have finished casting the net and fastening the purse ring bridle. At this time, when it is certain that the schools are completely surrounded, the lamp boat moves outside of the net circle. **(Fig. 1)**

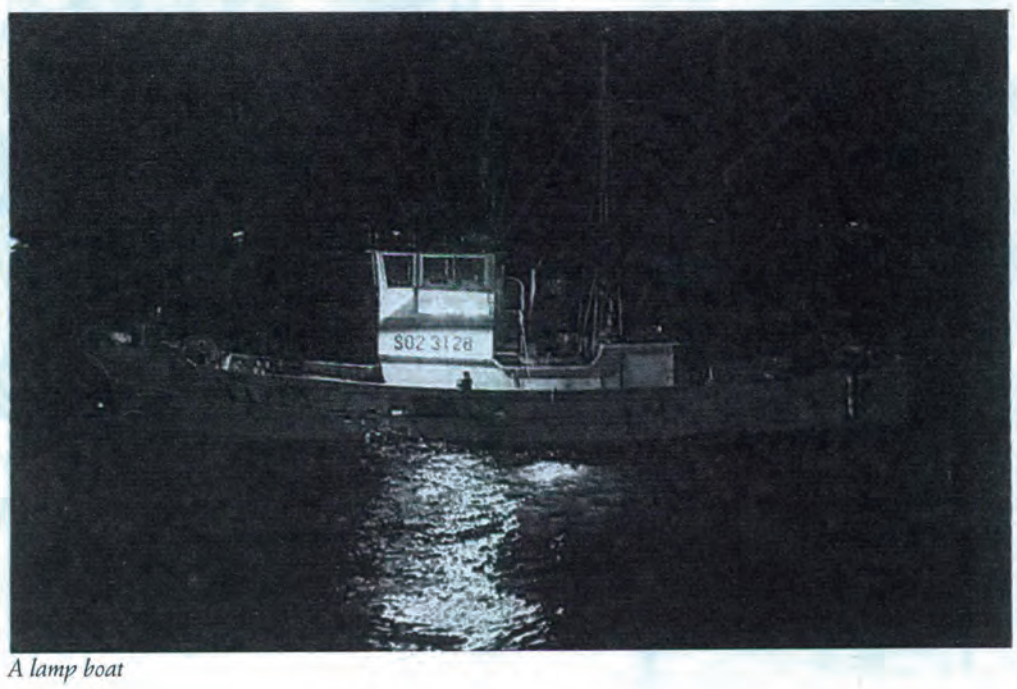
Stick-held dip net fishery

Stick-held dip net is a very efficient fishing technique that can be considered the most modern development of the lift net methods. The most representative fishery using this technique is offshore saury fishery. Upon reaching the fishing ground, the saury stick-held dip net fishing boat first turns on the fish-attracting lamps on the starboard side of the boat and begins cruising at a slow pace over a large area of water gathering schools of saury as it goes. When the number of fish following the lighted area on the water surface becomes large enough, the boat stops and the stick-held dip net is strung on the port side of the boat and lowered into the water. Next, the fish-guiding lamps hung out near the upper edge of the net are turned on, while at the same time the fish-attracting lamps on the starboard side of the boat are turned off. At this point the fish rush under the boat toward the fish-guiding lights on the net side and, when it is verified that enough fish are over the net, it is raised and the fish are caught. **(Fig. 2)**

Fig. 1. Purse seine fishery



Mackerel and saury are being caught in this 19.9-ton class purse seine operation.



A lamp boat

Squid jigging fishery

Jigging for common squid is a fishery conducted at night. Migrating schools of squid are located by means of an echo sounder and the best fishing site is chosen. The boat is then anchored by means of a sea anchor and the fish-attracting lamps hung above the deck are all turned on. Next, the automatic jigging machines located along both sides of the boat are moved into position out over the side and turned on. The fishing gear consists of single lines fitted with about 30 jigs (lures) each at one-meter intervals.
These lines are wound onto the elliptical drum of the jigging machine which rotates first in one direction and then the other to keep the jigs constantly moving up and down with a pulsing motion in the water. The squid latch on to the jig and wrap their tentacles around it until they are brought up out of the water, at which point they naturally let go and fall onto the deck of the boat. The squid jigging operation continues nonstop in this way until dawn. **(Fig. 3)**

★ ★ ★

We use the word taxis to refer to the phenomenon in which an animal reacts to an external stimulus with some particular pattern of action. Various forms of taxis can be induced by stimuli ranging from light, water flow and electrical current to chemical agents, gravitational force and any solid objects. In the case of fish, the primary form of taxis observed is phototaxis, or taxis in response to light.

With the exception of some species living in the very deepest waters, most fish have highly developed optical organs. They are very sensitive to light and dark and also distinguish colors and shapes. Fish demonstrate two types of taxis with regard to light, depending on the species; a positive response in which they move in the direction of the light, and a negative response in which they flee from the light source. Sardine species, mackerel and jacks have a strong positive reaction to light, while other species like yellowtail, sea bass, catfish and carp have a weak reaction.

Also, within the same species the response can change with the developmental stage of the life cycle. For example, eel will gather around light in the fry stage but show a negative reaction to light when they become adults. Why do fish gather at the sight of fish-attracting lights? As yet, not enough is known about the phototaxic mechanism in fish. Of the various theories that have been proposed, the two prominent ones are the "compulsive motion theory" and the "trial and error theory."

Compulsive motion theory: According to this theory, when fish receive a strong stimulus from a single light source, it causes a disturbance of the balance of light energy they receive from the right and left eyes. In order to recover the balance of their optic organs the fish have a compulsion to either swim directly toward the light source or around it in a circular pattern.

Trial and error theory: This theory states that each species of fish has its own optimum light environment. In response to stimuli from the changing environment the fish undertake a variety of exploratory movements in search of ideal environmental conditions.

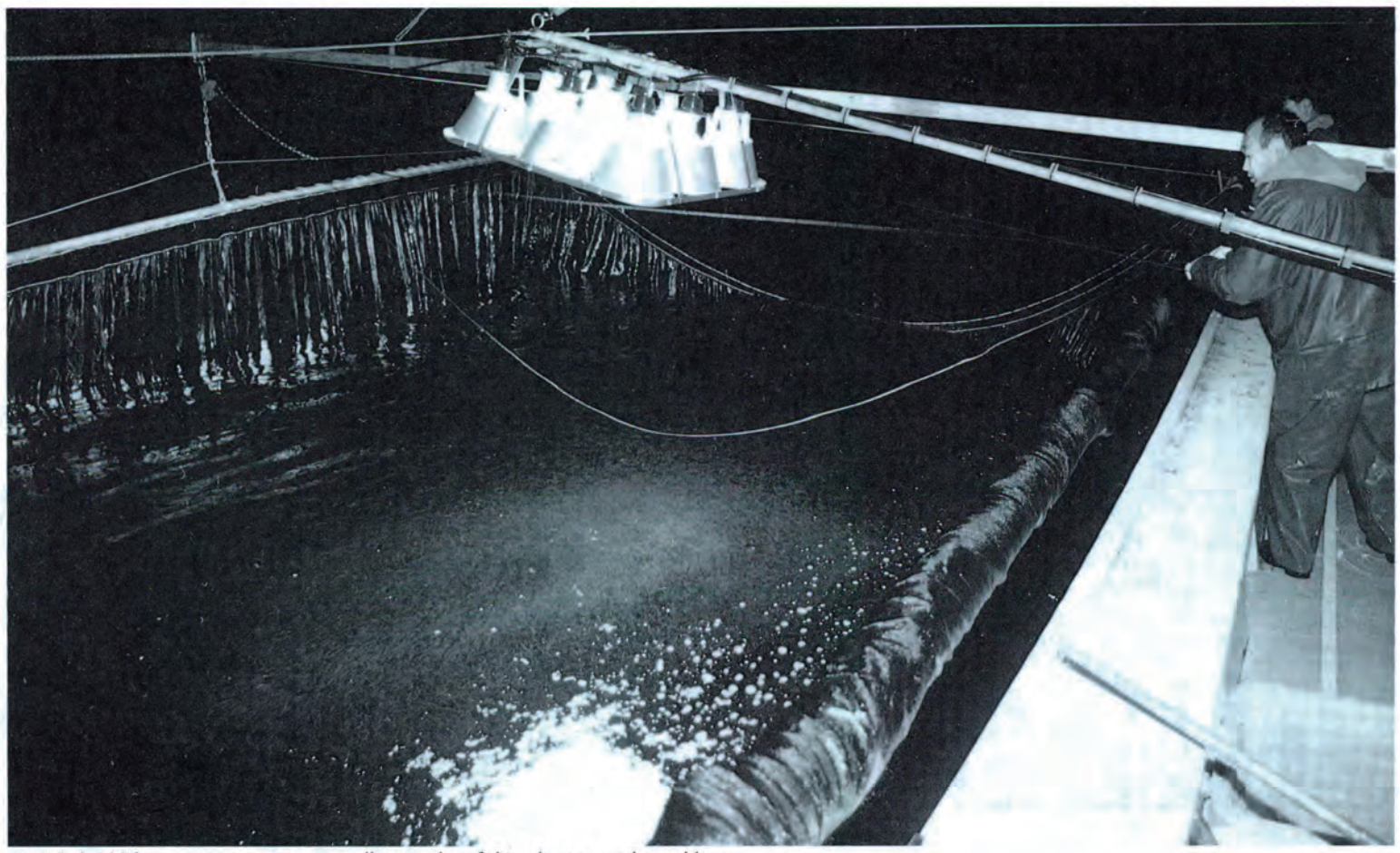
Although these are conflicting theories, they do share a common point in that they assume the fish are reacting to external changes in an attempt to regain their preferred orientation.

The two functions of the fish-attracting lights are to gather the fish together and then keep them in one place. But with regard to these, differences are observed in the response of the fish to varying levels of intensity of the light in the water and also over time. The fish do not simply stay in the brightest area under the fish-attracting lights. When they reach the light source they immediately turn around and head away toward the dark until they turn once again and head toward the light. There is a constant turnover of the fish under the lights, as they repeat cycles of congregation and dispersal.

Many fishermen believe that the brighter their lamps the higher the fish-attracting efficiency will be. However, in tank experiments using 100V, 150W underwater lamps, it was found that jack mackerel swam in a circular motion around the lamp at 15 ~ 0.1 lux, but it is in the range of 2 ~ 0.2 lux that the fish gathered in high concentrations, with the highest concentration being reached at a level of 0.2 lux.

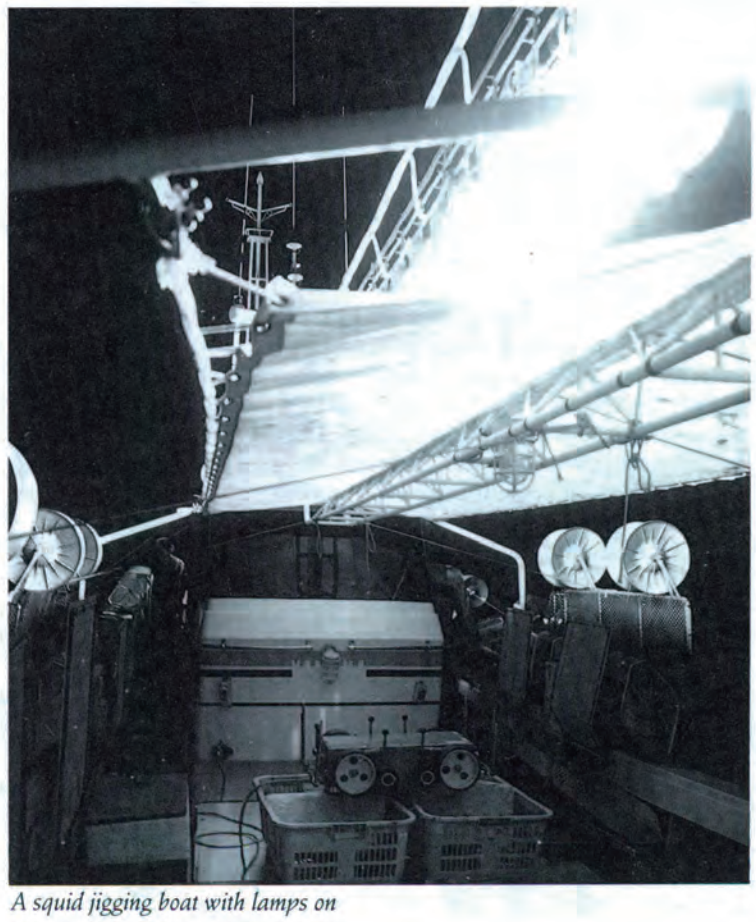
As another example, we can look at the findings of squid fishermen in the Japan Sea, where the development of new fishing grounds in the 1960s led to a rapid growth in the number of fishing boats competing with each other for catch using increasingly brighter lamps. At one stage, however, it was discovered that additional increases in the power of the lamps did not lead to any increase in catch. Subsequently, when different positionings of the jigging machines were tested — suspending the lines in the dark area under the boat, in the bright area under the lamps and in the border area between the light and dark areas — it was discovered that the largest catch was made when the lines were operated in the border area. Squid have optical organs that are highly sensitive to very low levels of light. Underwater observation reveals that the squid's movement is slow and poorly articulated when moving from dark toward light, but is quick and precise when moving from light toward dark. Therefore, the dark area under the boat is very important for catching squid. **(Fig. 3)**

Much research by marine biologists will certainly continue to be done concerning the questions of how fish are stimulated by the light and dark created by fish-attracting lights and how it affects catching efficiency.



A stick-held lift net operation using a small 5-ton class fishing boat to catch sand lance

Fish-attracting lamps on a squid jigging boat



A squid jigging boat with lamps on

Fig. 2. Saury stick-held dip net fishery

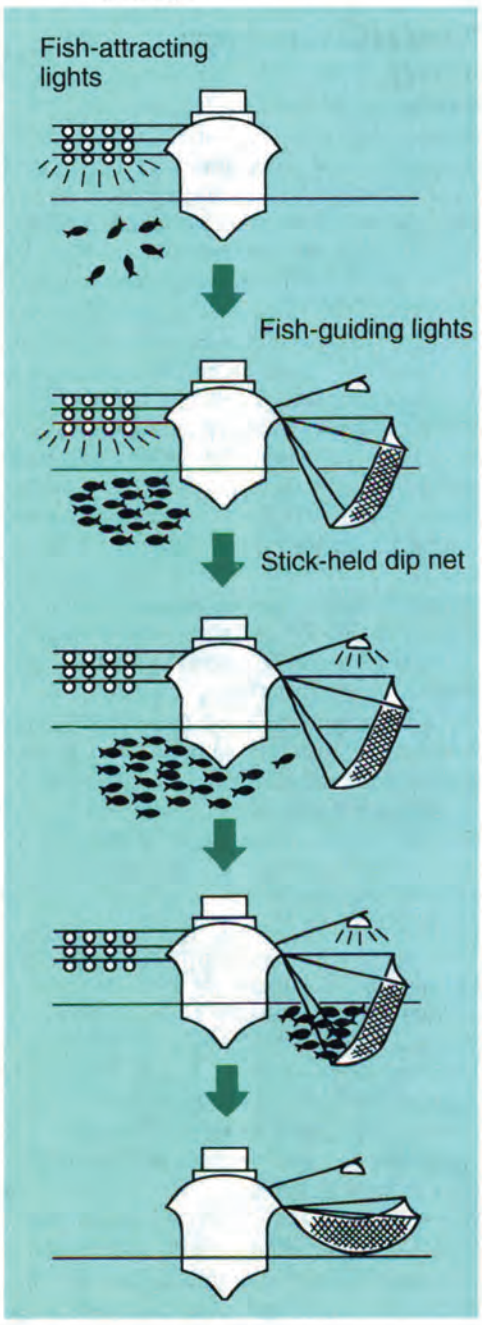
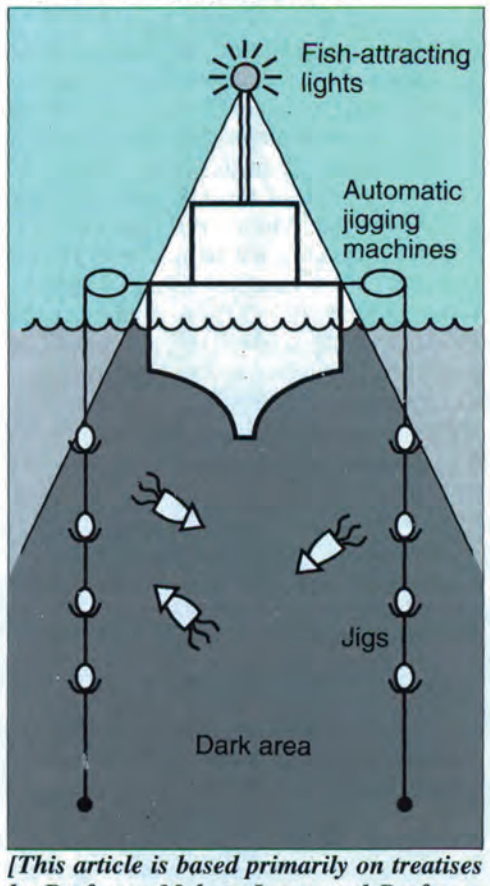


Fig. 3. Squid jigging fishery



[This article is based primarily on treatises by Professor Makoto Inoue and Professor Michio Ogura]

Payao Fishery in Okinawa

Attempts to build a semi-tropical fishing industry

A short history of fishery in Okinawa

With the Japanese defeat in World War II, the Okinawan Islands came under the military governance of the United States in 1945. During this rule a local Ryukyu Government was formed to govern the islands until 1972, at which time Okinawa once again became part of Japan. Since the return of Okinawa to Japan, the government has continued efforts to bring the standard of living of the islands on par with that of the mainland by promoting infrastructure improvements to support independent development in the areas of industry, transportation, life environment, welfare and education, etc. under its comprehensive Okinawan advancement and development program.

Okinawa Prefecture is situated in the semi-tropics at the southern tip of the Japanese archipelago and consists of some 60 islands spread out over a wide area of ocean that extends more than 1,000 km north and south and 400 km east and west. The Okinawa islands are hemmed with coral reefs that create a ring of shallow sea area around them, but all of the islands rise sharply from the ocean floor ranging from 1,000 to 2,000 meters in depth, meaning that there is very little area corresponding to a continental shelf with a depth of 200 m or less.

The sea on the east side of Okinawa drops off into the Ryukyu Trench and then on into the Pacific Ocean, while on the west side there are many rocky reefs extending from the Senkaku Islands off the west coast of Kyushu down to the northern tip of Taiwan, beyond which lies the broad continental shelf of the East China Sea. The Kuroshio warm current, which flows along the northwest edge of the Okinawa Islands, keeps the water temperature above 20° year-round. This Kuroshio current also serves as a corridor that brings migrating fishes like skipjack and tuna into the Okinawan waters, where they can be caught in fishing grounds around the region's numerous rocky reefs. However, the Kuroshio current is a high-temperature, high-salinity current that is low in nutrient salts and a poor environment for plankton production. As a result, it demonstrates characteristics typical of a tropical sea environment, in which there are a large variety of species but none that proliferate in large quantities.

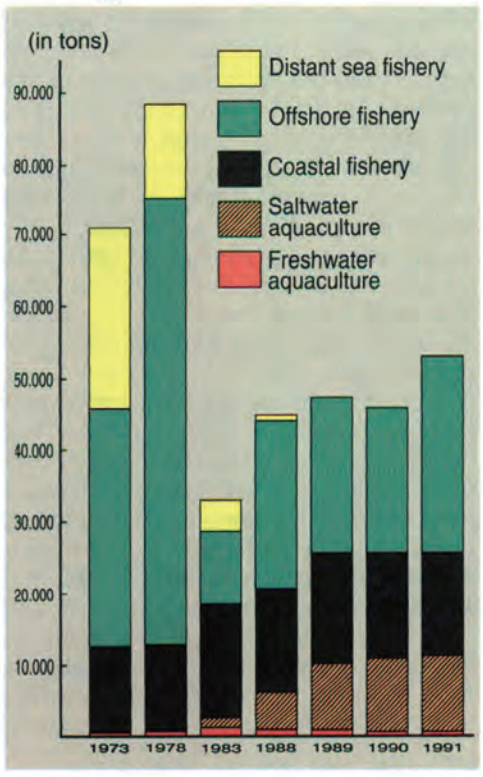
Traditionally, the fisheries of Okinawa developed within coral reef waters that could be used as main fishing grounds. In tropical regions the coral reef serves as an important spawning ground for all types of marine resources. The reef has a breakwater function and seaweed beds form in the calm waters inside, making for good nursery grounds and a good growth environment for fish fry. In addition to resources of seaweeds, spiny lobster, "gazami" crab and shellfish, fish species like rabbitfish, lethrinids and black porgy are caught by diving, gill net and small-scale set net fisheries. The waters outside the coral reef with a depth of 5 to 60 m are a place where the young fish spawned and raised in the shallow waters within the reef grow to a larger size. Here a large variety of species like fusilier, snapper, porgies, wrasse, grouper, parrot fish, shrimp and squid are caught by angling, gill net and a unique Okinawan form of fishery called drive-in net, in which a large number of divers work together to drive fish into a common net.

From the traditional fisheries based in the waters of the coral reef, Okinawan fishermen began to branch out into offshore and distant ocean fisheries. Out beyond the coral reef slope into the offshore waters, angling and deep-water longline fisheries have developed for the resources of demersal fishes like snappers and lethrinids that inhabit the waters around rocky reefs. Troll fisheries also developed for the migrating schools of skipjack, tuna and billfishes that ride the Kuroshio current.

Okinawa also boasts the tradition of dauntless "Itoman" fishermen, who in olden times ventured as far south as Micronesia in small sailing canoes. Entering the modern era of motorized boats, the activities of Okinawan fishermen in the southern seas grew more extensive. Establishing fishing bases in Papua New Guinea, the Solomon Islands and Palau, Okinawan 19-ton tuna longline boats, 19-ton skipjack pole-and-line fishing boats, 49 ~ 69 ton tuna longline, 200 ~ 300 ton tuna longline and 300 ~ 500 ton skipjack pole-and-line fishing boats grew in number to the point that their catch constituted 60% of Okinawa's total fishery production by about 1970.

After about 1977, however, the establishment of 200-mile economic zones by the various countries and subsequent strengthening of international fishing regulations resulted in a decrease in catch rates and a subsequent search for new, more distant fishing grounds that decreased the profitability of these fisheries. This combined with other factors like a decrease in labor willing to work on distant-sea fishing boats to place further strain on the industry, eventually decreasing its international competitiveness greatly and leading to a rapid decline in the number of operators involved in distant-sea and southern-based fisheries. **(Fig. 4)**

Fig. 4. Okinawa fishery production by type



Shinichi Tohyama, 50, has been a fisherman for 28 years. He used to do longline or diving fishery from his small "sabani" rowboat, until seven years ago when he began payao fishery. Now he engages in payao fishery from March to October and bottom gill net fishery from October to February. His yearly catch brings in an income of ¥7 to 8 million (US$70,000 ~ 80,000), 60% of which comes from payao fishery. He supplements this by taking out sport fishermen a few times a month to bring his total income to a level equal to or slightly above the average urban worker. He fishes about 300 days out of the year, or, as he claims, "almost every day there isn't a typhoon in the area."

Meanwhile, the active programs of on-land development that followed Okinawa's return to Japanese governance, dealt a big environmental blow to the coral reef fishing grounds. Urban development, farming/fishing village improvement projects and the building of resorts led to landfill projects that ate away at the already limited shallow-sea fishing grounds. Development projects also caused large quantities of the islands' red clay to be carried out to sea by rivers, thus damaging the quality of the coral reef fishing grounds further.

While the retreat of distant-sea and southern-based fisheries was causing a large number of fishermen to return to coastal fishery, the deterioration of the coral reef fishing grounds brought attention to the importance of building new fisheries in the coastal and offshore waters outside the coral reefs. One of the solutions that arose in answer to these problems facing Okinawa fishermen was the payao fishery that we introduce here in this issue.

We should note here that Okinawa has saltwater aquaculture industries for kuruma prawn, mozuku [Nemacystus decipiens] seaweed, and pearl oysters as well as freshwater culture of eel and carp. All of these are industries that began to flourish about the time of Okinawa's return to Japan in 1972, taking advantage of the warm climate of the islands. Among these, the kuruma prawn and mozuku culture industries have continued to grow and contribute significantly to the prefecture's fishery production, whereas the freshwater culture enterprises have shown rather poor developmental potential as a result of such disadvantages as a lack of suitable inland water resources and higher costs for culture seeds, feed and transportation due to the prefecture's distance from the major markets. Also concerted efforts in the field of tuna fish-farming have led to successful results in artificial seed production recently that have become the focus of worldwide industry attention.

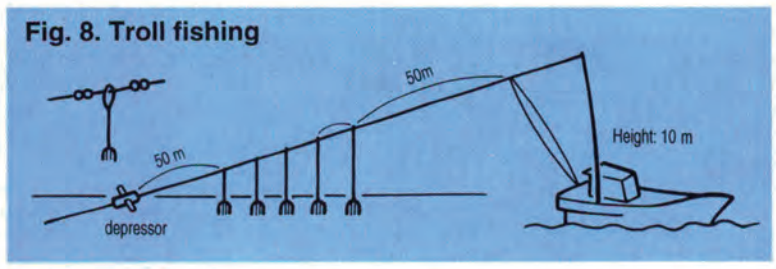
Introduction and spread of payao fishery

Fishing techniques making use of brush shelters have been common in all parts of the world since olden times. In Japan, too, these techniques were used widely in the main fishing grounds of the Japan Sea from the 17th century up until World War II. After the War, however, a shortage of materials to build shelters and other problems like conflict over rights to the fish that gathered around them, led to the natural disappearance of this method.

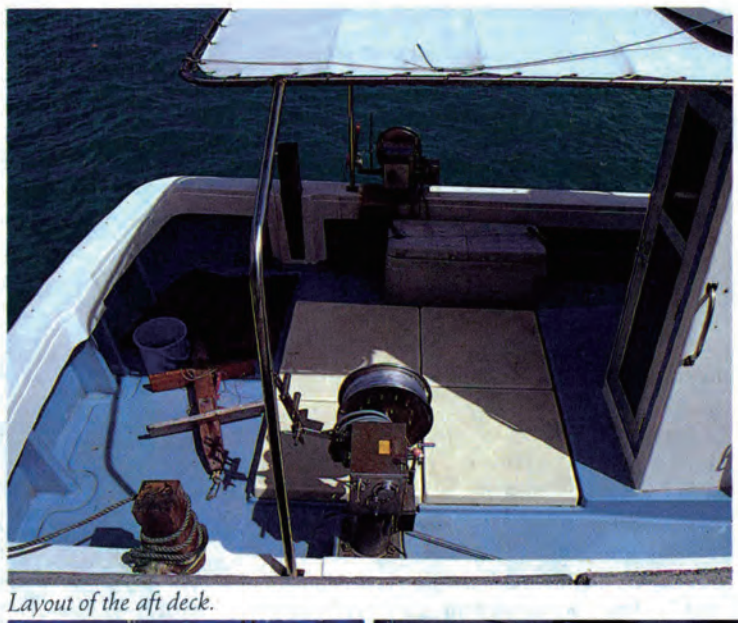
British cultural anthropologist, James Hornell, writes that the origins of brush shelter fishing techniques observed in India, China, Southwest Asia and central Africa can be traced back to prehistoric times. In this type of fishery tree branches with full leavage are tied together in bundles and set afloat individually or linked with a longline in places on rivers, lakes or shallow sea waters where fish tend to gather. After a certain amount of time has passed, the bundles are raised slowly and the fish and other marine animals that have taken shelter in among the leaves are shaken out to be caught in a net. In Japan, variations of this method have been used traditionally in certain regions of the country to catch dolphinfish, squid or eel.

The word "payao" comes from the Philippines, but the same type of fishing devices are also referred to in Malaysia as "unjang" and in Indonesia as "rampon." Like brush shelters, it is a type of fish aggregating device (F.A.D.) in the form of a floating fish shelter. In recent years the term payao has become most commonly used to refer to these devices.

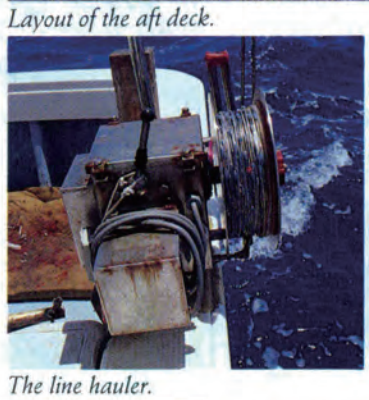
In 1979, the South Pacific Commission (SPC) conducted successful experiments with payao in the seas around Hawaii. This led to the rapid spread of payao fishery



After arriving at the payao, the line is set and the trolling begun in a figure "8" pattern either on the up-current or down-current side of the payao. The decision as to whether to troll up or down current from the payao is made based on the color of the tide, the roughness of the waves and the type of fish to be caught. Boat speed is kept at 6 - 7 knots, except for rough days when the waves make the depressor jump too much, in which case speed is decreased to about 5 knots.



Layout of the aft deck.



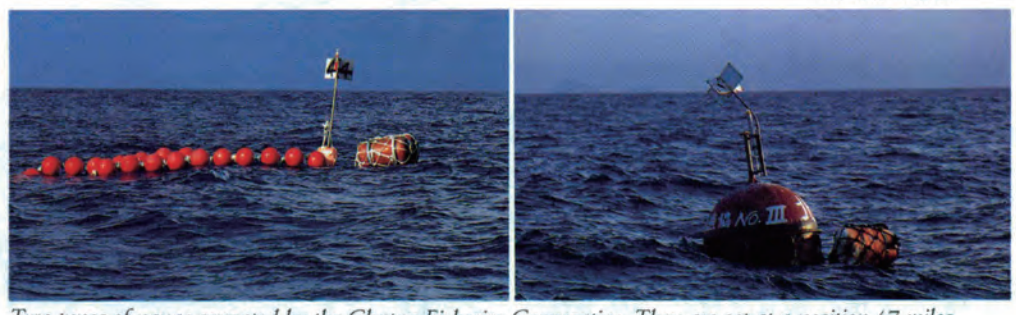
The line hauler.

The wheel house

techniques in the countries of the South Pacific. In Japan the Okinawa Fisheries Experimental Station and the Miyakojima Fisheries Cooperative both set up payao devices in offshore waters with a depth of 800 ~ 1,000 m in 1982, and had positive results. After that, during the years 1984 and '85, the number of cooperatives engaging in payao fishery experiments spread throughout the prefecture. By the end of 1985 some 80% of the prefecture's fishery cooperatives had set up payao devices and the prefectural government recognized the need to set up a regulatory system in November of that year to prevent a chaotic proliferation of the devices in prefectural waters. Under this license system the local fishery cooperatives are given responsibility for controlling the set-up and operation of payao devices, of which there are now some 177 units in the waters of Okinawa. (**Fig. 5**)

A payao fishery operation is usually conducted by a single fisherman working from a small 3 ~ 5-ton boat and employing a troll or hand line fishing method. In Japan the operation of net fishery in the vicinity of payao devices is prohibited. The troll method is particularly effective and has produced good results for Japanese fishermen. Compared to the total troll fishery production for Okinawa of 904 tons in 1982, the 1991 figure showed a 290% increase to 2,682 tons. In terms of total catch value, this represented a 310% increase from 425 million yen (US$4.25 million approx.) to 1.34 billion (US$13.4 million approx.). When compared to the growth rate of other types of fishery, it becomes clear that this big increase is due to the contribution of payao-based fishery.

In the seas around Okinawa, the main objects of troll fishery are skipjack, Spanish mackerel, frigate mackerel, yellowfin tuna, billfishes and dolphinfish. The make-up of species is the same for trol fisheries using payao. In short, it can be concluded that the payao are effective in attracting the same kinds of fish, while eliminating the time and labor otherwise required for searching out productive fishing grounds and, thus, greatly increasing the efficiency of the fishing business.



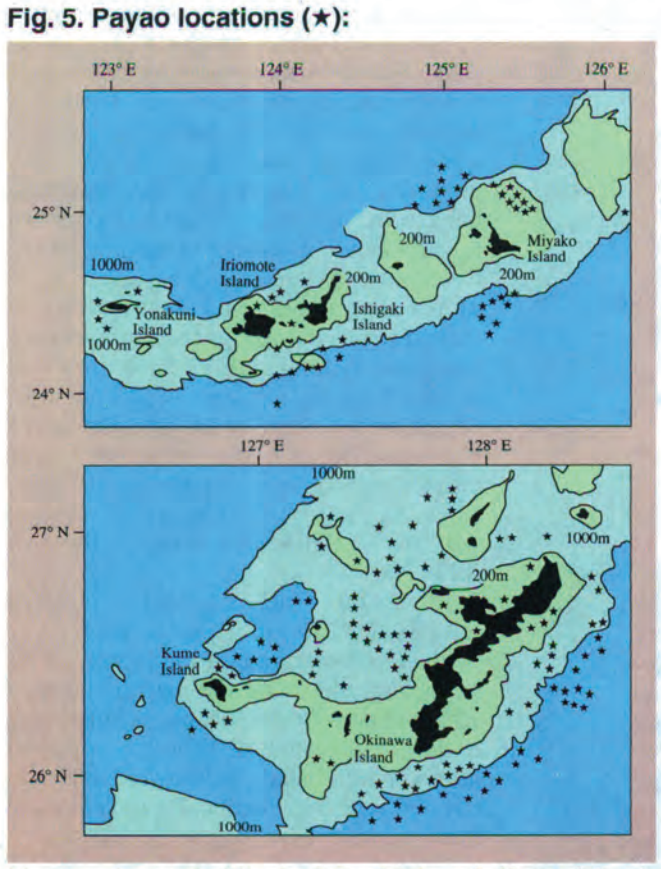
Two types of payao operated by the Chatan Fisheries Cooperative. They are set at a position 47 miles (approx. 75 km) due west of the Chatan harbor, and about three miles (4.8 km) from each other.

Summary of payao devices

A payao consists of three basic parts, 1. the float structure (raft), 2. the anchoring lines and 3. the anchor. In the case of Okinawa, three private sector manufacturers each developed and marketed their own designs initially. As shown in **Fig. 6**, these three were called the Toray type, the Shinto type and the Nippi type after the names of the manufacturers. Over time, however, the local fishery cooperatives each added their own modifications and improvements to create what would best be called a next generation of "homemade types."

Whereas a payao installation by one of the

Fig. 5. Payao locations (★):



Yonakuni Island - Miyako Island (above); Kume Island - Okinawa Island (below); maps redrawn from figures cited in Ohshima, 1987. ***(by M. Izumi)***

The catch is cleaned of gills and innards and kept with crushed ice in the boat's fish hold.

▼The depressor

◀The fishing lures

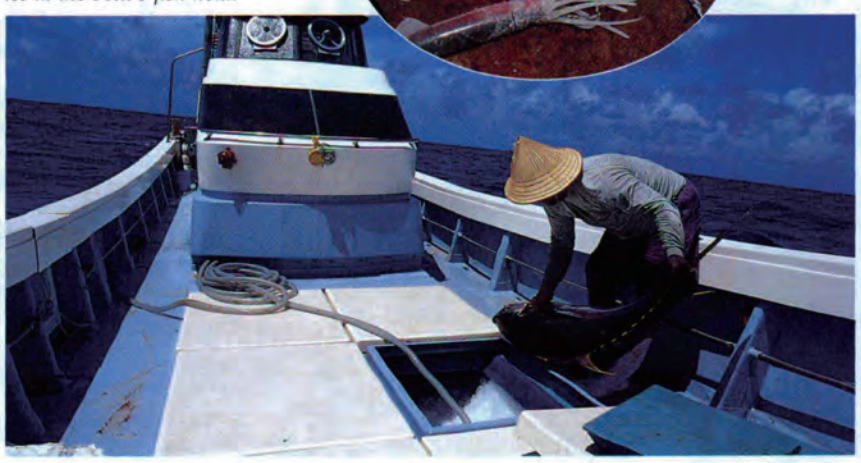
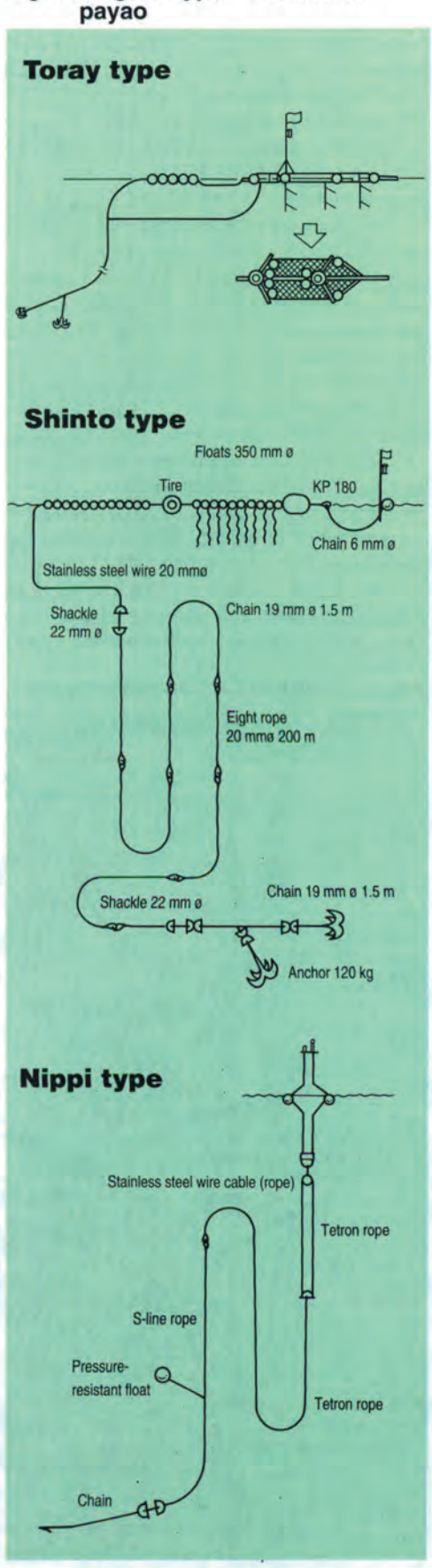


Fig. 6. Original types of Okinawa payao



three manufacturers ranges in cost from one to two million yen (US$10,000 ~ 20,000), a homemade type made of materials like used telephone poles or bamboo can be made for about half the cost. Under the existing programs for the promotion of payao fishery, prefectural and local fishery cooperative funds are available to cover about half the cost of each installation.

As for why payao are effective in gathering fish, numerous researchers have put forth theories of explanation. Their theories cite the following reasons:

1) Small fish feed on the seaweeds and planktons that grow on and around the payao structure, and middle and large size fish gather to feed on the small fish, thus creating an independent food chain centered around the payao.

2) The fry and young of various species gather in the shadows of the payao as a place to hide from predators.

3) Fish have an innate habit of gathering in the dark areas beneath objects in the sea.

4) Some species of fish have the habit of laying their eggs on floating masses of seaweeds, etc.

5) Fish are attracted to the underwater sound given off when waves break against floating objects or anchoring lines.

However, given the fact the response of fish to the presence of a payao differs with species and with changes in season or sea conditions, it seems hard to limit the reason for fish aggregation to any one explanation. It is probably closest to the truth to assume that, when various conditions are right, a number of factors will combine to produce a positive fish-attracting effect.

The types of materials that a maker chooses in building a payao depends on which of these above factors he places the most importance on. Of the payao used in the various regions of Southeast Asia, we can identify several distinct types. **(Fig. 7)**

According to studies by fishery research stations, the types of fish that gather around payao are numerous, with about 30 species being identified. However, the payao's effectiveness in attracting larger fish like skipjack and tuna seems to vary with the location of the payao; with installations set in waters with a depth of over 1,000 m having the highest gathering ratio.

When preparing a payao installation, the most important quality to consider is the durability of the device as a whole. Because the device is set in the open sea, there is always considerable danger of the float body being broken up by waves or the anchoring lines being broken by the ocean currents. Generally, a spot on the ocean floor that has steep crevices is chosen for setting the anchor. A payao is usually expected to last for one to two years, but improvements in the materials used in the body structure, anchoring lines and shackles, etc. has increased the durability of some recent models to over two years.

The fishing port at Chatan. The tall building in the center is the ice factory.

Impact on the fishing community

The impact of payao fishery on the fishing industry of Okinawa has not been uniform throughout the prefecture, as different localities have approached the fishery in different ways. The different local approaches can be roughly categorized into the following types.

1) In localities where there are large numbers of fishermen and decreasing space in local fishing grounds, conversion to payao fishery has been a way of thinning out the ranks of fishermen working the limited local fishing grounds.

2) In localities that are bases for middle-size boats engaged in offshore fishery for skipjack and tuna, payao fishery using small 3 ~ 5 ton boats is used as a supplementary fishery during the off-season for fishermen with limited financial resources who normally work as hired fishing hands on the middle-sized offshore boats.

3) In localities suffering from an aging or deterioration of local coral reef fishing grounds, neighboring fishery cooperatives have banded together to set up payao installations as a way to revive coastal fishery.

4) On isolated islands far from the main island of Okinawa, fishermen have joined together to specialize in payao fishery for high-value fish like tuna and billfishes, consolidating shipments in order to overcome the inherent disadvantage in high transport costs isolated islands suffer from.

5) Cooperative operation of payao fishery serves as a means to heighten the fishermen's mutual understanding and respect and thus improve overall fishery resource management.

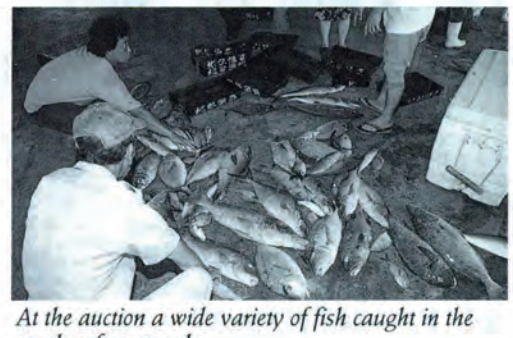
Only recently has payao fishery begun to take root in Okinawa and, probably, it should still be considered to be in the experimental stage. Its potential has been recognized and there is a possibility that it will continue to develop in a variety of directions. However, there are also several problem points that can be cited as important subjects for future consideration.

1) In Okinawa at present, the fishery cooperatives are in charge of managing payao operation and improving technology, fishery experimental stations are conducting surveys and research, and the prefectural government assumes responsibility for governing and licensing payao operations, but at some point a limit must be recognized for the optimum number of payao that the waters around Okinawa can support.

2) The cooperative that has set up a payao installation is recognized as having exclusive fishing rights concerning that installation, but some ordered system of operation will have to be established for payao installed as a joint venture by two or more cooperatives. At the same time, solutions must be worked out for dealing with the conflicts of interest with sport fishermen.

3) Being inherently a group of isolated islands, distribution routes for fishery products in Okinawa as a whole still fall far behind standards on the main islands of Japan. Major efforts must be made not only to develop demand for fishery products in the Okinawan islands themselves but also to develop effective distribution routes to the main islands.

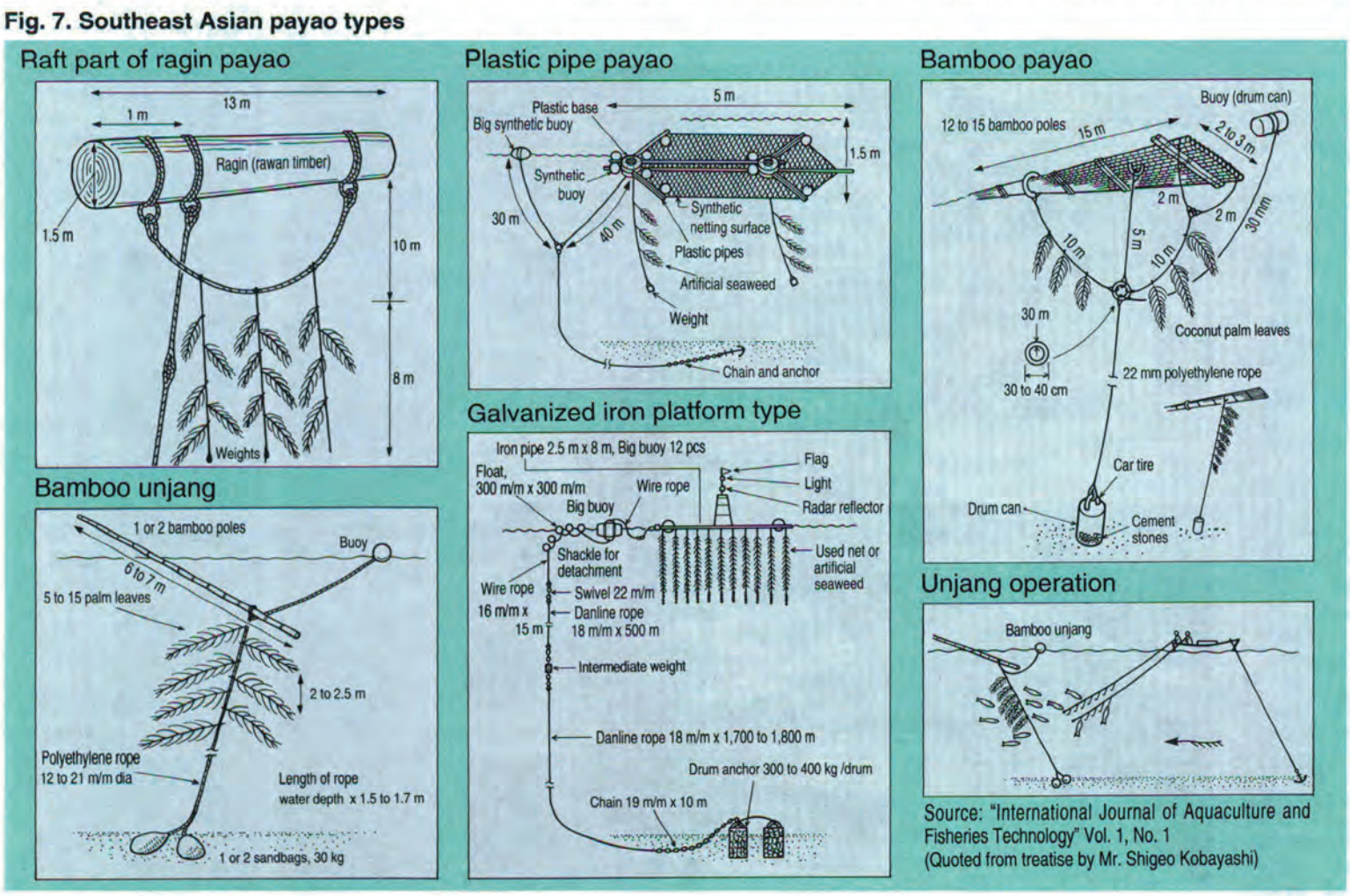
At the Cooperative's fish market an auction is held every morning at 9:00



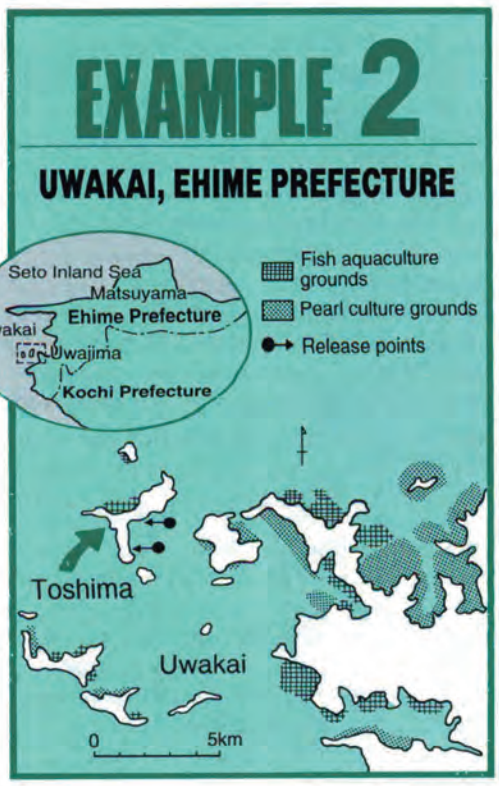
At the auction a wide variety of fish caught in the coral reef go on sale.

In Okinawa there are places where the fishermen make a joint investment to operate fresh fish wholesale outlets. At present four local fishery cooperatives run such shops, all of which are doing well and attracting attention from neighboring cooperatives.

Fig. 7. Southeast Asian payao types



Source: "International Journal of Aquaculture and Fisheries Technology" Vol. 1, No. 1
(Quoted from treatise by Mr. Shigeo Kobayashi)



Domestication type fish farming of striped jack

An experimental marine ranch

A view of the aquaculture grounds at Toshima island. The Uwakai area has a complicated Rias type coastline with numerous islands offering many areas of sheltered water. Also. the fact that it is located at the point where the Seto Inland Sea meets the Bungo Straits, means there is a good tidal exchange of water along its coasts, bringing in a constant supply of clean oceanic water. Thanks to these favorable conditions, the waters of the Uwakai area are used for fish and pearl-oyster culture. Of the 700 people living on Toshima island, 200 are engaged in fishery. In the past purse seine fishery for sardine was the main fishery of the island, but due to poor business and an insufficient labor supply, the fishery failed in the 1960s. At that point the island's fishery cooperative decided to revitalize its fishing industry with aquaculture. At present 82 operators are involved in aquaculture, producing 5,500 tons of catch in 1993, worth some ¥5.3 billion. Among boat fisheries pole-and-line angling by fishermen of middle or advanced age is the major type of fishery. Their catches totaled 180 tons in 1993, worth ¥200 million.

Photo top: Fish released in 1987, bottom left: fish released in 1988, bottom right: fish released in 1989 (photographed June, 1989)
(Photo courtesy of the Ehime Fisheries Experimental Station)

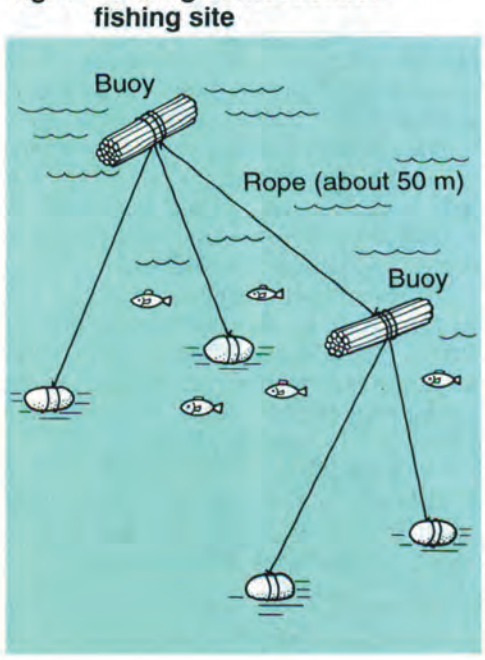
Feeding-type fishery

In southwestern Japan, fishery in which regular feedings are used to "domesticate" a population of fish until they grow to a catchable size has been conducted for yellowtail, amberjack and striped jack for many years. Starting first in Kagoshima Prefecture on Kyushu in the late 19th century, this type of fishery soon spread throughout an area that included all the coasts of Kyushu, Yamaguchi Prefecture on Honshu and Kochi Prefecture on the southern coast of Shikoku. At its peak near 1935, this type of fishery was conducted in about 50 fishing grounds throughout the region, each yielding a catch of 30,000 to 50,000 fish per season. However, with the shortage of materials like bamboo necessary for the fishery after World War II, it went into decline. Today feeding-based fishery continues to be conducted only in a few areas with particularly favorable natural conditions.

The common traits of all fish that become the object of this kind of fishery are that spawning and hatching occur in the open sea, after which the young migrate to the coastal waters to spend their formative period in the protected waters of inland seas or bays. Upon reaching the age of one year, the fish then return to the open sea to begin cycles of migration. Domestication type fishery involves designating a certain spot at sea where feeds like shreaded anchovy, sardine, blue sprat or mackerel is spread on the water every day to keep a migrating school in one place for a given period, during which time a large number of fishermen make catches from the school by angling. (**Fig. 9**)

For the fishing ground, an area of shallow sea with a mild current and a depth of 30 to 50 m is chosen. The ideal bottom topography is a sunken flat with a white sand bottom surrounded by rocky reef. Such spots are most likely to provide a successful feeding effect because they are not preferred habitats for demersal fishes and there is reduced chance of reef-dwelling fishes taking a share of the feed.

Fig. 9 Feeding-domestication fishing site



Sea farming

Recognizing the favorable characteristics of mackerel family fishes as objects of fish farming, the Japan Sea-farming Association (JASFA) began experiments in domestication-type fish farming with striped jack in 1987. Among the experimental fish farming efforts being conducted today in nine prefectures, this one is the focus of particular attention because it shows one of the greatest potentials as a future direction for resource-cultivation type fishery.

Using technology introduced from overseas, Japan first began practices of artificial hatching and release with salmon and trout at the end of the 19th century. The next experimental research in artificial seed production and release of marine resources began in 1963 for kuruma prawn, gazami crab and red sea bream in the Seto Inland Sea region. The organization that was given the responsibility for carrying on the fundamental research and practical experiments for these new efforts with government support was the Japan Sea-Farming Association. Since then, this organization has succeeded in artificial seed production for about 80 species of fish, crustaceans, shellfish and other marine animals.

Cultivation fishery is the practice of producing fry (seeds) by artificial means and then releasing them in a suitable natural sea environment where they can grow and be nourished by the natural productivity of the sea with the aim of maintaining and/or increasing the available fishery stocks of that area. In order for this kind of cultivation to be successful, the following three requirements must be met.

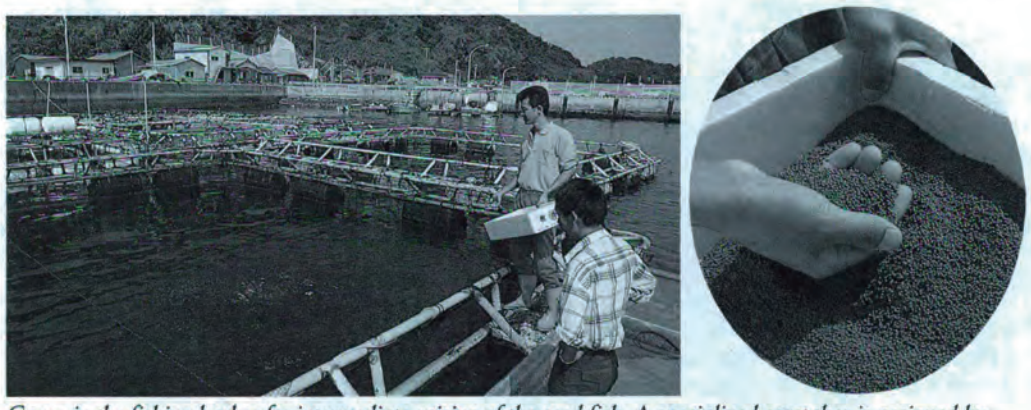
(1) Healthy seeds must be raised and released in a way that keeps the natural mortality and population losses through predation to a minimum.

(2) Ways must be established to prevent small-scale local fisheries like gill net and trawls from catching the young that have been released before they grow to a marketable size.

(3) A sufficiently high recapture rate must be achieved to make the cultivating operations economically viable.

Of these, **(1)** involves the technical problems of successful seed production from artificial incubation through the early to intermediate stages of growth. With regard to this, research efforts continue in the areas of suitable raising environment, stock density in the raising process, feeds and methods of intermediate raising, all with the aim of raising large quantities of low-priced seeds that have the same vitality and swimming capabilities (mobility) as natural fry. **(2)** is a problem of fishing ground management. The establishment of mesh-size regulations for fishing nets and "fish-back" movements to return small fish catch to the sea, are proof that fishermen's consciousness of the cultivation efforts and resource conservation are increasing. However, in coastal fishing grounds shared by numerous kinds of fisheries, the problem of thoroughly protecting the released stock is a very complex one. As for **(3)**, this is a problem involving the behavier of the species being cultivated. Operators of cultivation fishery must first choose a species that tends to stay in one specific area of the sea as opposed to species that tend to scatter over a large area. Also, it is essential to learn about the species' life mode and understand where and how the young live during each stage of their life cycle. Once these things are known, it then becomes possible to draw up an effective fishery schedule with regard to the cultivated stock.

Up until now, great progress has been made in solving problems **(1)** to **(3)** with regard to stationary species of shellfish and crustaceans and the anadromous migrators like salmon and trouts, and cultivation efforts have thus produced good results. However, with regard to fish species other than salmon and trouts, the history of cultivation fishery is still short, and techniques for the successful management



Cages in the fishing harbor for intermediate raising of the seed fish. A specialized caretaker is assigned by the cooperative to manage the operations of receiving the seed fish, caring for them throughout the intermediate stage, releasing them and carrying out the feeding-domestication afterward. A fine-particle composite feed is used in the intermediate raising stage.

A yellowtail culture site. In each of these 10-m square, 8-m deep net cages 2,000 ~ 3,000 yellowtail are being raised. Depending on the growth stage, the operators supply 50 ~ 100 kg of fresh sardine mince or moist pellets a day. By observing the conditions of the fishes' feeding the operators make adjustments in the amount of feed supplied to prevent over- or under-feeding. Even so, it is estimated that about 20% of the feed falls through the net cage uneaten.

of cultivation resources are still underdeveloped. In the areas of production efficiency and return on investment in these cultivated stocks, there are still many problems that must be dealt with.

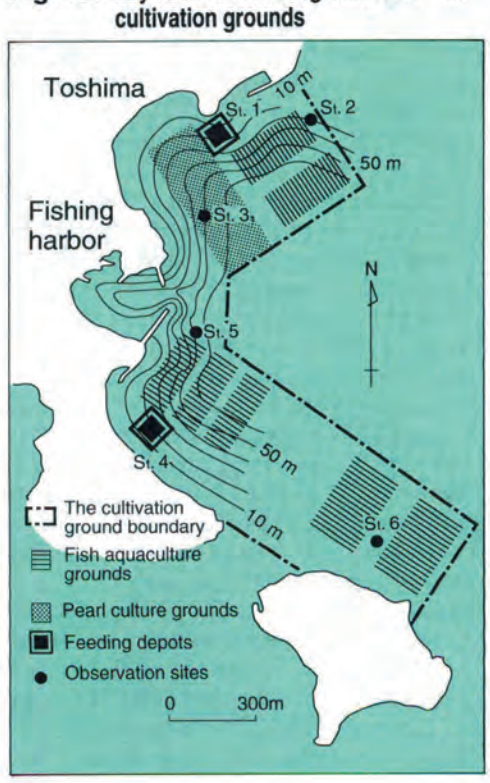
The framework of a domestication-type cultivation fishery experiment

This experiment began with the goal of taking advantage of the habits of striped jack in order to keep the fish in the vicinity of the release point as long as possible, thus maximizing the recapture ratio. During the fry stage, natural striped jack live around floating masses of seaweeds, etc. Young that later migrate into coastal waters have been observed swimming in schools near jetties, etc., along the shores of harbors. When the young reach adult size they once again move to the open sea where they live in the vicinity of islands or rocky reefs. Striped jack have a strong schooling instinct, as well as an instinct to orient there movements around some type of "base." Thus, the aim of striped jack domestication-type cultivation fishery has been to take advantage of these schooling and base-orientation instincts, to which is added the learned response to regular feedings, in a way that keeps the stocks from scattering and makes them effectively permanent residents of the area around the chosen "base." Existing fish culture grounds were chosen as the site for this experiment. By choosing such a site, the operators could take advantage of abundant quantities of excess feed that falls through the nets of the culture fish cages, and also have these cages serve as the natural "base" for the striped jack population.

Fig. 10 shows an example of a plan for an experimental feeding-domestication type fishing ground. Here, in waters containing extensive blocks of aquaculture cages, two feeding depots (marked ▣) were set up at locations on the shore side near the cage blocks. The area within the dotted line was designated a "domestication-type cultivation fishing ground" and observation points were set up at several locations. The experiment has been conducted according to the following procedures:

(1) In May, the local fisheries cooperative received striped jack seeds raised to a length of 3 cm by the JASFA and continued intermediate raising in fish cages in the fishing harbor for five months until the young reached a body length of 17 cm.
(2) In October, the cages containing the young were moved to the feeding site at which they would be released and raised there in the cages for another month to allow the fish to become acclimated to the new environment. After this month the fish were tagged and released.
(3) In order to prevent immediate scattering due to the shock of release, the cage net was slowly lowered to the bottom while the fish were being fed at the surface.
(4) For several days after the release, the fish were fed at frequent intervals with composite feeds or moist pellets containing fresh sardine mince. After this the frequency of feedings was gradually reduced to a few times a day. These feedings continued from October until March of the following year.

Fig. 10. Layout of the feeding-domestication cultivation grounds



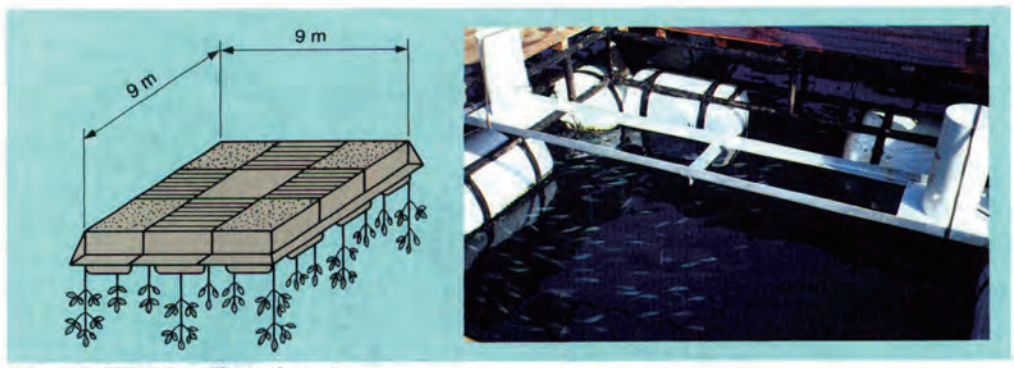


Fig. 11. The feeding depot
A raft made of steel L-frames is placed on styrofoam floats and a roofing of plywood and canvas put over it to create a shadow in the water. Tree branches with dense leafage are also hung in the water. Feeding is done from the open spot in the middle. The standing white cylindrical drum is a solar-powered automatic feeder.
(Photo courtesy of the Ehime Fisheries Experimental Station)

One- to three-ton class fishing boats for angling. Several boats fish in a group anchored about a dozen meters from the aquaculture preserves. Besides striped jack they also catch a reef fish called isaki grunt.

Practical aspects of feeding-based domestication

The success of this kind of fishery depends on how successful the operators are at inducing the fish stock to make the transition from feeding at the initial feeding depots to feeding on the excess feed that falls through the nets of the neighboring culture fish cages.

During the initial stage of the feeding-domestication process, the fish stay within a relatively small area with a radius of about 60 meters, swimming slowly around the surface waters of this area at a depth of 0 ~ 3 meters during the daylight hours. When small schools do happen to venture out of the area around the feeding depot, they show a strong tendency to return immediately. As soon as the feeder starts to dispense feed the fish gather at once and feed while swimming at a fast pace around the feeder. At this stage the contents of the stomachs of the fish observed was almost exclusively of the composite feed being dispensed at the feeder.

As the striped jack grow, their area of activity steadily widens and they acquire the habit of feeding also on the excess feed dropping from the nearby culture cages. One day, about three months after release, the population suddenly moved all at once to the area of the closest aquaculture cages several dozen meters away and proceeded to form schools of 5,000 to 6,000 fish that then took to swimming back and forth between the cages and the original feeding depot. During the winter months the swimming depth increase to 5 ~ 10 m. Studies have shown the low temperature threshold for natural striped jack to be 14°C. In this experimental cultivation fishing ground the winter water temperature drops to about 13° C.

Nonetheless, observations showed that the experimental stock stayed within the cultivation ground through the winter, thus proving that the domestication process had been successful in keeping striped jack in the desired area. During the feeding period of the domestication process, the local fishery cooperative prohibited all fishing within the designated grounds to protect the newly released fish. From spring into summer of the year following the release, striped jack with a body weight of about 1 kg were caught in the cultivation grounds by angling. In autumn of that year, when the water temperature began to drop, members of the released stock began migrating south along the coast where they were caught in small set nets some 20 ~ 30 kilometers away. The fish caught here had reached a body weight of 1.5 ~ 2.0 kg. In contrast to the 5.7% recapture ratio by angling and set net fishery for the stock of 120,000 striped jack released in 1987 without any feeding-domestication conducted after release, the stock of 110,000 released in 1988 with the subsequent feeding-domestication period of six months described above showed a dramatic increase in recapture ratio to 11.7%, thus proving clearly the effectiveness of the domestication process.

Outlook for the future

Recent underwater surveys at the cultivation site have revealed large numbers of second- and third-year fish among the schools inhabiting the waters directly under the culture cages. Since the catch rate is poor for angling fishery conducted around the cages and the area's waters are not suitable for purse seine, boat seine or gill net fishery, a suitable new fishing method is presently being sought. Considerable difference is seen in the results of similar experiments being conducted in other parts of the country. And in some cases, projects have already been abandoned for lack of positive results. The primary factor determining the viability of a feeding-type cultivation fishery seems to be the environment of the fishing grounds. First of all the sea environment must be suitable for the type of fish being raised. Secondly, the amount of excess feed coming out of the aquaculture cages becomes a factor. The number of fish released has to be calculated to balance with the amount of excess feed supplied by the cages.

If in fact a practical and sustainable system of seed production → intermediate raising → release → feeding-domestication → raising in the aquaculture ground → recapture, can be achieved, the domesticated schools of striped jack will become an asset that will make a great economic contribution to the fishing community, just as the cultivated resources of shore-dwelling shellfish like abalone and top shell do today. Such a success would also open the possibility of feeding-domestication type cultivation fishery for other types of fish as well.