A Survey of JAPANESE RESEARCH on SHELLFISHERIES and SEAWEEDS

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A SURVEY OF JAPANESE RESEARCH ON SHELLFISHERIES AND SEAWEEDS

by

John B. Glude
Chief, Branch of Shellfisheries
Bureau of Commercial Fisheries
U.S. Fish and Wildlife Service
Washington, D. C.

INTRODUCTION

Molluscan shellfish have been cultured in Japan for several centuries, and efficient methods have been developed which require a minimum of equipment or supplies that cannot be produced or obtained locally. In general these methods depend on abundant, low-cost labor. Some of these methods might be utilized in the United States if our modern technology could reduce labor cost to an economic level.

Shellfishery scientists in Japan have written hundreds of valuable reports, nearly all in Japanese. Certain results, methods, and research techniques might be helpful to U.S. biologists who are faced with similar problems, but the barriers of distance and language have prevented a free exchange of ideas.

The purpose of my trip to Japan in July 1958 were to explore the status of shellfishery research, to locate sources of scientific information that might be of value to U.S. biologists, and to encourage international exchange of such scientific information. The term "shellfishery" as used in this report includes both molluscs and crustaceans.

Japanese research on seaweeds and methods of seaweed cultivation were also observed. These observations may be of importance in the United States if our small fishery for marine algae should develop into a system of controlled cultivation.

Author's Note.--Presently employed as *Assistant Regional Director*, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service, Seattle, Washington.

FACILITIES FOR FISHERIES RESEARCH

Three groups of laboratories perform fishery research in Japan: (1) the Central Fisheries Agency and its eight regional fishery research laboratories, (2) the Prefectural laboratories or experimental stations, and (3) the laboratories of various educational institutions. The eight regional fishery research laborabories of the Ministry of Agriculture and Forestry, Central Fisheries Agency, were established in 1949, when the fishery research program was reorganized. In general, the biological research of the regional laboratories concerns long-range studies of basic nature, such as investigations of nutrient salts in sea water, surveys of marine plankton, and ecological studies of commercially important fish and shellfish.

Prefectural fishery experimental stations or laboratories work directly with the industry, and their research tends to cover practical problems. Typical examples include predicting the time of setting of oyster larvae, investigating methods for inspecting seed oysters destined for export to the United States, and studying causes of shellfish mortality.

University laboratories staffed by professors, instructors, and graduate students specialize in basic research because most results are used as theses for advanced degrees. Some of this research is extremely valuable because it provides fundamental information and new research methods that can be used to solve fishery problems.

OYSTERS

Methods of oyster culture observed during this survey were generally the same as those described by Glude (1949) and Cahn (1950). The hanging method of oyster culture has become even more prevalent than it was in the late 1940s. It was reported that over 90 percent of the oysters produced in Japan were grown by this method in 1958.

The hanging method of oyster culture involves the suspension of the oysters below some device which keeps them from touching bottom. This device may be a long fence or rack made of vertical posts driven into the bottom and connected by horizontal poles, or it may be a floating raft. Racks are generally used in a shallow bays, and rafts in deeper water. In both cases the oyster or scallop shells with young oysters attached are spaced at intervals on vertical ropes or wires suspended below the raft or rack. In one method a hole is punched in each collector shall and the shells, separated by pieces of bamboo 4 to 6 inches long, are strung on wires. The wires may vary in length from 6 to 25 feet depending on the depth of the water. Since the lowest shell does not touch bottom at any time, crawling predators cannot attack the oysters.

In some places twisted rice-straw rope dipped in tar is used to hold the oysters in position. This rope will last 12 to 15 months, which is long enough to produce a crop of oysters. When this rope is used the shells with seed oysters attached are simply inserted between the strands of the rope. The young oysters grow very rapidly

Oysters are suspended below rafts where they grow rapidly and escape crawling predators.

Mature oysters grown below rafts are harvested by cutting wires upon which they were suspended.

and in a short time become large enough to hold the collector shell in place.

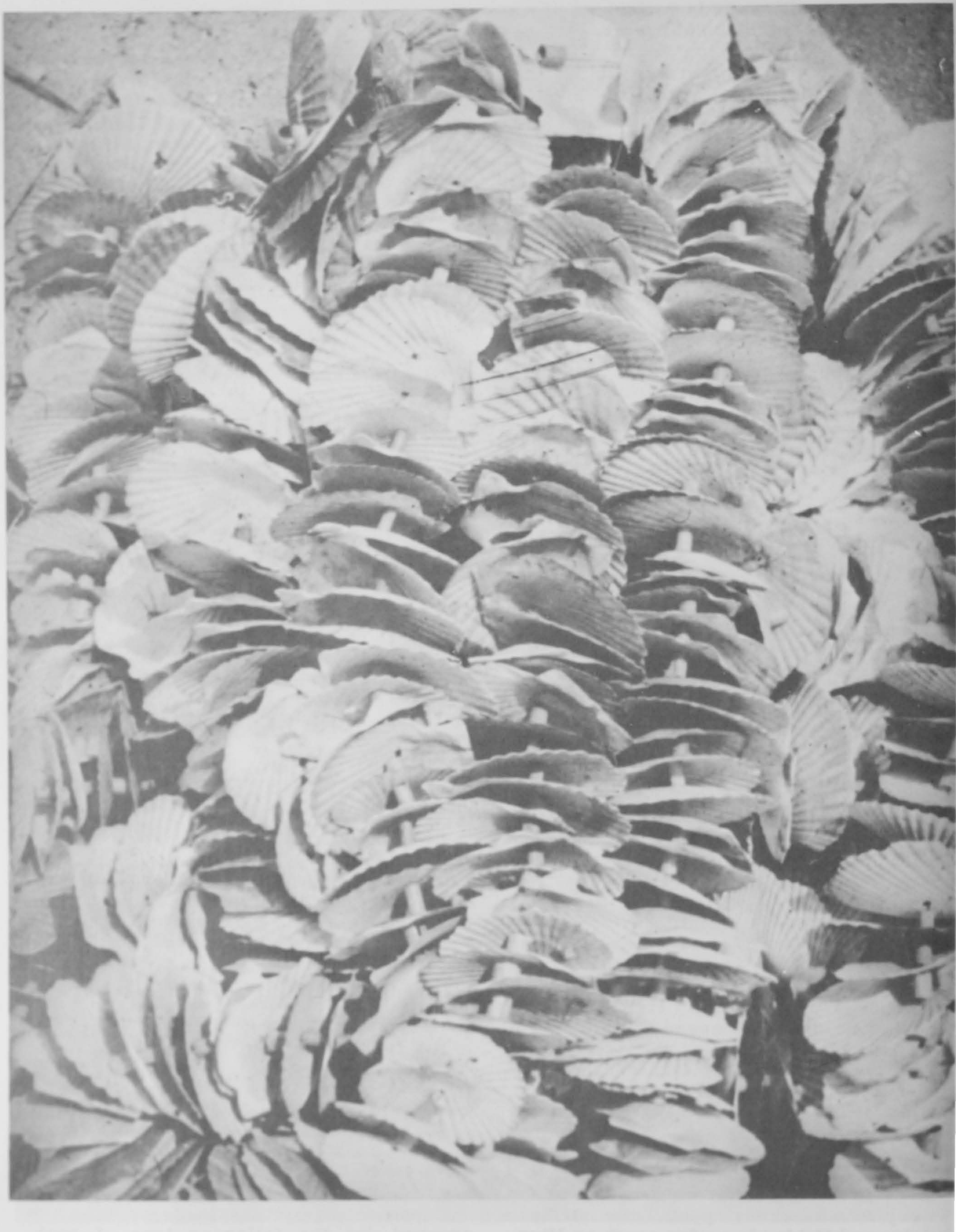
During recent years the principal improvement in the raft method of oyster culture is the use of cast concrete floats instead of wooden barrels or steel drums in the Hiroshima area. These concrete drums, with 3/4-inch thick walls, are made nonporous and exceedingly strong by spinning the mold at high speed while the concrete hardens.

The increased use of scallop shells as oyster spat collectors was also observed. Scallop shells are generally preferred for culture of oysters by the hanging method because these shells withstand wave action better than oyster shells. For use in the oyster industry, shells of the scallop *Pecten yessoensis* are shipped from northern Honshu and Hokkaido as far south as Hiroshima.

The southern scallop *P. laqueatus* is also used in the Hiroshima area for collecting oyster spat and has some advantages over the larger northern scallop. The shells of the northern scallop are quite flat, so they are usually strung on wire with bamboo spacers about 1/2-inch long between shells to provide a good circulation of water. The shell of the southern scallop, however, is more cupped, and it is not necessary to put spacers between shells.

Other types of cultch are used as substitutes for scallop and oyster shells. The heavy shells of the large mussel *Mytilus crassitesta* are satisfactory if oyster setting is exceptionally good; otherwise, they may catch too few spat to provide useful seed.

Research on oysters in Japan might be grouped by the following type of problems.



Scallop shells used as cultch are strung on wire and separated by bamboo spacers.

Setting and Seed

Because excellent setting areas are restricted and the setting season is short, it is important that the predictions of time and place of setting be accurate. For example, in a small area close to Hiroshima the rate of setting is approximately 100 spat per shell per day, whereas about 1 mile away the setting rate is only about 5. The Prefectural laboratories predict the time of setting and also record the attachment of barnacle larvae. Oystermen are advised to withhold placing oyster collectors in the water until barnacles have set.

In Matsushima Bay where seed oysters are collected for export to the United States the growers are well organized and employ their own biologists to predict the time at which cultch should be placed in the water.

Culture and Harvesting Methods

The Prefectural fisheries experimental stations conduct research to develop better methods of oyster culture or harvesting. The staffs of these stations work directly with the fishermen and specialize in the application of known principles to increase production.

Biologists of the Central Fisheries Agency sometimes cooperate with prefectural biologists in attempts to develop new oyster culture methods. For example, at Hiroshima, biologists of 18-inch square wire baskets which were dipped in asphaltum. This method, used in growing pearl oysters, had not been applied in the culture of edible oysters. Researchers found the baskets lasted 3 years and that the oysters which were produced were of better shape and higher quality than those grown by the conventional hanging method.

Processing and Marketing

In many parts of Japan, oysters are grown in waters near centers of population and for this reason are not eaten raw. Some attempts have been made by industry to purify the oysters from contaminated areas so that they would be safe to eat without cooking. In one shucking plant at Hiroshima the oysters were washed in salt water taken directly from the harbor, but supposedly sterilized by adding chlorine directly to the supply line about 12 inches before it is discharged into the tile-lined tubs. The adequacy of this method of purification was not known.

Another method of purification of oysters has been developed by Tadao Sato of the Matoya Wan Oyster Research Laboratory in Mie Prefecture. This method consists of passing sea water through a coarse filter to remove larger particles and then under a series of ultraviolet lights to destroy the bacteria. The water is then sprayed into long, narrow concrete tanks containing trays of oysters. Water and oyster feces are removed continuously from the bottom of the tank by a siphon arrangement. This method was reported to be successful in reducing the bacterial scores sufficiently so that the raw oysters could be eaten safely.

The Effect of Pollution on Oysters

Several Japanese laboratories have done research on the effect of polluting substances on aquatic organisms. Tomiyama and Inouye (1949) described an apparatus for measuring the effect of polluting substances such as hydrogen sulfide upon fish and shellfish.

Fujiya (1955) reported on studies at the Inland Sea Fisheries Research Laboratory on the effect of industrial wastes and chemicals upon the heartbeat of the oyster. In these experiments he tested the effect of diluted sea water, hydrochloric acid, sodium hydroxide, sewage, sodium sulfide, rayon waste water, sulphite pulp mill waste water, and the insecticides parathion, tepp, and endrin.

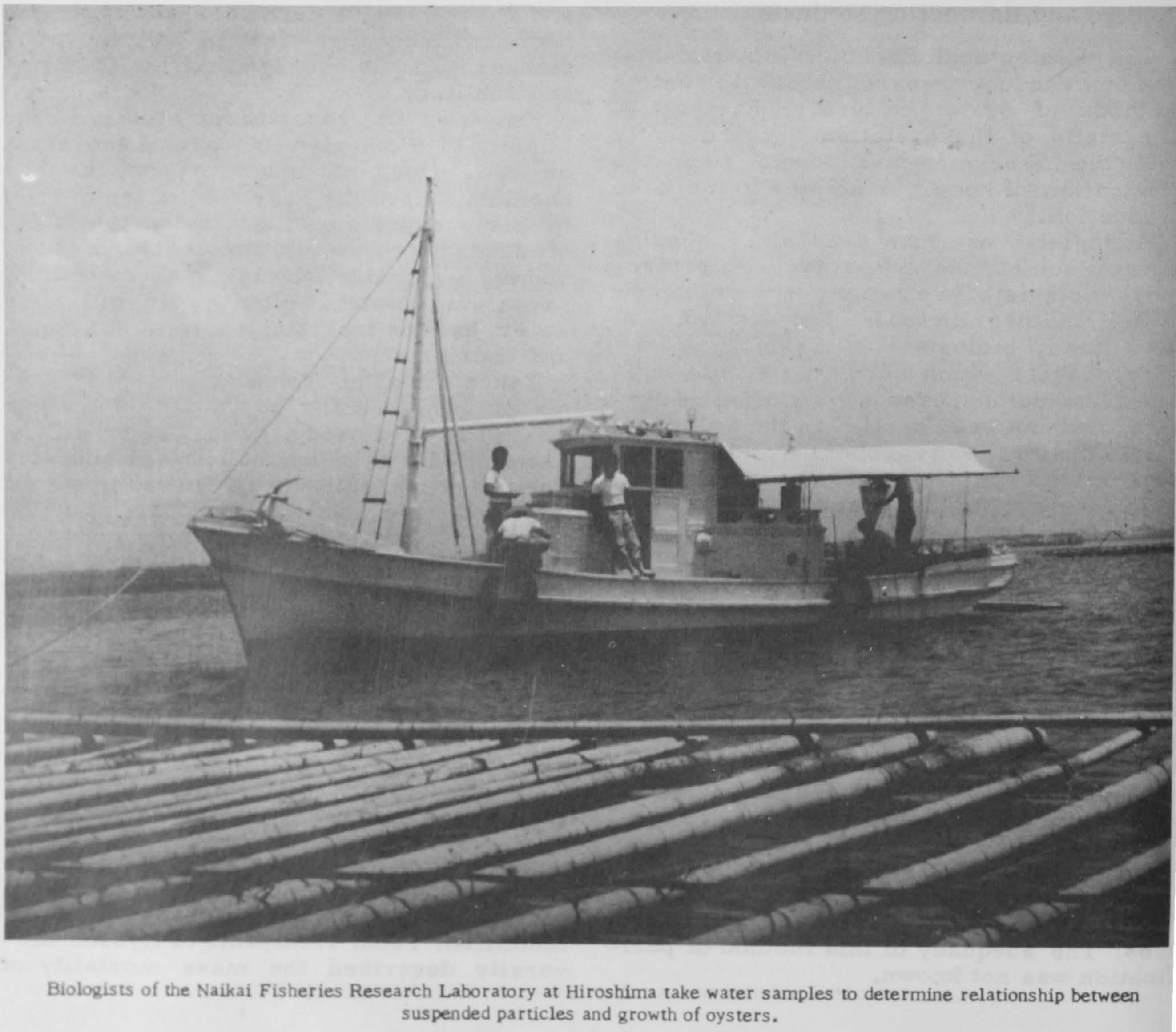
Takeo Imai of Tohoku University told me of a method for bioassay of pollutants which has been used at their Onagawa Laboratory. In this method a 24-hour-old culture of mussel *(Mytilus)* larvae is placed in a test tube and one drop of a pollutant is added. The behavior of the larvae indicates the effect of the pollutant, since a mussel larvae will close its shell, retract its velum, and sink to the bottom in the presence of a harmful substance. While this method is not as accurate as those in which growth and mortality are measured, it provides an easy method for rapid determinations of the toxicity of various substances.

Causes of Oyster Mortality

Mortalities of oysters have been reported from various places in Japan, and the causes of some of these have been satisfactorily identified. Tetuo Tomiyama of Kyushu University described the mass mortality of oysters in Lake Hamana in Shizuoka Prefecture. This mortality occurred after the bottom of this salt-water lake had been stirred thoroughly by wave action during a storm. Seishi and Tomiyama (1942) attributed death to the release of sulfides from the bottom into the water. In laboratory experiments Tomiyama found that large quantities of hydrogen sulfide killed oysters. Small quantities of hydrogen sulfide caused the oysters to gape and then to fill with silt which smothered them. Tomiyama stated that hydrogen sulfide is likely to cause oyster mortality because most oysters live in areas where a slight change may release this gas from muddy bottoms.

Biologists of the Hiroshima Prefectural Fisheries Experimental Station reported extremely high mortalities of oysters near Hiroshima in the summer during and following the spawning season. Mortality in some places was as high as 90 percent and was greatest in the upper layers of water. In a series of five papers: Fujita, Matsubara, Hirokawa, and Araki (1953, 1955); Takeuchi, Matsubara, Hirokawa, and Tsukiyama (1955, 1956); Takeuchi, Matsubara, Kirokawa, and Matsuo (1957), the authors described inflammatory changes in the oyster, and bacteria isolated from infected oysters. These authors concluded that bacterial disease caused these mortalities.

Takeo Imai of Tohoku University told me of a heavy mortality of recently set oysters in Matsushima Bay during the first part of August 1957. During this period there was a great amount of rain, high turbidity, low salinity, and some red tide.



Biologists of the Naikai Fisheries Research Laboratory at Hiroshima take water samples to determine relationship between suspended particles and growth of oysters.

Many of the spat died about August 10. Low dissolved oxygen was first believed to be the cause, but this was not proven.

In general, the mortality of oysters cultured by the hanging method from rafts or racks is low in comparison with those cultured on the bottom. The suspended oysters are above the silt and are protected from their crawling enemies. These conditions together with their more rapid growth rate, results in a high survival to time of harvesting.

Factors Inhibiting Growth and Fattening

Many biologists have observed that oysters and clams living a short distance above the bottom grow faster than when placed directly on the bottom. Several explanations have been advanced for the difference in growth rate and fattening under these two conditions. One theory is that food is more abundant higher in the water because of the increased currents there. Another explanation is that silting has a less adverse effect when the shellfish are placed above the bottom. Several Japanese biologists have reported that there are certain factors in the bottom which inhibit growth and fattening.

Tomiyama of Kyushu University found that hydrogen sulfide in small quantities caused oysters to gape. He believed that the hydrogen sulfide caused a reduction in rate of water circulation of the oysters but did not express this quantitatively.

Biologists of the Inland Sea Fisheries Research Laboratory at Hiroshima examined bottom samples by chemical analysis for indications of pollution but were also interested in possible effect of bottom substances on clams.

Ito and Imai (1955) described decreases in the rates of growth and fattening of oysters that were suspended near the bottom in areas where oyster culture has been practiced for a long time. Productivity was restored by moving the rafts to a new location where oysters had not been raised previously. The authors found that feces from the oysters and other organisms had produced a large increase in hydrogen sulfide in the bottom muds under the rafts and in the waters immediately over this mud. They ascribed the loss of productivity to the inhibiting effect of hydrogen sulfide and other decomposition products.

In Kesennuma Harbor, Miyagi Prefecture, oysters have been cultured on rafts for about 30 years. In 1958 this bay had about 6,000 rafts. Each raft had about 200 strings of oysters, with about 200 oysters per string. Imai computed that these oysters could filter, in 3 or 4 days, a quantity of water equal to the total volume of Kesennuma Harbor. The growth rate of oysters had decreased in this area, and fattening was rather poor. Imai, Ito, Nakamura, and Onodera (1957) stated that the oysters were overcrowded and recommended that growers reduce the number of rafts in this bay.

Kawamoto of Mie University described a situation in which the growth of fish was inhibited by substances in the bottom of a pool. The Shirahama Laboratory of the Kinki University maintained a salt-water pond where yellowtail (*Seriola dorsalis*) were grown. Small fish about 10 inches long were caught in the sea and transplanted to this salt-water pond which was connected to the sea by several screened pipes. The yellowtail were fed dead sardines and other fishes, but care was taken not to feed them excessive amounts. The fish reached a length of 20 inches in 2 years and were marketed. After the pond had been used for several years, the growth rate of yellowtail became much less than that of the first crop. A great increase in green algae such as *Ulva* was also noted. Kawamoto was called in and found high levels of ammonia nitrogen in the water. The increase in ammonia nitrogen was caused by the yellowtails' excretory products that had accumulated on the surface of the mud. By removing the surface of the mud with a suction dredge, the growth rate of yellowtail was restored to the original level.

In the United States few studies have been made on factors in the bottom which might inhibit growth and fattening of fish or shellfish. This appears to be an extremely important field of research that might explain differences in productivity of various shellfish producing areas and point the way toward improvements that will bring great commercial benefits.

Particle Size as an Index to Productivity

Hanaoka of the Inland Sea Fisheries Research Laboratory at Hiroshima described unpublished studies of measuring suspended material in the water as an index to suitable areas for culturing shellfish. Particle size had been used only as an index to suitable areas, and it was not known whether there was a cause and effect relationship between particle size and growth rate of oysters.

Artificial Propagation

Various species of shellfish have been artificially propagated at the Onagawa Laboratory of Tohoku University. The methods used in the artificial propagation of shellfish described by Imai and Hatanaka (1949 and later papers) were similar to those used at the Bureau of Commercial Fisheries Biological Laboratory at Milford, Conn. Parent oysters were induced to spawn by raising the water temperature. Larvae were placed in containers and fed special foods. At Onagawa a noncolored flagellate of the genus *Monas* was used as principal food. At Milford other species of phytoplankton have proven more satisfactory.

In earlier Japanese experiments chemicals were added directly to containers to encourage the growth of *Monas* in the same water used by the oyster larvae. During recent years the larvae were fed daily a dense culture of *Monas* containing up to 100 million cells per cubic centimeter. This change in procedure was made because the former method sometimes adversely affected the quality of the water.

At the Onagawa Laboratory, oyster larvae were grown in concrete tanks which had been in continuous use for over 10 years. Larger tanks, which were approximately 10 by 13 feet and 4 feet deep, hold about 1 million larvae. Oyster larvae raised in these tanks were collected on scallop shells and grown to adult size to determine their genetic characteristics.

Although oysters could be propagated in a laboratory or hatchery, this method was not used commercially in Japan. Natural reproduction of oysters in the Matsushima Bay area was reliable enough to produce an adequate supply of seed for exportation to the United States and for domestic use.

Oyster Predators

Crawling predators such as starfish and various species of boring snails are serious oyster predators in Japan. For this reason most Japanese oysters are raised by raft or rack methods. The Japanese oyster drill, *Ocinebra (Tritonalia) japonica,* is a serious menace in production of seed oysters for export to the United States. Although this drill has become established in certain oyster producing areas of the State of Washington, further infestations have been prevented by thorough inspection of seed oyster shipments at producing areas in Japan.

In 1956, when biologists of the Bureau of Commercial Fisheries discovered that the eastern oyster drill, *Urosalpinx cinerea,* is repelled by copper (Glude, 1957), the suggestion was made to Imai that the reaction of the Japanese oyster drill to copper be investigated. Imai, Ito, Shiraishi, and Shibuya (1958) reported that the Japanese drill was very sensitive to copper and could be repelled by using copper as a barrier. The Japanese were hopeful that this method would be effective in keeping oyster drills out of seed shipments to the United States and recommended this method to oyster growers in Matsushima Bay. Imai also stated that the Japanese oyster drill was very susceptible to smothering when covered with a $\frac{1}{2}$-inch deep layer of silt.

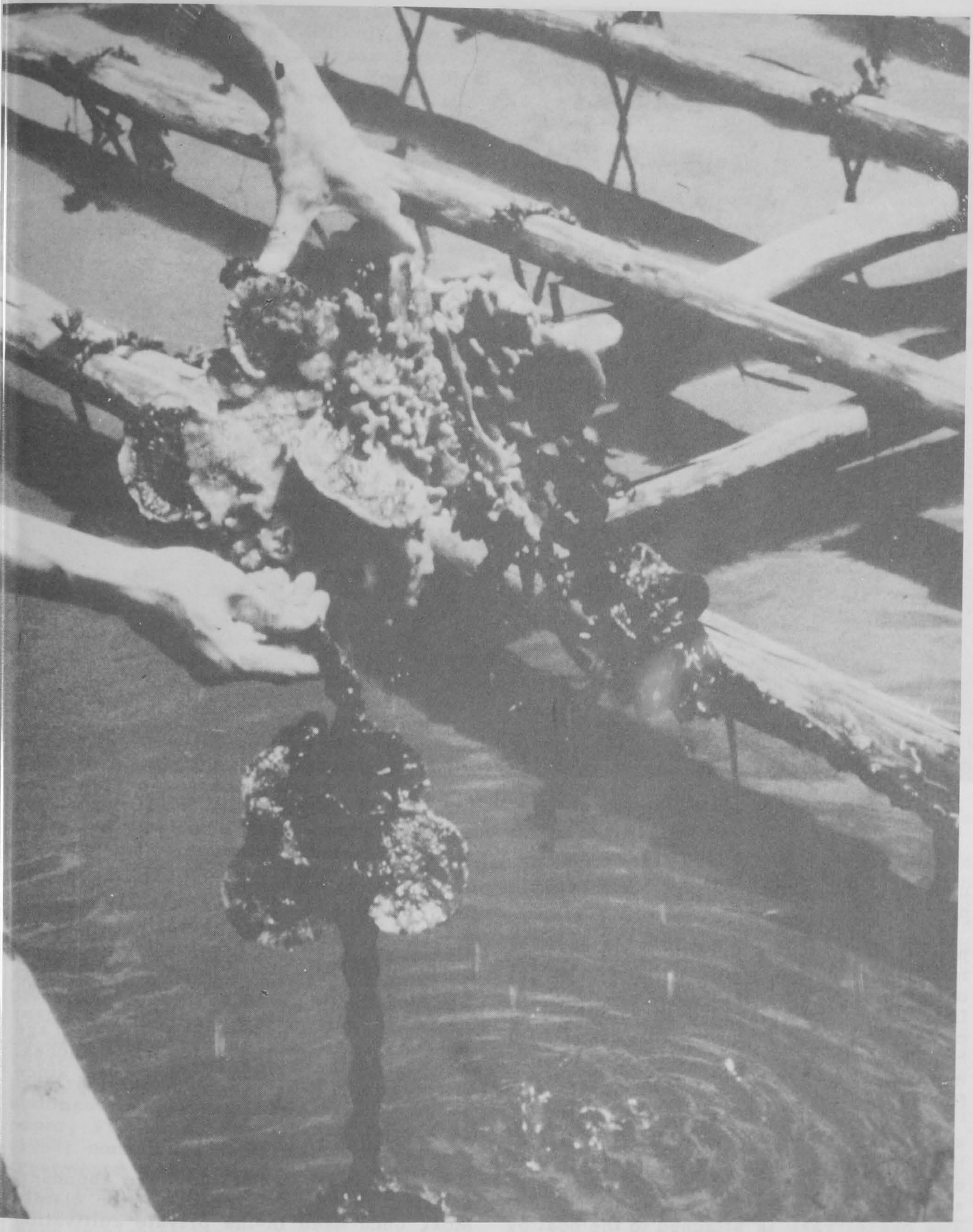
Amio at the Shimonoseki College of Fisheries was studying the reproduction and life histories of various boring snails including *Purpura clavigera* and *bronni* (formerly *Thais bronni*) and the Naticidae (Amio 1955).

CLAMS

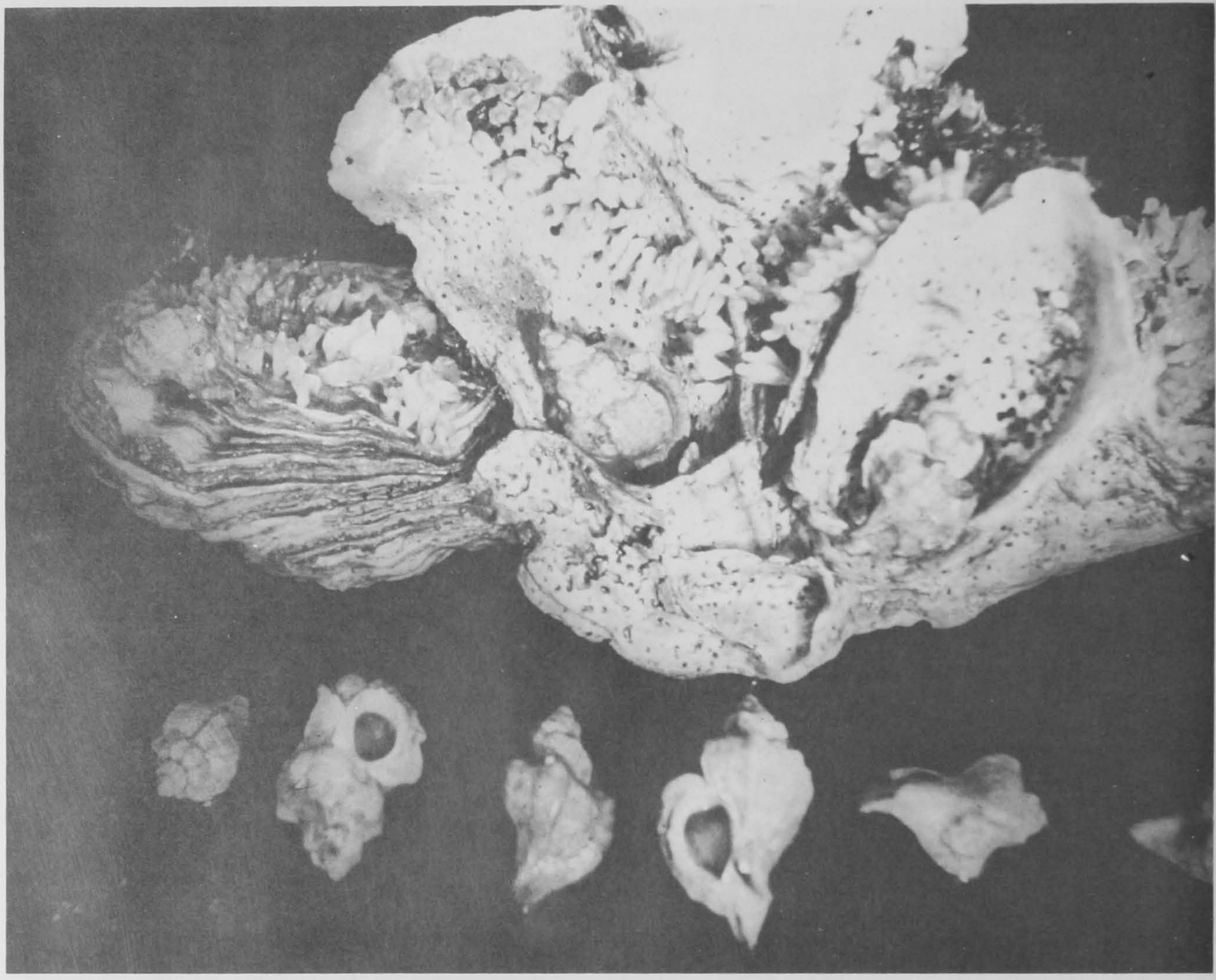
Nearly all species of clams occurring in Japan are used for food. Since many of the beds are located near centers of population, clams are seldom eaten raw. Clams are usually marketed in the shell but in some places are shucked in public markets. Some species, including the baby clam, asari, *(Tapes semidecussata)* are canned with or without smoking or are frozen for export to the United States.

Methods for culturing, harvesting, and marketing clams observed in 1958 were generally the same as those described by Cahn (1951) and Glude (1947).

The Central Fisheries Agency has a staff of biologists stationed at Regional Fishery Research Laboratories to investigate problems of the clam fishery. For example, Tokai Regional Fishery Research Laboratory was asked to investigate the cause of deformed shells of the clam, *Mactra sulcataria,* in beds at Hommoku near Yokahama. In each case deformation was at the posterior end and had occurred after the clams had reached a length of about 1 inch. This deformation did not cause death of clams but so changed the shape of the shell that shucking became difficult and the value of the clam was reduced. Biologists determined that this deformity was caused by overcrowding. When deformed clams were transplanted to areas where they were less



European oysters artificially propagated at the Onagawa Laboratory of Tohoku University are suspended below rafts to determine growth and survival.



The Japanese oyster drill ocinebra *(Tritonalia)* japonica deposits egg capsules on oyster shells where young drills will have ready access to new oyster spat.

crowded, the growth of the shell became normal.

The clam, *Mactra sulcataria,* formed the principal product of the Hommoku Fishermen's Association, whose fishermen caught over $30,000 worth of this clam in 1957. In addition, they caught over $3,000 worth of asari. This fishery, operated on public bottoms, is managed by the local fishermen's association, and only members can fish in this area.

The clams are caught with a basket rake approximately 3 feet wide with a 15-foot handle. These rakes have 20 steel teeth each five-eighths of an inch wide and spaced about seven-eights of an inch apart. The basket rake is attached to the boat by two lines, one leading forward from each side of the stern. The rake handle is held in approximately a vertical position by one man standing at the bow facing aft. The boat is moved astern toward an anchor which has been set previously, by taking in the anchorline slowly on a hand-powered winch. This moves the rake slowly through the sandy bottom.

M. sulcataria are harvested at 1 year of age and a length of 1 3/8 to 1 1/4 inches. Production per unit of area is great since the clams are very crowded.

Clam Predators

During years when they are abundant, starfish are serious predators on clams. Most beds used in the private cultivation of clams are exposed at low tide, and starfish can be picked by hand. Controlling starfish on public beds or on beds below the low tide level is more difficult. Dredging was the only method used for removing starfish from clam beds in Tokyo Bay. It was found preferable to dredge for starfish during the first part of the summer while they were concentrated in deeper waters. Starfish control was not practiced to any great extent on public bottoms.

Chemical control of starfish with unslaked lime was not considered to be practicable in Tokyo Bay because of the large quantity of edible seaweed cultivated in this area. Sugawara of the Chiba Prefectural Fisheries Experiment Station stated that one part of unslaked lime in 10,000 parts of water killed seaweed spores attached to shells on the bottom.

Starfish were extremely abundant in 1953 and 1954 and again in 1957. Sagara and Ino (1954) found that the optimum temperature for starfish larvae (bipinnaria) was 5°-20° C., and for young starfish, 5°-26° C. They suggested that the year class of 1953 was unusually successful because of the low temperatures that summer. Ino, Sagara, Hamada, and Tamakawa (1955) concluded from field surveys that the spawning season for the starfish *(Asterias amurensis)* extended from January to April, with the peak in late February through early March. The water temperature in Tokyo Bay at this time approximated that in coastal waters of Hokkaido in July when the starfish was known to spawn in that locality.

Another predator reported by Hamada and Ino (1957) was the nudibranch *(Philine japonica)*. This sea slug, slightly over 1 inch long, was considered to be a serious predator on young commercial clams.

Research on Clam Culture

Research at the Inland Sea Fisheries Laboratory at Hiroshima covered such subjects as effect of industrial wastes on bivalves (Fujiya, Chikuni, and Yamada, 1958) and spatial distribution of clams on natural sea beds (Furukawa and Suzuki, 1953). Furukawa (1955) described a new penetrometer for studying the hardness of sediment on submerged bottoms. In another paper, Furukawa, Suzuki, and Nakamura (1957) considered the effects of various treatments and various bottom conditions upon the farming of the clams *Meretrix* and *Mactra*. Lack of English translations of these important papers has prevented the use of this information by U.S. shellfish biologists.

PEARL OYSTERS

Methods used in Japan to produce cultured pearls in 1958 were generally the same as those described by Cahn (1949), except for certain refinements. For example, wire baskets in which pearl oysters are suspended below rafts are given a plastic coating, which prevents corrosion and makes the baskets last longer.

The construction of the National Pearl Research Institute Laboratory at Kashikojima in Mie Prefecture in 1955 stimulated research on pearl oysters. This attractive laboratory is staffed with good scientists and splendidly equipped for pearl studies. Results of research at this laboratory are generally published in the Bulletin of the National Pearl Research Laboratory. Typical research included the measurement of the color of pearls by use of a recording spectrophotometer, the structure of pearls shown by an electron microscope, factors causing variation in color in pearls, and factors affecting the quality of pearls.

Although it appears unlikely that a cultured-pearl industry could be developed in the United States, methods used in pearl-oyster research may be applied to U.S. shellfish studies.

The Japanese also harvest wild pearl oysters in the Arafura Sea north of Australia. Ino of the Tokai Regional Fishery Research Laboratory accompanied the pearl shell diving expeditions in 1956 and 1957 and made observations on pearl oysters *(Pinctada sp.)*. The 6-month fishing expeditions included 15 to 30 boats and 500 to 600 men.

Since this fishery is near the Australian coast, it was supervised by the Australian Fisheries Department which established a minimum size on pearl shells. About 73 percent of the shells went to the United States where they were used for pearl buttons, and 13 percent went to England. Total production of this fishery was reported to be about 500 tons of shells per year. Competition by plastic buttons limited the market for pearl buttons, and the price of shells was low.

Mean width of the Arafura Sea pearl shells was 8 to 10 inches. During expeditions in 1956 and 1957 many valuable pearls were found, including one which was valued at over $60,000.

Pearl divers worked 5 to 6 hours per day during 10-day periods of neap tides when currents were weak. No diving was done during the 5-day spring tide periods

The National Pearl Research Institute operates a modern well-equipped laboratory at Kashikojima.

because currents were too strong. Diving was dangerous, and 77 percent of the divers were affected by bends during the May to November season. Most diving was in water 15 to 20 fathoms deep.

Pearl divers used only a half suit or a helmet supplied with compressed air. Although cheap, this diving outfit was dangerous since divers had to remain in an upright position. The expeditions had no decompression chamber for treatment of bends during 1956 and 1957. When a diver was affected, he was lowered again into the water and left there for a period of several hours and then brought slowly to the surface. Occasionally this treatment would be continued through the night. In spite of this hazardous duty, there was no shortage of divers. The average wage was about one-half million yen (about $1,400) for the 6-month work.

Using the large pearl oyster *Pinctada* the Japanese have recently begun to produce cultured pearls in Australian waters. The first pearls were hemispherical and were produced by placing an object in contact with one of the valves. In using these pearls, a circular section of the shell is left attached to the pearl. This produces a beautiful pearl for use in jewelry such as brooches.

SCALLOPS

The scallop *Pecten yessoensis* supports a large commercial fishery in northern Japan. The fishery is characterized by rather wide fluctuations from year-to-year and place-to-place.

Gotaro Yamamoto of the Biological Institute of Tohoku University at Sendai has studied the scallop for many years and has described the results of his studies in a number of excellent publications (Yamamoto, 1953, 1956, 1957).

Yamamoto reported that survival of scallops in Mutsu Bay in northern Honshu was good in two or three locations and poor in the rest of the Bay. Small scallops of 1/4 to 1/2 inch in diameter, attached to vegetation, were collected at Hamaokunai where the setting was heavy, but survival poor. These scallops were taken to Arito, where the survival was good, and left to grow from late July until the following April. About 25 percent of the 1 million transplanted scallops survived. If they had not been transplanted, survival would have been less than 1 percent.

In April, Yamamoto transplanted these larger scallops to areas where survival of small scallops usually was poor. The larger scallops survived in these locations because they were more resistant than small scallops to silting, low oxygen tension, and other unfavorable conditions.

Laboratory experiments confirmed field observations that large scallops were more resistant than small scallops to unfavorable environmental conditions. Yamamoto found that levels of silting, turbidity, low oxygen, and hydrogen sulfide which killed scallops of 1/4 to 1/2 inch in diameter could be tolerated by scallops of 2 1/4 to 2 1/2 inches.

No comparable research on scallops or other commercial mollusks has been reported in the United States. This would seem to be an important field for research. If the young of our commercial mollusks are found to be more susceptible to adverse conditions than larger sizes, this factor would have to be taken into account in commercial farming. This could provide the explanation for the observed mortalities in some areas of newly transplanted oyster and clam spat.

As an application of Yamamoto's findings, 700 million scallops about 2 1/4 to 2 1/2 inches in diameter were transplanted from places where survival was good to other locations around Mutsu Bay where setting or early survival were poor. In 1958 the catch of scallops in Mutsu Bay was high, and it was believed that the transplanting program contributed to this high catch. Transplantings of this type could form the basis for a fishery for 6 or 7 years, since the life of this scallop was reported to be at least 8 to 10 years. Similar transplanting methods might be applied in this country to the bay scallop which is notable for its great fluctuations in abundance.

A novel type of scallop culture was tried by Tanita, Chief of the Shellfisheries Section of the Tohoku Regional Fishery Research Station at Shiogama. The small bay scallop *Chlamys nipponesis*, which is similar to the Eastern Bay scallop, attaches to ropes or bamboo which are used in oyster culture in the inshore waters. Later this scallop breaks off its byssus and drops to the bottom. Tanita drilled holes in their shells and tied them to ropes or bamboo poles to prevent them from dropping to the bottom. Even though the scallops are protected from crawling predators, some of the swimming crabs of the family *Portunidae* attack them while they are suspended from rafts.

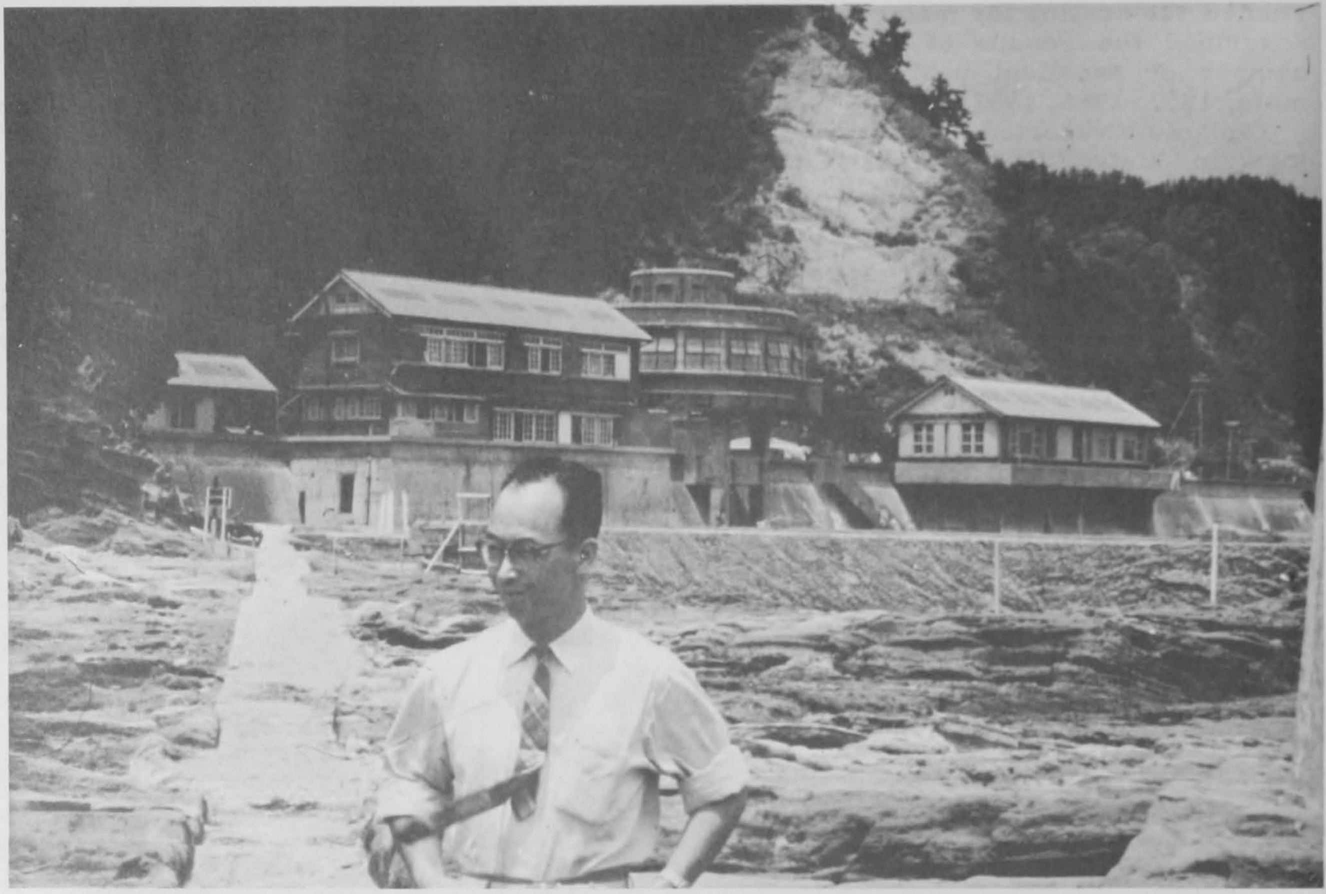
ABALONES

Abalones are used extensively as food throughout much of Japan. They are caught by divers, usually women, in waters of medium depth along the rocky coasts and are usually kept alive until they reach the consumer.

Notable among the Japanese reports is a paper by Takashi Ino (1952), describing biological studies on the propagation of the Japanese abalones of genus *Haliotis*. Ino reported that the abalone fishery was controlled by minimum size limits and fishing seasons. He advocated transplanting the northern *Haliotis discus hannai* to southern waters to increase its rate of growth. This recommendation was based upon experiments showing that this abalone which grows to commercial size in 4 years in northern Japan will reach the same size in 9 months if transplanted in southern Japan where the waters are warmer. Fishermen's associations were reported to be using this method in an attempt to increase scallop production in southern Japan.

SHRIMP

Shrimp fisheries in Japan are extensive, and many species are utilized commercially. Fresh shrimp are breaded and cooked in deep fat to produce an extremely palatable product called tempura. The freshness of the shrimp is extremely important, because the flavor and texture of tempura made from fresh shrimp are far superior



Takaski Ino of the Tokyo University of Fisheries Laboratory at Kominato is a specialist on abalones.

to those from shrimp which has been dead for some time.

Although shrimp were not actually propagated at the time of my visit, there were several places in Japan where shrimp were being stored temporarily in tanks of sea water. When needed, the shrimp were packed in special containers and shipped to market so they were alive when they reached the consumer. The Kosei Fishery Company at Kisarazu on Chiba Peninsula had about 30 concrete tanks which were used to hold shrimp. A similar plant was located in Shizuoka Prefecture. Shrimp, usually *Penaeus japonica*, were bought from the fishermen and were placed in these tanks for short periods of time before they were shipped alive to Tokyo and other centers of population. If the demand was low, the shrimp were held for a longer period in these tanks. In some cases shrimp had been kept for 5 or 6 months and were reported to have increased in weight over 500 percent.

Live shrimp packed in cardboard boxes and surrounded by dry refrigerated sawdust were found to stay alive commercially for 2 days and experimentally for 3 days. Refrigeration of sawdust as well as the procedure for shipment of shrimp was reportedly covered by Japanese Patent No. 394046. The reported retail price in specialty stores in Tokyo was one thousand yen ($2.78) for 20 live shrimp.

Concrete tanks used at Kisarazu for holding shrimp were about 18 inches deep and approximately 8 feet square. The bottom of each tank was covered with 2 to 4 inches of coarse sand, and the water level was maintained 4 to 6 inches above the sand. Sea water was supplied to each tank through iron, plastic, or bamboo pipes and drained into a large sump below floor level. From this sump water was pumped by continuously operated iron centrifugal pumps to a steel supply tank about 15 feet above floor level. Each pump was equipped with a pulley for gasoline-driven auxiliary power in case of electrical failure. Water flowed by gravity from the overhead tank to each of the concrete holding tanks. This recirculated water system practically eliminated the silting problem. Some sea water was added each day to make up for leakage and evaporation, and approximately once a year the entire water supply was changed. During the winter the water was heated slightly by running it through pipes in a fresh-water well in which the ground water was warmer than the air.

Not more than 32 pounds of live shrimp were placed in each tank and fed clams or small pieces of fish. Feeding was only at dusk when a few shrimp at a time emerged from the sand, completed their feeding, and again buried themselves. If the shrimp were not fed until later at night, they would all emerge from the sand at one time and fight each other to get the food, causing extensive mortalities. It was important to determine the food requirements accurately, because if the food supply was inadequate the shrimp would eat each other. If too much food was supplied, the water would become contaminated.

Methods used in Japan for holding shrimp and marketing them alive might well be used commercially in the United States. A specialty product of this type should find ready acceptance among people who have discovered the exquisite flavor of fresh shrimp.

Biological research on shrimp is carried on in various places in Japan, including the Naikai Fisheries Research Laboratory in Hiroshima. Biologists of the Hiroshima laboratory described the shrimp fishery of the Inland sea and stated that 60 to 70 species are present and more than 20 of these are used commercially (Masuda, Takioka, and Kobayashi, 1957). Shrimp are caught mostly by small trawlers in the Inland Sea.

Japanese shrimp are divided ecologically into two types (Masuda, 1956). One type includes the large species, such as *Penaeus japonicus* and five others, which spend all or part of their first year in the intertidal zone and then move offshore. The second type includes the smaller species of shrimp such as *Metapenaeopsis acclivis, M. barbatus,* and *Trachypenaeus* sp., which spend all of their life in deeper water. Of the total landings, approximately 20 percent by volume are of the first type, but these constitute about half of the value.

Shrimp which live as juveniles in the intertidal zone go to deep water in September if spawned in June. If spawned in August they migrate to deep water the following June to August. Protection of the young stages of these shrimp is difficult because drainage of swamp lands and contamination by industrial wastes and sewages destroys their environment. Local governments have set minimum sizes to protect young shrimp, and biologists (Masuda, 1956) have recommended preserving estuarine areas which are important for early development of these species.

No decrease has been noted in the landings of the second type of shrimp, which spend their entire lives in deeper water. Biologists are principally interested, therefore, in increasing exploitation of these species.

The Japanese have recognized the importance of estuaries in the production of penaeid shrimp. American biologists are likewise concerned over the possible destruction of estuaries along the South Atlantic and Gulf coasts and the possible effects on shrimp production.

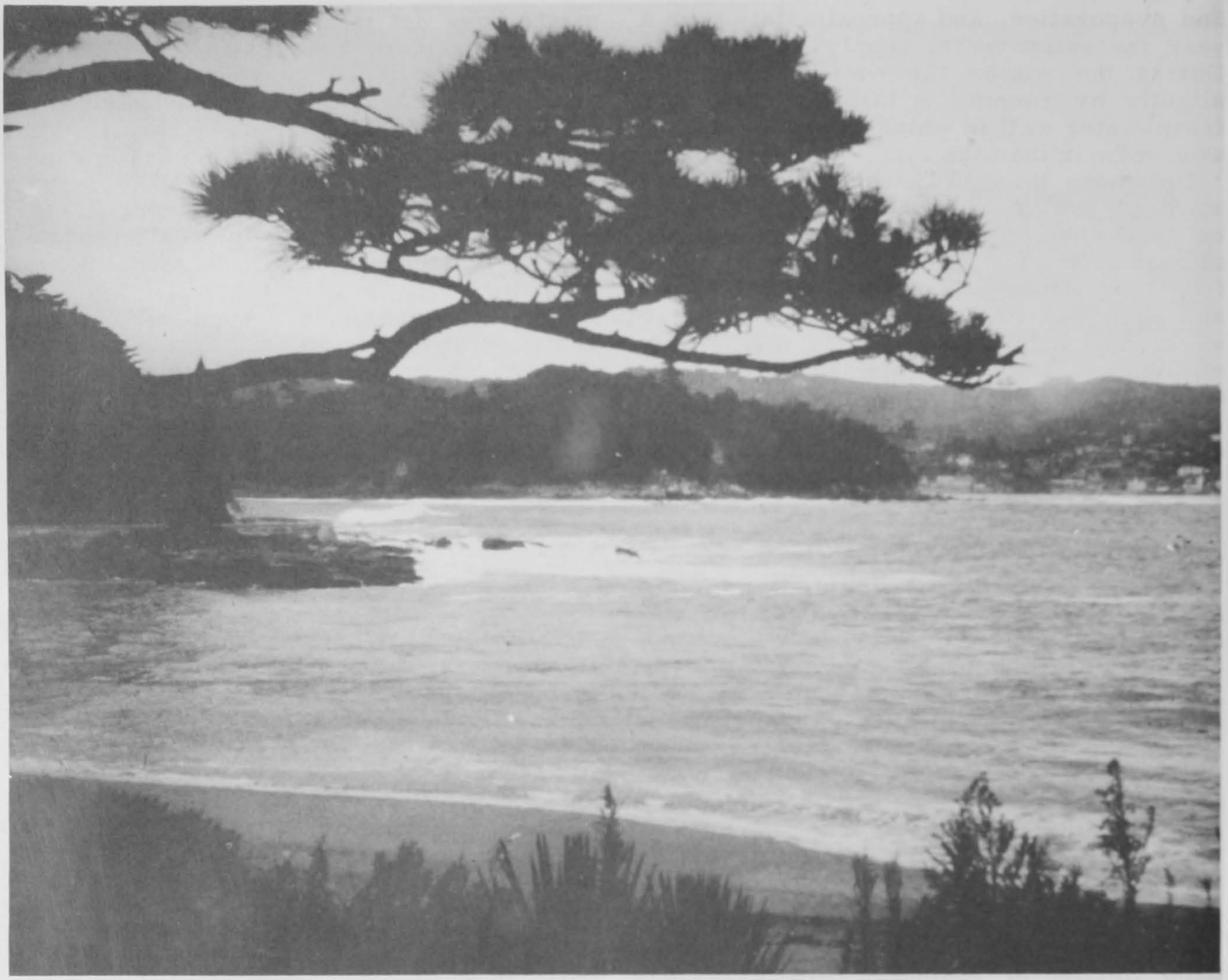
SPINY LOBSTERS

The Japanese spiny lobster, *Panulirus japonicus,* is the object of an important inshore fishery during the winter and early spring. This species provides an excellent food product with a high market value.

Anchored gill nets with mesh openings about 2 inches square are used in the spiny lobster fishery in Wakayama Prefecture. Fishermen set their nets in the evening along rocky shores and reefs and remove them the next morning.

Spiny lobsters can also be caught in traps. Takashi Ino constructed permanent traps at Kominato on Chiba Peninsula. Each trap consisted of a concrete tank set into a rocky beach with the top just above high tide level. An entrance channel was cut through the rocks from the sea to the trap. The entrance to the trap consisted of a funnel which extended into the tank and some distance above the bottom. The lobsters come in through the funnel, drop to the bottom to get the bait, and cannot escape. Ino stated that one of these traps had caught up to 80 pounds of lobsters in 1 week.

Harada (1957) reported on ecological observations of the Japanese spiny lobster in its larval and adult life. In these studies, at the Seto Marine Biological Laboratory, Shirahama, larvae were observed and collected in the sea, but Harada was not successful in culturing them in the laboratory. Collections of larvae at sea were made by towing a net at the surface. Harada had also used SCUBA diving equipment to take water samples near the bottom and to collect juveniles and adults.



Spiny lobsters are caught in nets set along rocky shores in Wakayama Prefecture.

SEAWEEDS

Seaweeds, such as genus *Porphyra*, are cultivated extensively in Japan for food. In some places the value of the seaweed crop exceeds that of oysters and clams.

Because of the commercial importance of seaweeds, Japanese scientists in many locations are working on various problems in connection with the propagation, processing, and marketing of these algae. At the Naikai Fisheries Research Laboratory at Hiroshima scientists discovered a fungus which attacks the seaweed during the wintertime if the temperatures rise above a certain critical level. In this case they proposed controlling the fungus by growing the seaweed at higher tidal levels so that it would be exposed to cold air during low tide. Laboratory experiments also showed that cultures of fungus in liquid medium could be killed by using malachite green, crystal violet, and other organic dyes.

Other scientists, including Katada at the Kisarazu Laboratory and Kurogi at the Shiogama Laboratory, were studying various details in the life history of seaweeds. Kurogi (1953) described studies which showed that the carpospores of the red seaweed *Porphyra* penetrate into the shells of oysters and clams during the period from February to October, causing the shells to turn black.

Filamentous thalli form during the summer and in the autumn produce and release monospores. The monospores float in the sea for a short period and attach to bamboo which has been placed in the water as collectors. The seaweed grows rapidly and is harvested and marketed from December to April. Part of the research of these laboratories included the development of better methods for collecting the carpospores and monospores.

Chemists at Tohoku Regional Fisheries Research Station at Shiogama were studying the composition of agar from the red seaweed *Gelidium* grown in waters of varying salinities. Agar from *Gelidium* grown in more saline waters was reported to be of better quality than that grown in the brackish waters.

Another algae, *Gracilaria,* is also grown commercially in Tokyo Bay as a source of agar, although the agar from this genus is reported to be somewhat inferior to that from *Gelidium*. Katada, at the Kisarazu Laboratory, was developing methods of using clam shells as a surface for the attachment of spores of *Gracilaria*.

Although it is unlikely that an extensive demand for fresh or dried seaweed for food would develop in the United States, various seaweeds are used here in the production of agar. Japanese research on seaweeds may develop methods which could be applied in this country to increase the production of these algae.

CONCLUSIONS

Observations made during a trip to Japan in which 19 laboratories demonstrated the value of personal discussions between scientists conducting similar studies. Scientific literature which is necessarily concise makes it difficult to appraise adequately the quality of research. Personal discussions can resolve these questions even though there are language difficulties.

The quality of Japanese research should not be underestimated because of inadequate laboratory facilities. Some of these laboratories were staffed by excellent researchers who were producing high-quality results in spite of these handicaps.

Better services for translating Japanese literature into English are essential because few American biologists can read Japanese. English summaries included in many Japanese papers are usually too brief to provide an adequate description of the work. I recommend that all Japanese journals be examined carefully and any papers having applications to fishery problems in this country be completely translated and made available to U.S. fishery biologists.

A number of Japanese biologists would welcome the chance to come to the United States for a period of study and research in our laboratories. Many of these are well-trained biologists with specialized knowledge. Conversely, there may be opportunities for American biologists to work in Japanese laboratories. International cooperation of this type should result in a quicker solution to problems facing our commercial fisheries.

ACKNOWLEDGMENTS

Many people contributed to the success of this trip. The staffs of the Central Fisheries Agency and the various regional laboratories made arrangements for my itinerary. Takeo Imai, Dean of the College of Agriculture and Fisheries at Tokohu University in Sendai, scheduled my trip in northern Japan.

Without exception, the scientists that I met were helpful, courteous, and eager to discuss their research and to learn of ours. The freedom of these discussions was encouraging and demonstrated again the common bond between scientists who obtain the facts that are used in the management of natural resources.

This report was prepared with a certain amount of trepidation because of the risk of generalizations concerning Japanese research on the basis of information gathered during a relatively short visit. Language difficulties might also have introduced errors in my understanding of research methods or results. The section containing literature cited was prepared to indicate the type of shellfishery research in Japan.

The following laboratories were visited:

- Tokyo University, Tokyo
- Tokai Regional Fisheries Laboratory, Tokyo
- Tokugawa Institute for Biological Research, Tokyo
- Prefectural Laboratory, Chiba
- Tokyo University of Fisheries Laboratory, Kisarazu
- Tokyo University of Fisheries Laboratory, Kominato
- Central Fisheries Agency, Clam Laboratory, Hommoku
- Misaki Marine Biological Laboratory of Tokyo University, Misaki
- Kyushu University, Fukuoka
- Shimonoseki College of Fisheries, Shimonoseki
- Naikai Regional Fisheries Research Laboratory, Hiroshima
- Prefectural Fisheries Research Laboratory, Hiroshima

Seto Marine Biological Laboratory, Shirahama
National Pearl Research Institute, Kashikojima
National Pearl Research Institute Field Laboratory, Kashikojima
Sato Marine Laboratory, Matoya Bay
Tohoku University, Sendai
Onagawa Laboratory of Tohoku University, Onagawa
Miyagi Prefectural Laboratory, Shiogama

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