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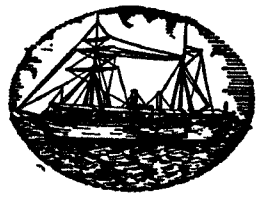

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PEARL CULTURE IN JAPAN AND ITS LESSONS FOR INDIA

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ABSTRACT

The present article is the outcome of the author's study of the pearl culture industry of Japan during the years 1966–68. Observations made at the Mikimoto Pearl Culture Farm to a great extent, together with the information collected from personal enquiries and from the existing literature, have helped in writing this account.

The history of growth of the industry is traced and the present status discussed. The activities of pearl culture farms are outlined. The various phases of pearl culture are illustrated with photographs. Brief mention is made of the pearl culture industry in other parts of the world. An account of the natural pearl fisheries of India, a brief review of the earlier attempts on induced pearl formation, and some plans for future experiments on pearl culture in India are given.

BRIEF HISTORY OF PEARL CULTURE IN JAPAN

ON a full moon night, a beautiful princess was torn away from the arms of her lover on the banks of Ago Bay by the gods of evil, and the tear drops rolling down on the rosy cheeks of the Queen of Night from the heavens turned to treasures in the green waters of Tatoku— Thus goes a Japanese legend describing the origin of the beautiful pearl in the Bay of Ago. Even today of the many serene bays that abound the Japanese coasts the Bay of Ago reigns supreme in the production of quality pearls.

Before 1893 finding a pearl in the oyster was a lucky accident. The Meiji Era which ushered in communications and contacts with the outside world throwing the gates of Japan open to social, cultural and economic revolutions also made many an enterprising man gather the pearl oysters from the floor of the ocean and lay them on demarcated areas in the bays to harvest pearls from the oysters after a time. Ago Bay in Mie Prefecture, Nanao Bay in Ishikawa Prefecture and Omura Bay in Saga Prefecture were the areas where the pearl oysters were naturally abundant. Due to unscrupulous removal of the oysters from the beds the stocks were becoming gradually depleted.

The story of pearl culture in Japan is inseparable from the story of Kokichi Mikimoto, the Pearl King, who was a noodle vender in his youth, one of the humblest of all trades in Japan. It occurred to him that there should be a way to farm these oysters and make them produce pearls. He discussed with Professor K. Mizukuri of Tokyo University and came to know that it is the irritation of the oysters caused by a foreign body that makes them secrete the pearly layers. Mikimoto gathered the oysters and set them out in guarded areas near Jinmyōmura, a fishing village in Mie Prefecture, in the year 1888. He introduced all conceivable materials like bits of shells, coral pieces, bits of metal, ground-up fish scales, etc. into the mantle of the oyster. He was not at all successful in the beginning and in 1892 a red tide took toll of all his oysters. Undaunted by this crushing misfortune he set his mind on it with renewed vigour and tried again. In 1893 fortune smiled on him and he found semi-spherical pearls in five of his oysters.

He patented the technique of producing semi-spherical pearls and began commercial production. This partial success led him to improve the technique for getting spherical pearls and began using mother-of-pearl nuclei. He had planted about a million oysters by 1905 around Tatoku. A red tide again invaded the bay and he managed to salvage only a small portion of the stock. Contemporaneously scientists also got interested in evolving a technique for producing spherical pearls and the names of Tatsuhei Mise, Otokichi Kuwabara and Tokichi Nishikawa deserve special mention. Nishikawa, a son-in-law of Mikimoto, is accredited with the formulation of the only tenable theory of man-induced pearl formation. He, in 1907, reported that a pearl is formed when the pearl-secreting cells of the mantle migrate into the body of the oyster under the stimulation of a foreign body and form a pearl-sac by division which covers the nucleus with nacre to form the pearl. Mise, in May of the same year, applied for the patent on his spherical pearl method and on the needle used for inserting the nucleus. In 1913 Nishikawa succeeded in the experimental production of spherical pearls, and after his death in this year, his assistants, the Fujita brothers, adopting the same method started industrial production of spherical pearls. Perfect round cultured pearls were sent to the market for the first time in 1919 and the largest cultured pearl was 0·45 gm. in weight and 3·0 mm. in diameter. In 1928 the patents for the production of spherical pearls were distributed among all interested and the number of culturists have increased gradually. Since then great strides have been made in improving the farming conditions and culture techniques and the pearls produced now range from 0·019 gm. in weight and 2–3 mm. in diameter to 2·74 gm. in weight and 12–13 mm. in diameter. The Japanese today enjoy monopoly in cultured pearl trade with no immediate fear of any competition.

There are quite a number of publications on pearl culture in Japanese, of which that of Shinju Yoshōku Zenshō Henshu Iinkai Henshu (1965) describes in detail all the aspects. The publications in English of Butcher (1966), Cahn (1949), Eunson (1956), Fisheries Agency, Japanese Government (1952), Homma (1957), Matsui (1958) and Tange (1963) will form a useful reading on the subject.

Molluscs Employed in Pearl Culture

Marine Molluscs

Pinctada martensii (Dunker) (Jap. name—Akoya gai).—This is the most commonly used pearl oyster for culture and constitutes about 98% of the weight of all the marine shells used. The pearls produced are spherical and are the 'cultured pearls' of the trade.

Pinctada margaritifera (Linne.) (Jap. name—Kurochiōgai).—The 'blacklip' pearl oyster is used mainly for producing half-pearls. Rarely spherical black pearls with a mysterious brilliancy are obtained in nature.

Pteria penguin (Röding) (Jap. name—Mabegai).—The wing-shell is employed for producing half-pearls known as 'Mabe' pearls.

Haliotis discus Reeve (Jap. name—Awabi).—The ear-shell is used for culturing irregular pearls to a small extent.

Freshwater Molluscs

Hyriopsis schlegeli (Martens) (Jap. name—Ikechiogai).—This freshwater mussel is the most commonly used among the freshwater shells.

Cristaria spatiosa (Clessin) (Jap. name—Karasugai).

Unio margaritiferus (Linne.) (Jap. name—Kawashinjugai).

These species are used generally for producing irregular pearls of small size. Occasionally round pearls are also obtained.

Extent of Pearl Culture

The Japanese pearl oyster, *Pinctada martensii*, occurs in the comparatively warmer waters of Japan and the distribution is limited to the south of lat. 35° 10′ N. (Kominato, Chiba Prefecture) on the Pacific Coast, and south of lat. 37° 10′ N. (Nanao, Ishikawa Prefecture) on the Japan Sea Coast. The Kuro-shio (meaning Black Current) flowing northwards from the tropics follows closely the Pacific Coast of Japan as far as latitude 35° N. which coincides with the northern limit of the pearl oyster distribution. Just north of Chiba Prefecture it turns north-eastward and flows into the open Pacific. On the other hand the Kurile Current carrying the Subarctic Water creates a massive southward stream of very cold water and this affects the entire northern Pacific coastal area. The warm Tsushima Current enters the Japan Sea *via* the Tsushima Strait and flows along the western coast of Japan to the north. Into the Japan Sea on its northern side there is an influx of cold water. It is this current system which limits the distribution of the pearl oysters to the warmer southern waters of Japan where, in the bays, the temperature does not fall below about 10° C. at any time of the year. Pearl culture is practised in all the calm bays facing the open sea.

In all, about 25 prefectures are engaged in pearl culture and they are : Ishikawa, Fukui, Saitama, Kyoto, Hyogo, Okayama, Shimane, Hiroshima, Yamaguchi, Fukuoka, Saga, Nagasaki, Kagoshima, Miyazaki, Kumamoto, Oita, Ehime, Kochi, Tochigi, Kagawa, Tokushima, Wakayama, Mie, Aichi and Shizuoka. In the order of production Ago Bay in Mie Prefecture accounts for about 70% of the total output of spherical pearls, followed by Omura Bay bordering Nagasaki Prefecture (about 12%), all other prefectures contributing the rest in small quantities. Presently there are more than 4,000 pearl farms covering a total area of over 30,000 acres. Hardly a score of them are big companies which have established names. The rest are small groups or family-scale operations supplying their products to the big companies.

In Okinawa culture for semi-spherical pearls is practised using *Pinctada margaritifera* and *Pteria penguin*. In Amami-Oshima and Tsushima also pearl culture is done. Freshwater pearls are produced mainly in Lake Biwa in Shiga Prefecture and Kasumigaura in Ibaragi Prefecture.

Spat Collection and Culture of Mother Oysters

The supply of oysters for the pearl farms, two decades ago, came from the natural grounds. Women divers, known as 'Ama', were engaged for diving and collecting the naturally grown oysters from the beds. After the war due to the fillip given to the industry by the Japanese Government the demand for the mother oysters showed a tremendous increase. But it could not be met with immediately, as in 1944 there was a big earthquake and in 1945 and 1946 cold current swept the Ago Bay which resulted in the decrease of the quantity of pearl oysters to a considerable extent. The situation made the culturists start collecting the spat and farming the mother oysters to ensure a steady supply for the farms. This deprived the pearl divers of their job and they took to collection of materials other than pearl oysters. Presently they are engaged in the collection of *Turbo*, abalones, and algae in the prefectures of Mie, Chiba, Shizuoka and Ishikawa. The pearl culture industry at present is divided into two clear-cut realms, the mother oyster culture and the pearl culture proper, practised mutually exclusively.

The spat collection industry is concentrated more on the southern areas, especially the southern Kii Peninsula and Nagasaki area. Spat collected near the mouth of the Ago Bay in the open sea are also used for culture but it constitutes a very small quantity. Spat settlement in the farm areas is generally poor and open-sea conditions appear to be more conducive for the veligers to settle down on the substratum. Not long ago shells of abalones, oysters and scallops were used for collecting the spat, but now cedar sprigs are generally in use. These are suspended from rafts from just below the surface to about 3 m. in depth. Dense spat settlement is observed at 2 to 3 m. The spawning season of *P. martensii* is from about May to September, the peak

being the June–July period. When there is active spawning the whole area is said to become milky with the gametes extruded by the oysters lying underneath. The fertilised ova grow to the umbo stage in about 8 days and settle down on the collectors in about 2 to 3 weeks. The spats are allowed to grow until they attain the size of the nail of the thumb. Then they are dislodged from the collectors and grown in spat cages of fine mesh hung from rafts. The young oysters of the summer brood grow to a weight of about 5 to 10 gm. in the next spring (March–April), about 25 to 30 gm. by autumn (September–October), and about 35 gm. by the second spring. It is these oysters of about 35 gm. in weight which are about a year and a half in age that are used for the operation. Oysters of about 25 gm. are also sometimes used according to the needs of the situation. These mother oysters are bought by the pearl culturists in spring and autumn and are transplanted in the pearl farms. These are grown in cages until they are ready for nucleus implantation.

Recently, great strides have been made in artificial fertilisation by inducing the oysters to spawn and fertilising the gametes in ammoniacal solution. Seed oysters resulting from this method are also cultured and used in the industry.

Specially constructed ships are employed for transporting oysters from one place to another. The ships are provided with holds which carry pearl oyster cages. Special valves at the bottom of the holds allow free circulation of sea-water through the live oysters when the ship is under way. Trucks are used for transportation when the places are not too far apart.

Environmental Conditions

Pearl culture farms are generally situated in enclosed bays which have connections with the open sea. The tidal effect is much less in the interior of the bay and such areas are preferred for establishing the farms. In the bays where pearl culture as well as edible oyster culture are practised the former is done in the interior of the bay and the latter near the bay mouth. Even in the interior part, places where there is a river flow are considered more suitable. Where pearl culture is practised in open seas, such as the Seto Inland Sea, areas bordered by chains of small islands are chosen.

Depth preferred for pearl farms is usually 15 to 20 m. as the growth of the oyster is good at such depths. The minimum depth required is about 5 m. Gravelly bottom is suitable and sandy or muddy bottoms are avoided.

Temperature plays an important role in the biological activities in temperate waters. The most suitable range for the pearl oyster has been found to be from 18 to 25° C. Above 28° C. the oyster shows signs of exhaustion and below 13° C. the oyster enters into hibernation. Below 10° C. the oyster either dies or suffers damage from which it does not recover. The pearl oyster nets are hung at such depths where optimum temperature conditions prevail. The changing climatic conditions cause differences in temperature at various depths and accordingly the depth of the pearl oyster nets is altered so as to keep them in suitable temperature layers. For example, in summer the surface temperature of Ago Bay is around 28 to 30° C. and hence the nets are lowered to a depth of about 7 m. where the temperature is 23 to 26° C. During spring and autumn it is around 23 to 25° C. at 2 to 3 m. and hence the nets are hung at this level. During winter the temperature goes down to 9 to 11° C. in the Ago Bay and consequently the oysters are transplanted in warmer southern areas where even in winter suitable temperature conditions prevail.

Pearl oysters seem to prefer high salinities but oysters raised in such waters produce pearls with a golden tint. For this reason areas where river-water flows into the bay are preferred. Though there is the fear of sudden dilution by the influx of inundated rivers this is offset by the rich nutrients discharged into the bays by them.

A good current is necessary not only as a source of oxygen but also to bring in the plankton on which the pearl oyster feeds. The current also helps in cleaning the oysters as it flows through the farm.

The quality and quantity of plankton and the chemical substances and trace elements present in the water greatly influence the growth of the pearl oyster and the colour and lustre of the pearls. It has been found that the gold and cream-coloured pearls contain more of copper and silver, whereas the skin- and pink-coloured pearls contain more sodium and zinc. Culturing pearl oysters repeatedly in the same grounds has been found to cause deterioration in the quality of pearls produced. Apparently, the bottom conditions too play their part in the quality of pearls. Culturists are always exploring grounds where ideal conditions for quality pearl production exist.

FARM ESTABLISHMENT

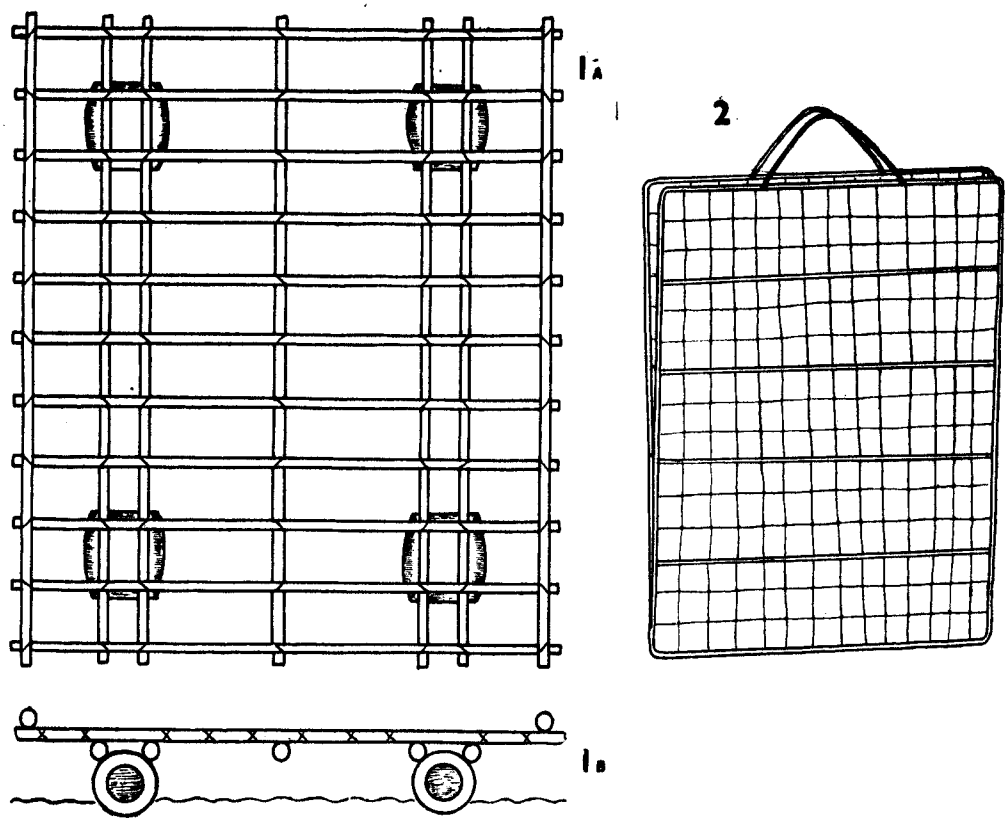
The pearl culture farms are located in the bays where suitable conditions, as stated in the foregoing section, prevail and the establishment consists of four divisions, namely, the farm in the sea, the nucleus implantation laboratory, the pearl collection centre and the material repair shed, the last three situated on the shore near the farm. The various activities of the pearl culture farms are illustrated in Plates I to VI.

The pearl oysters bought from the mother oyster culturists are grown in the farm until they attain the proper size for nucleus implantation. The method of growing the oysters has undergone several improvements since the early days when the oysters were simply strewn on the bottom in demarcated areas. Later the oysters were put in bamboo baskets and hung from rafts. Until the 'fifties the pearl string method was practised for culturing the pearl oysters. In this method a hole was pierced along the byssus groove of the left valve of the oyster and ten or more of them were connected by a vinyl string passing through the holes at intervals of 7 or 8 cm. The string was wound around a thick rope or a bamboo pole hung vertically from the rafts. Nowadays pearl oyster nets are used along with bamboo baskets and iron cages, the latter two being employed for specific purposes.

Floating raft.—The raft, known as 'ikada' in Japanese, is made of wooden poles ('sugi no ki' or 'hi no ki') and the overall dimensions are $6{\cdot}4 \times 5{\cdot}5$ m. The construction is illustrated in Fig. 1. Seven long poles and ten short ones go to make a raft and they are secured with ropes as shown in the figure. The raft is floated on 4 wooden drums coated with coal tar, each of 88 to 90 cm. length and 53 to 55 cm. diameter. The pearl oyster nets are hung from the short poles at ten points marked 'x' in the figure. The whole structure is either at level with the surface of the water or raised to about 30 cm. Though the raised constructions are prone to more damage due to winds and waves it facilitates field work better. The rafts are arranged in longitudinal rows of 7 to 10 and they are anchored with stones or iron anchors. When the rafts are near the shore fixed objects on the shore such as trees, rocks etc., are used to anchor one end of the row. While the wooden rafts are suitable for calm bays, they are not for the open-sea conditions where the wave action is considerable. Due to their non-flexibility heavy damage is caused by the high waves. Rafts made of synthetic floats and ropes are used in such areas. Such rafts are a common sight in the Seto Inland Sea now. Being flexible they are not damaged by rough-sea conditions. Field work is done from small dinghies in these farms.

Pearl oyster net.—The pearl oyster net consists of two rectangular frames measuring about 60×45 cm. made of iron rods of about 5 to 7 mm. thickness coated with synthetic material, black or green in colour, hinged together at one end and they close like the two covers of a book (Fig. 2). Cross-rods divide the frame into five or six sections. The entire frame is interwoven with vinyl wires. The oysters are arranged on this frame, 6 or 8 in each row depending on the size of the oysters, with the ventral side up and the anterior side of one overlapping the posterior side of the other. This provides substratum for the attachment of the byssus. A maximum of 48 oysters can be accommodated in a single net. After arranging the oysters a terracotta block bearing the batch number is attached to the top row and the frame is closed. All the four sides of the frame are fastened with rope and the oysters are held in position without slipping down. The nets are hung from the rafts by semi-synthetic ropes, usually one for a

rope, but there are cases where even as many as 5 nets are attached one below the other depending on the depth and the suitability of the area.



FIGS. 1–2. Fig. 1A. Construction of a floating wooden raft, top view; Fig. 1 B. The same, front view; X marks are the points from which pearl oyster nets are suspended. Fig. 2. Pearl oyster net.

Floating shed.—Covered sheds are erected on floating rafts when the farm is a little away from the shore. Periodical cleaning of the oysters and the nets is done in these sheds and they also form resting places for the field workers.

Nucleus implantation laboratory.—The laboratory is situated on the shore. The mother oysters are brought here, cleaned and supplied to the technicians who operate on the oysters and implant the nucleus.

Pearl collection centre.—The pearl oysters are brought to this place at the end of the culture period and pearl collection is done by pulverising the shucked oysters in rotating drums.

Material repair shed.—This is also a shore establishment where the farm materials are mended after in use for some time. The nets, baskets and cages are subject to fouling while in water. These are removed to the shed cleaned by mechanical devices and dried. Coal tar coating is given to the materials.

CONDITIONING OF THE OYSTERS

Conditioning is an important programme in pearl culture work. It is a process by which the oysters are starved, made to discharge their gametes and rendered weak in order to keep the meta-

bolic activities at a low level. In this condition the oysters do not respond to the external stimuli very violently.

Many methods are adopted to achieve this before the nucleus is inserted into the oysters. The oysters are crowded in bamboo baskets, about 150 in one, and are lowered to greater depths where the plankton food is poor and the velocity of the current is low or there is no current at all. They are lifted up and lowered down alternatively at intervals of a few days and due to the temperature difference at different depths the oysters spawn at higher temperatures. They are also taken to the open sea and left for about 3 to 4 hours. Due to the difference in temperature and specific gravity of the water the oysters discharge their gametes. This process is repeated frequently until the gonads become almost empty. Another method is to overcrowd the oysters in steel cages and to drop them on the floor of the bay. Due to conditioning the adductor muscle becomes weak and hence the valves can be easily opened at the time of operation. The gametes are almost extruded and do not form a hindrance at the time of the nucleus implantation.

Nucleus Implantation

The theory of pearl formation has become well known among the scientists. Natural pearls are a result of an accidental entry of a foreign matter into the pearl oyster. The foreign body may be a tiny grain of sand or a parasite, which sets up an irritation when it has entered the oyster. The oyster unable to get itself rid of the unwelcome intruder attempts to reduce the irritation by coating the foreign substance with its nacreous secretion, the process continuing throughout the life of the animal, which results in the formation of a beautiful pearl. When this takes place within the tissues of the oyster the resulting pearl is generally spherical or of a symmetrical form, but when between the mantle and the shell the pearl attaches itself to the inside of the shell and becomes baroque of different shapes. Even the so-called nucleusless pearls have a small nucleus to begin with which may be some epithelial cells or blood cells of the oyster that subsequently become degenerated and unidentifiable at the time of examination, appearing as though there is no nucleus.

In the production of cultured pearls man artificially introduces a foreign substance into the body of the oyster compelling the latter to protect itself against this irritation by coating the foreign matter with its nacreous secretion in concentric layers, and finally harvests the pearl by sacrificing the animal itself. Though it may look so simple as that the process is quite a complex one and it took years of concerted work for the Japanese scientists and culturists to perfect the technique. Producing semi-spherical or half-pearls is comparatively easy and is achieved by introducing a foreign material between the shell and the mantle at a proper place whence the chances of rejection are very little. But getting spherical pearls requires admirable skill as it involves slitting the body of the oyster and inserting a fairly large-sized foreign material into its system.

Training of technicians.—Since the implantation operation requires great skill, patience and dexterity of fingers, mostly young girls are employed for the job. Those who have completed their middle school education and are about 15 years old are given training in the technique. The period of training lasts from about a few months to 2 years depending on the size of the nucleus they will be required to handle, taking the maximum time for the larger nucleus groups. During the training period the oysters operated by each trainee are maintained in separate batches and the skill attained by them is judged by the results obtained at the time of pearl collection.

Season of operation.—Nucleus implantation is done from May to October, intensive work being carried out only in a few months in this period depending on the availability of proper oysters and also the hydrographical conditions of the bay. Generally it is done for about 100 days in a season. The oysters begin spawning as the water temperature increases from May onwards. The conditioning process makes them spawn early in the season and by June the gonads are almost empty. The period when the temperature shows a rising trend is considered ideal for the operation. But even when the temperature is on the decline with the onset of autumn in September nucleus implantation is carried out. The winter that follows causes a steep fall in temperature below the

optimum level. Hence the late operated oysters suffer a greater mortality while transporting them to warmer areas as they have not had much time to recoup after the operation.

Tools used in operation.—The instruments used are not as sophisticated as the final products of the operation are and consist of simple knives, needles and spatulas made of stainless steel. *Oyster stand* ('Kaidai'): Consists of two notched plates one clamped to a vertical rod and the other apposing on it. It is mounted on a wooden board. The oyster is fixed firmly between the two plates at the time of operation. *Shell opener* ('Kaikōki') : A pair of tongs with a slipping ring used in opening the oyster for the operation. The width of the opening is limited by the slipping ring and no undue tension is caused on the adductor muscle. *Spatula*: This is used to push the gills aside so as not to interfere with the operation. *Foot-puller* ('Hikigake') : A flat instrument with a sharply bent end to pull the foot aside. *Incising and graft needle* ('Kuchikiri mesu—Saibo okuri') : A needle with one end sharply flattened for making the incision and the other end pointed to introduce the graft tissue. *Nucleus introducer* ('Soniyuki') : A needle with cup-shaped ends for inserting the nucleus into the body. *Scissors and pincers* : For cutting and removing the mantle of the oyster. *Graft cutting knife* ('Saibo mesu') : For preparing grafts from the mantle.

Nucleus.—Japan does not have suitable shells for making beads and hence the entire demand is met from imported shells. Before World War II shells of *Lampratula* spp. from China used to be imported. Subsequent to the War shells are being brought from the United States of America. The tributaries of the River Mississippi abound with freshwater mussels, pig-toe shell, Dove shell, Three ridge, and Butterfly shell, of the species of *Tritogonia, Quadrula, Pleurobema, Amblema* and *Megalonais* whose shells are thick having a massive nacreous layer. These mussels themselves produce pearls and until recently they were exploited for this purpose. At present almost the entire quantity of these shells from this river is sold to Japan for manufacturing mother-of-pearl nuclei. The Japanese industry locally produces from these shells shiny beads of different sizes by cutting, grinding and polishing them. The beads range in diameter from 1 to 10 mm. or more, but the ones more commonly used in the case of *Pinctada martensii* are from 3 to 8 mm. The bead manufacturing industry is concentrated in Osaka and Mie prefectures.

Preparation of oysters for the operation.—The conditioned oysters are brought ashore to the laboratory. They are thoroughly cleaned and those infested with parasites are discarded. A blunt knife is inserted through the postero-ventral corner between the valves and the latter are slightly opened. A wedge made of light wood of about 5 cm. long is pushed through the antero-ventral corner and the knife is withdrawn. The oysters thus prepared are arranged in enamel trays and passed on to the technician's table.

Preparation of graft tissues.—The graft tissue plays an important role in pearl formation as it is the basic material from which the pearl-sac is formed by the proliferation of the cells. In the beginning when attempts to produce spherical pearls were made the nucleus used to be completely covered by the mantle tissue cut from an oyster other than the one used for implantation. Later it was found that even a small piece of the mantle tissue will serve the purpose and this method is currently used. Oysters used for the preparation of the graft tissues are selected according to the size of the oyster used for nucleus implantation, both being of the same size, and which have not undergone the process of conditioning. They are opened and both the right and the left mantles are cut out. The mantle is spread on a wooden block and is cleaned of the mucus. A long strip of the mantle is prepared and it is divided into a number of square bits and smeared with a solution of eosin in sea-water. The size of the mantle piece is decided according to the size of the nucleus and the size of the pearl oyster itself. Since ultimately it is this piece of tissue which decides the formation and quality of the pearl extreme care is taken in the preparation of the mantle pieces and any mistake made will either result in the non-formation of the pearl-sac or formation of inferior pearls. The prepared tissues are passed on to the technicians.

Implantation of nucleus.—The technician inserts the shell-opener through the postero-ventral corner of the oyster thereby releasing the wooden wedge inserted earlier. The oyster is then clamped on the stand diagonally with the byssal side to the right of the technician. The mantle and the gills are gently pushed aside so as not to interfere with the operation. The byssal threads are also kept off and the foot is pulled to some extent to get the gonad elevated a little. There are some potential areas inside the gonad which have been found to favour pearl-sac formation without affecting adversely the normal functions of the oysters. A slit is made on the gonad and a passage is cut through. The mantle piece is then taken to the place of implanation and left there. This is followed by the introduction of the nucleus. Improper orientation of the mantle piece and nucleus will result in the formation of an irregular pearl-sac and the resulting pearl will not be spherical. After the implantation of the nucleus the shell-opener is taken out by slipping the ring down and the oyster closes its valves. The oysters which could not be operated on successfully are discarded. The operation on an oyster takes less than 2 minutes and in an eight-hour day a technician can operate from 250 to 300 oysters.

Generally two nuclei are implanted at different places, but occasionally a third one is also used. In the multi-nucleus operations one nucleus is always larger and the other two are smaller. When large quantities of seed pearls are desired as many as 20 tiny nuclei are inserted into the gonads. In this case the pearls produced are small, of about 2 to 3 mm. in size, and irregular in shape. These pearls known as 'keshi' pearls are used only for pharmaceutical purposes and not in jewellery. In the case of freshwater mussel *Hyriopsis schlegeli* more than 20 minute mantle pieces are inserted into the mantles of the mussel and the pearls produced are non-nucleated, generally pink in colour, small in size and irregular in shape.

Post-Operation Care of the Oysters

The operated oysters are removed from the laboratory to the farm and are very carefully handled. Rough handling or exposure to strong stimuli would result in the rejection of the nucleus. The oysters are arranged on the pearl oyster nets and hung at a place and depth where the water is very calm, current is negligible and light penetration is poor. This is done to keep the metabolic activities of the oyster at a very low level so that it does not react strongly to the presence of the foreign material inside its system. The oysters are kept under these conditions for about 2 to 3 weeks and later shifted to the normal place. During this period the mantle piece, inserted along with the nucleus, becomes the centre of activity and by cutting new cells on all sides it ultimately encircles the whole nucleus. This new layer of cells surrounding the nucleus is called the pearl-sac and it takes about 3 to 7 days for its formation. After about 12 to 14 days nacre begins to be secreted by the pearl-sac and deposited on the nucleus in a concentric manner. This is just the beginning of the formation of the cultured pearl.

Subsequent to the nucleus implantation the number of nets for a raft is reduced from 100 to 80 to provide better conditions for growth of the oysters. The implanted oysters are subjected to an X-ray examination at the end of about 3 months to find out if the nuclei have been retained or rejected. This is done only in cases where nuclei of over 8 mm. diameter have been used as the chances of rejection are more among them than those which have received smaller nuclei. The oysters which have successfully expelled the nuclei are discarded and this forms about 25 to 30% among the larger size-groups.

Culture of Nucleus-Implanted Oysters

The nucleus-implanted oysters after their initial care grow in the pearl oyster nets under normal conditions where there is a current of moderate velocity and optimum temperature conditions exist. The oysters in nature are exposed to a variety of fouling and boring organisms. Spat of pearl oysters and other oysters, barnacles, ascidians, sponges and seaweeds settle down and grow on the shells. The nets are lifted up and brought to the floating sheds where the oysters are taken out and the fouling

animals and seaweeds are scraped with a knife. Depending on the amount of fouling cleaning is done 3 to 4 times a year. The cleaned oysters are again arranged on the nets and left in the sea. A good settlement of the fouling organisms is taken to indicate the richness of water to sustain good growth of the pearl oysters themselves and such areas are preferred despite the disadvantage of fouling.

Besides the winter transportation of the oysters to warmer areas the oysters are also taken to other grounds for the purpose of make-up culture. As the colour of the pearl depends on various factors, such as the chemical constituents and metal ions present in the water and the quality and quantity of the planktonic organisms on which the oysters feed, grounds which are known to produce quality pearls are sought after and the oysters are transported there to get the make-up coating of desired nacreous substance on the pearls. Wakasa Bay, Notojima, Ago Bay and some areas in the Inland Sea around Hiroshima are known to produce quality pearls.

The period of culture varies from 6 months to 3 years from implantation of the nucleus, depending on the size of the implanted nucleus. For less than 4 mm. nuclei the period is about 6 months, for 4–5 mm. nuclei about one year, for 5–7 mm. nuclei two years and for 7–9 mm. nuclei about three years. The duration varies from place to place according to the nature of culture grounds. Though the Japanese pearl oyster *P. martensii* is known to live for 10 years or even more those above 6 or 7 years are not generally used for cultured pearl production as they have already passed the prime period of growth.

Pearl Collection

Pearl collection at the end of the culture period is done always in winter from November to February. During the preceding summer months due to high temperature conditions the oysters grow vigorously and the nacreous layer secreted is thick but of poor lustre. Under winter conditions thin and numerous layers of nacre are deposited and this makes the pearl lustrous. Also the pH of the body of the oyster is in the range of 7·3 to 7·5 in winter and the pearl at this time has a good iridiscence.

The pearl oyster nets are lifted ashore and oysters of different batches are gathered separately. The meat with the pearls is shucked and mixed with slack lime. This lot is placed in wooden barrels and closed. The meat is pulverised without harming the pearls by wooden blades rotating inside he barrel. The pearls settle down at the bottom due to their higher density. The pulverised meat alone is washed out by running water and the pearls are collected in another container. They are washed with neutral soap water and dried.

The pearls are then assorted according to shape and size. Of the pearls collected about 30% are of no commercial value as gems and hence rejected. Among the rest 30% are of good quality and 40% are just marketable. The pearls are sent to the processing section where they are further assorted and strung into necklaces or set on broaches or rings or numerous other ornaments and sent to the markets.

The irregular pearls and the seed pearls are used in the pharmaceutical industry for preparation of drugs. The meat is edible, especially the adductor muscle which is used in 'tempura' a delicious Japanese preparation. Other parts of the body emit an unpleasant odour and hence not preferred. The shells are coarsely ground and used as fertiliser and chick feed.

Enemies of Pearl Oysters and Mortality

The enemies of pearl oysters can be broadly divided into three categories, *i.e.*, those which affect the shell, those which affect the internal tissues either as parasites or as commensals and those which prey on the oysters. In the first category can be grouped the polychaetes which encrust as well as bore the shells, of which *Polydora ciliata* is an important species, sponges, ascidians, barnacles,

oysters and mussels. To the second category belong the trematode parasites of the species *Bucephalus margaritae* and *B. varicus* affecting essentially the gonads and the gills, and *Proctoeces* sp. affecting the circulatory system and the pea-crab *Pinnotheres* sp. Octopus and some fishes form the third group. The former when present in large numbers brings about heavy mortality of oysters. Apart from these animals, red tides and cold currents which sometimes enter the bays cause havoc to the oyster farms.

A number of oysters die in the farm either due to the after-effects of the operation or natural causes. In the first year the mortality rate is about 15% and in the next two years about 10% each year, the total mortality during three years being about 30 to 40%.

Research Activities

Although the pearl culture industry has been well established the search to improve the quality of pearls has never ceased. There are several laboratories carrying out research on the various aspects of the industry. The National Pearl Research Laboratory at Kashikojima (Mie Prefecture) under the Fisheries Agency was established in 1955 with a branch laboratory at Kujima-go (Nagasaki Prefecture) for the express purpose of promoting the pearl culture enterprise. The research departments of several universities are also engaged in this field. The Fisheries Department of Mie Prefectural University, the Mie Fisheries Experimental Research Station, the Fisheries Department of Kagoshima University and the research laboratories run by the companies engaged in the pearl trade, like the Mikimoto Pearl Research Laboratory at Tatoku are doing valuable work. These researches aim at improving the culture grounds and the culture methods, obtaining pearls of desired colour and lustre by artificially feeding the oysters with different food materials and evolving new races of pearl oysters by cross-fertilisation for improving the quality of the pearl oyster itself.

Cultured Pearl and Its Classification

The cultured pearls fall under different categories. Based on the species of mother shells used in culture they can be grouped into (1) *Pinctada martensii* pearls, which are usually called the 'Japanese pearls' or the 'Japanese cultured pearls', (2) *Pinctada maxima* pearls which are larger than the former and are produced by the 'golden-lip' or the 'silver-lip' shell in the Australian waters and marketed by the Japanese traders, (3) *Pinctada margaritifera* pearls which are generally half-pearls produced by the 'black-lip' shell in some areas of Japan and in the South Seas, (4) *Pteria penguin* pearls or 'Mabe' pearls which are half-pearls produced by the wing-shell, (5) the freshwater pearls produced by *Hyriopsis schlegeli, Cristaria spatiosa* and *Unio margaritiferus* in the lakes of Japan which are of small size and irregular shape and (6) abalone pearls produced by *Haliotis discus.*

According to shape the pearls can be classified into round pearls, drop pearls, pear pearls, baroque pearls, half-pearls and three-quarter-pearls and based on colour they can be grouped into pink, white, yellow, cream, golden, green, blue and black pearls besides which there are many other shades resulting from a combination of two or more of the above colours.

Japanese Pearl Trade

The Japanese cultured pearls have stood well the test of time since Mikimoto for the first time exported his pearls in 1904 to the United States of America and today they have flooded the jewel markets all over the world. The annual production of pearls in Japan in the recent years has been about 25,000 kan (1 kan is 3·75 kg.) and more than 80% of it is exported. In 1967 the exported pearls amounted to 20,970 kan bringing in a foreign exchange of 51·5 million U.S. dollars. The main importers of Japanese pearls are the United States of America, W. Germany, Hong Kong, Switzerland, Australia, India, Spain, S. Africa, France and Canada. About 90 other countries

buy the Japanese pearls in small quantities. India imports about 2,400 kan pearls every year from Japan constituted essentially by the freshwater pearls.

In the later part of 1966 there was a slump in the world market for pearls and some of the reasons attributed have been over-production of the commodity, production of poor quality pearls and also the change of fashion among the young women to sport mini-skirts with which the pearl ornaments are not said to match! This slump resulted in the disposal of the stocks at lower prices and curbing the production of pearls by enacting regulations. Subsequently the industry recovered from this setback and reached its normal level of production and sales.

Pearl Culture in Other Regions

Japan which has developed a pearl culture industry of unique nature and held a monopoly over the years has also helped other countries in establishing the industry. An industry was established in Australia in 1956 with the inauguration of a project in Brecknock Harbour in the north of Western Australia (Wells, 1965). As this project was a success a few other farms were established and now there are 18 of them (including 2 in Papua) in Northern Australia, Kuri Bay and Torres Strait being the main centres of pearl culture activities. Of these 18, all but three are operated as joint-ventures between Australian and Japanese companies under the agreement that the Australians establish the farms and supply the pearl oysters and the Japanese attend to the operation and culture of the oysters and marketing of pearls. The Australian pearl oyster, *Pinctada maxima*, being much larger in size than the Japanese oyster *P. martensii* pearls up to 18 mm. in diameter are produced and this probably may be the largest size for the cultured pearls.

In 1958 an eight-man team of Japanese pearl culture experts was sent to the Philippines on invitation to investigate the possibility of a joint project with a local company. In 1951 a joint Japanese-Ryukyuan pearl culture company was formed in Okinawa for production of black pearls. In Hong Kong using *Pteria penguin* success has been achieved in producing semi-spherical pearls. A company works in the Palau Island in the South-West Pacific and another at Boetoeng, the south-eastern extremity of Celebes. In the Mergui area of Burma also some work seems to have been initiated in this direction.

Indian Pearl Fisheries

The Indian pearl oyster *Pinctada fucata* (Gould) [= *P. vulgaris* (Schumacher) *vide* Hynd (1955), Rao (1968)] is found on the rocky grounds, locally known as 'paar' of the submarine bank in the Gulf of Mannar along the south-east coast of India in a discontinuous stretch from about 8° 18′ N. to 8° 54′ N. lat. and from 78° 7′ E. to 78° 25′ E. long. The pearl oyster beds lie at a distance of about 12 to 20 km. from the coastline and at a depth of 15 to 25 m. (Figs. 3 and 4). There are more than 65 'paars' of which only a few like the 'Tholayiram paar', 'Kodamuthu paar' and 'Karuwal' groups have been known to be relatively more productive. Other species of pearl oysters that occur in the Indian waters are *P. margaritifera* (Linnaeus), *P. chemnitzi* (Philippi), *P. anomioides* (Reeve), *P. atropurpurea* (Dunker) and *P. sugillata* (Reeve) but these do not contribute to any fishery (Prashad and Bhaduri, 1933; Rao, 1968).

The pearl fisheries of the Gulf of Mannar have been of an irregular character and in the span of three centuries from 1663 to 1961 there have been only 38 official fisheries. While the pearl oysters were harvested annually in consecutive years from 1955 to 1961 this series was preceded by a long gap of 27 years when the beds were almost barren. The pearl fishery is conducted by the Department of Fisheries, Madras State, with Tuticorin as the base of operations. When the depart-

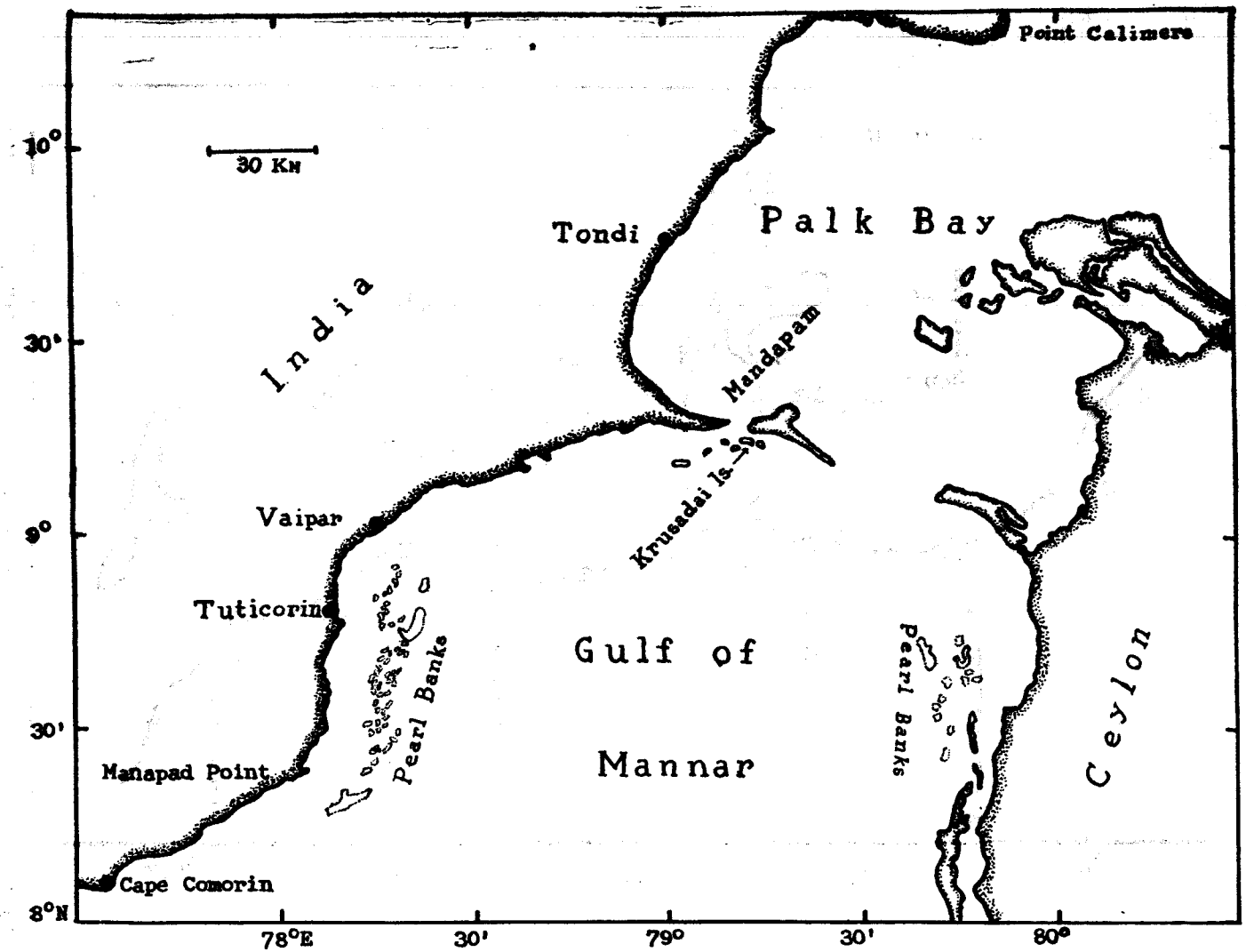


FIG. 3. Map showing Palk Bay and Gulf of Mannar and the location of pear lovster beds off the Indian and Ceylon coasts.

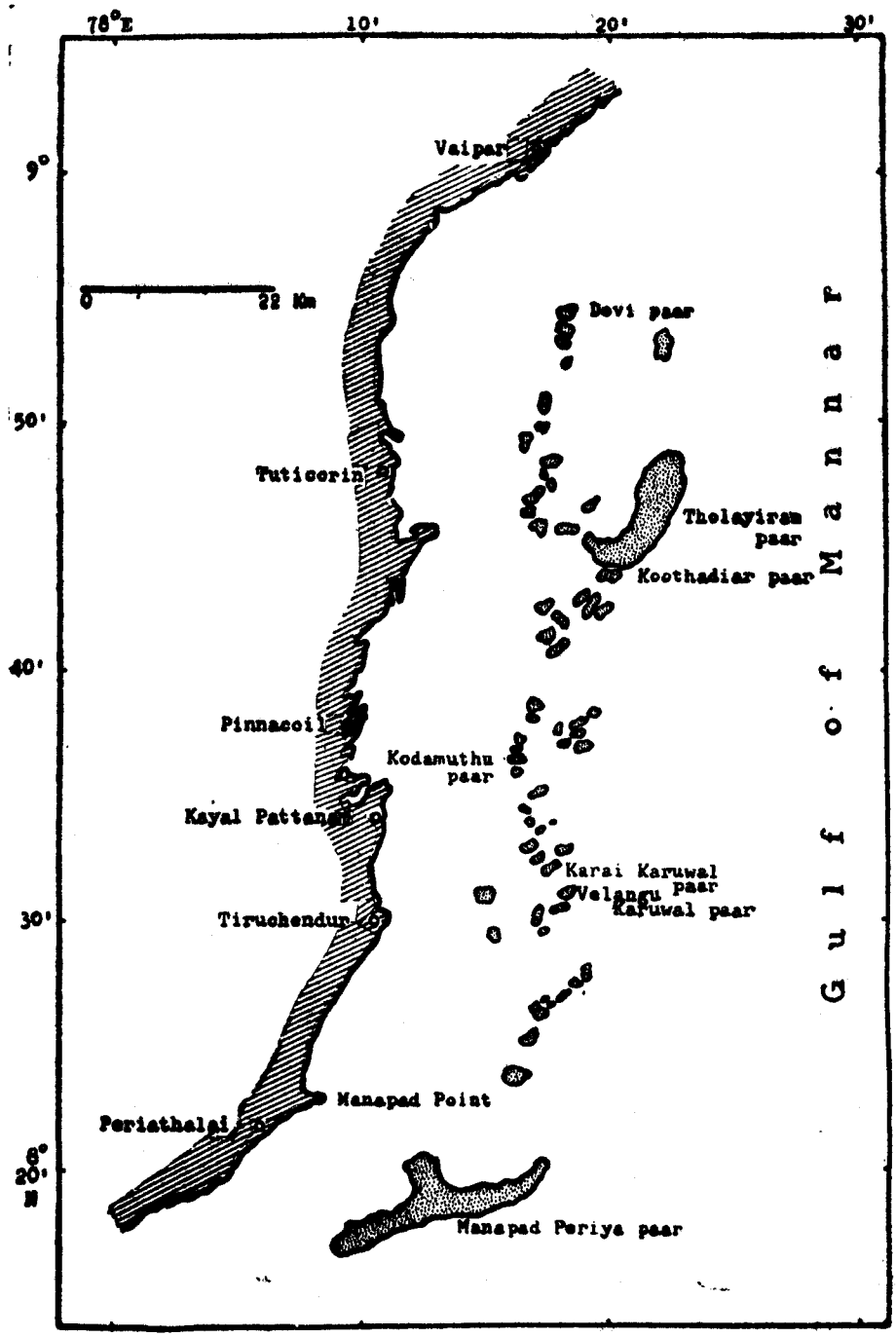


FIG. 4. Map showing the Gulf of Mannar pearl oyster beds on the Indian side (after Hofnell, 1222 and Baschleri, Salvadori, 1950).

mental surveys reveal the availability of fishable quantities of pearl oysters of over three years age and when the evaluation of pearl content shows satisfactory results a pearl fishery is declared to the public. The fishing season generally lasts for a month or two during January–May depending on the favourable weather conditions and the strength of the oyster populations. For the fishing, canoes with full complement of divers are towed to the pearling grounds and the divers skin-dive and pick the oysters. The catch is shared by the divers and the Government at a ratio of 2: 1. The oysters are bought by the merchants and the interested public, piled up in gunny bags and allowed to rot for a few days to get the meat soft and searched for pearls. In a good fishing season tens of millions of oysters are collected and the revenue that accrues to the Government is in the order of a few hundred thousand rupees. In 1958 which was the best year in the recent series 21·48 millions of oysters were fished and the income to the Government was Rs. 465,000. The total turnover of pearl business was estimated to be not less than one million rupees (Government of Madras, 1959).

While the pearl fishery of the Gulf of Mannar has been in existence from time immemorial, in the adjacent Palk Bay only one pearl fishery was held in 1914 off Tondi (Hornell, 1916 *b*). This did not prove commercially successful and attempts to find pearl oysters in fishable quantities in the subsequent years only yielded negative results.

Besides these two areas pearl oysters occur in the Gulf of Kutch on the North-west Coast of India along the northern coast of Halar District in Gujarat State. The Kutch oysters occupy the intertidal zone and are periodically exposed at receding tides. The pearl fishery conducted is entirely different in character, being regularly held every third or fourth year though on a small scale (Gokhale, *et al.*, 1954; Hornell, 1909). A pearl fishery of very little value in the Thana creek in Bombay is on record (Comber, 1905) but does not seem to have been there in the recent past.

A Brief Review of Pearl Culture Work in India

Hornell who took the responsibility of investigating the prospects of the Gulf of Mannar pearl fisheries along the Indian as well as Ceylon coasts in the early part of the present century for the purpose of improving the pearl oyster resources and conditions of fishing grounds came to the conclusion after long years of intensive study that "*the only economically sound way of making the Indian and Ceylon Pearl Fisheries permanently and regularly remunerative is to concentrate upon the inducement of pearls by artificial means in comparatively limited numbers of cultivated pearl oysters* and to avoid all expensive attempts to control the comings and goings of oysters upon the natural beds in deep water" (Hornell, 1916 *a*, p. 22). He himself had conducted experiments in 1908 on induced pearl formation and obtained six dust pearls of no commercial value (Hornell, 1916 *c*). It would appear that despite the encouraging start he could not pursue the investigations on production of cultured pearls.

Later, Sundara Raj conducted some experiments at the Krusadai Farm in 1938 (Devanesen and Chacko, 1958). His technique of operation as reported by the above authors was to narcotise the oyster and bore two small adjacent holes in the valve and the adjoining mantle. A bead of the chank shell wrapped in mantle tissue and tied with a catgut was inserted into the mantle cavity and tied on the outside of the shell. He later improved upon the technique by inserting the bead with the mantle fold into the mantle cavity and pulling the neck of the fold through a hole made in the oyster's mantle and removing the catgut. His efforts were not successful and he could obtain only two imperfect blister pearls away from the site of implantation (*vide* Devanesen and Chacko, *op. cit.*).

Continuing the experimental series at the Krusadai Farm, Devanesen and Chacko attempted from 1940 to produce cultured pearls using the following technique : The oysters were narcotised with menthol crystals. A few upper pallial muscle insertions near the mouth were gently detached and a mother-of-pearl ball was introduced in such a way that the ball is lodged in the virtual chamber formed by the adductor muscle, pallial muscle insertions on both sides and the hinge-line. The oyster, after it recovered, was returned to the sea. After a lapse of three months the authors found

the mother-of-pearl ball attached to the shell and coated with nacre. Their suggestion to obtain free cultured pearls was to remove the attached pearl and reintroduce it in another oyster using the same technique. They further suggested that at intervals of 10 to 15 days the oysters should be taken out and the ball set free again and again and the sac should be tied with a silk filament until a completely closed sac is formed (Devanesen and Chacko, *op. cit.*).

It may be of interest to mention here that the attention of the above authors was drawn to a review by Rao (1947) of the Economic Report No. 1 on the Pearl Shell, Beche-de-Mer and Trochus Industry of Northern Australia (Sydney, 1946) (*vide* Devanesen and Chacko, *op. cit.*, p. 10). This review reproduced in full in Appendix VI of the Report which deals with the "Artificial Culture of Oyster Pearls" in Japan. Details of nucleus implantation into the gonad of the oyster with the graft tissue are broadly given in the Report. The authors however ignored this report with the remark "the report published in the Journal is misleading and bristling with improbable statements and impracticable suggestions for technique so much so, that it is inadvisable to take it seriously and borrow hints from it for our culture-pearl technology". They, drew their own conclusions on the Japanese method stating "We guess that their method in broad outline must be similar to the technique followed here ... If so, there is no room any more for curiosity" (Devanesen and Chacko, *op. cit.*, p. 15). On the other hand it is felt, if some heed had been paid to this report and experiments conducted on those lines it is probable that some useful results could have been achieved. Subsequently, although pearl oysters were available in large numbers during 1955–61 the situation does not seem to have been taken advantage of for perfecting the culture technique.

Despite the failure to evolve a satisfactory technique it has to be fully appreciated that pioneering experiments were conducted in India by the Madras State Fisheries Department and very valuable information on some aspects of biology of the Indian pearl oyster have been obtained (Chacko, 1968; Devanesen and Chidambaram, 1956). Incidentally, it may not be out of place to mention here that a pioneering attempt was made in 1950 by the Madras State Fisheries Department to bring pearl oysters from the Persian Gulf to form a breeding reserve to populate the oyster beds in the Gulf of Mannar (Devanesen and Chacko, *op. cit.*, Appendix I). In all over 600 oysters were airlifted from Bahrain and out of this 79 at Krusadai and 38 at Tuticorin were successfully transplanted, the rest having suffered mortality at various stages.

Plans and Prospects of Pearl Culture in India

Endowed with a pearl oyster resource as it is, India should look ahead and rationally utilise this resource to get a steady yield of pearls rather than submitting to the vagaries of nature. The immediate need is to start a pilot scheme on pearl culture and perfect the techniques of operation and culture and work out details for production on a commercial scale.

Presently the main hurdle appears to be the paucity of oyster population in the natural beds of the Gulf of Mannar. However, for experimental purposes it should be possible to collect oysters in sufficient quantities. To this date the factors responsible for the irregular abundance of pearl oysters in the beds are not known except for some conjectures put forth by Hornell (1916*a*). No attempt has been made to give a settling surface other than the natural bottom for the setting of pearl oyster spat. It is worthwhile to take hints from the Japanese methods of spat collection where cultches are hung from rafts to get the best settlement from the subsurface to the middle layers. An interesting observation made by Chidambaram *et al.* (1951) on the 'Aluva paar' is that while divers did not collect any oysters from the bed, an examination of the buoy revealed the presence of 3 oysters attached to the stone weight, 10 on the rope and 7 on the bamboo pole on top. This single instance, though insufficient to draw any conclusions suggests that spat settlement could be expected to be better in the subsurface to the middle layers. Different kinds of spat collectors should be hung from rafts or buoys at different depths on a wide area in the natural grounds to study the

spat settlement. Young spat when collected should be grown in special cages until they attain a suitable size for the operation. When the oyster population gets replenished in a natural way every effort should be made to establish a farm on a large scale and to get a chain supply of spat in subsequent years for the farm. A knowledge on the duration of the planktonic phase of the larvae and their movements should be obtained.

Unlike in Japan where sheltered bays are many there are no such suitable grounds in the vicinity of the natural beds. Hence farming has to be attempted in open areas where the conditions may not be so congenial for the purpose. Already some experiments have been conducted in the Krusadai Farm near Mandapam in the Gulf of Mannar successfully keeping the oysters alive over a number of years and the future farm could be located in the same area. The chain of coral islands present in this area would give some protection to the farm. Another farm near Tuticorin in the natural grounds could be thought of, but work in this area would be possible only from about October to April. Synthetic rafts would be ideal for the open-sea conditions but considering the cost it will not be economical at this stage. Bamboo rafts can be used during the initial experiments. The oysters can be transported to the farm near Mandapam by road in about 4 hours time. Suitable methods of conditioning should be evolved to prepare the oysters for the nucleus implantation. For the nuclei some of the indigenous shells with a thick nacreous layer like *Turbo* and *Trochus* could be tried. Even to import the nuclei from Japan will not be uneconomical. The tools for implantation could easily be fabricated locally.

Systematic research work should be taken up on all aspects of pearl culture and the biology of the Indian pearl oyster as, at the best, the knowledge on the Japanese industry and the Japanese pearl oyster could only form guidelines for our experiments. Hydrographical and physico-chemical investigations should be taken up both at the natural grounds and the farm site with a bias to obtain information on the conditions most suitable for the growth of the pearl oyster and production of quality pearls. In tropical conditions where the water is more or less uniformly warm all through the year the deposition of nacreous layers can be expected to be faster than in the Japanese waters where warm and cold conditions alternate and it may take relatively less time in our waters to get a good sized pearl. The Gulf of Mannar pearl oyster *P. fucata* which is well known for the production of Oriental Pearls of a good colour and lustre and which is very much alike to the Japanese oyster should no doubt yield good quality cultured pearls. On the other hand the Kutch oysters produce pearls not of a lange size and good quality, but cross-breeding of this with the Gulf of Mannar oyster may result in a strain which may be hardy and suitable for culture in shallow areas and produce high quality pearls.

India is importing Japanese cultured pearls, mainly the freshwater ones, worth over a million U.S. dollars every year. The Japanese export figure for India for the year 1967 is 2,353·5 kan of pearls valued at 1,018,348·25 U.S. dollars. The demand for pearls in India is very much unlikely to fall as the pearl will continue to occupy an important place among the jewellery of the Indian women for years to come. Bombay, which is already an established trade centre for pearls, would provide marketing facilities. If the pearl culture technique under the Indian conditions is perfected the natural abundance, when it occurs, of pearl oysters could be taken advantage of for commercial production of cultured pearls and it will certainly be an economically viable enterprise.

Another aspect of importance of pearl oysters lies in their value as a good source of nourishing food. As stated earlier the adductor muscle of the oyster is a relished food in Japan. Gunasekera (1962), analysing the Ceylon pearl oyster, found the flesh content to be of approximately 15%, the adductor muscle alone forming 11%. Subjecting the flesh to chemical analysis he obtained the following values: moisture—74%; protein—19%; ash—2%; fat—2·5%; and carbohydrates—2·5%. He also found that the adductor muscle is the only portion fit for processing and that it keeps well in brine for an indefinite period before dry curing.

While developing our pearl culture industry the above aspect should be given due attention and investigations on the food value of the pearl oyster and seasonal changes in its chemical composition and, above all, popularisation of the pearl oyster meat among the public should be taken up. Hornell (1917) who was very much alive to this situation even half a century ago observed: "If ever a fish cannery be established on the shores of Gulf of Mannar, I believe that in those years

when pearl oysters are poor in pearls though abundant numerically, the canning of their flesh would prove a remunerative undertaking."

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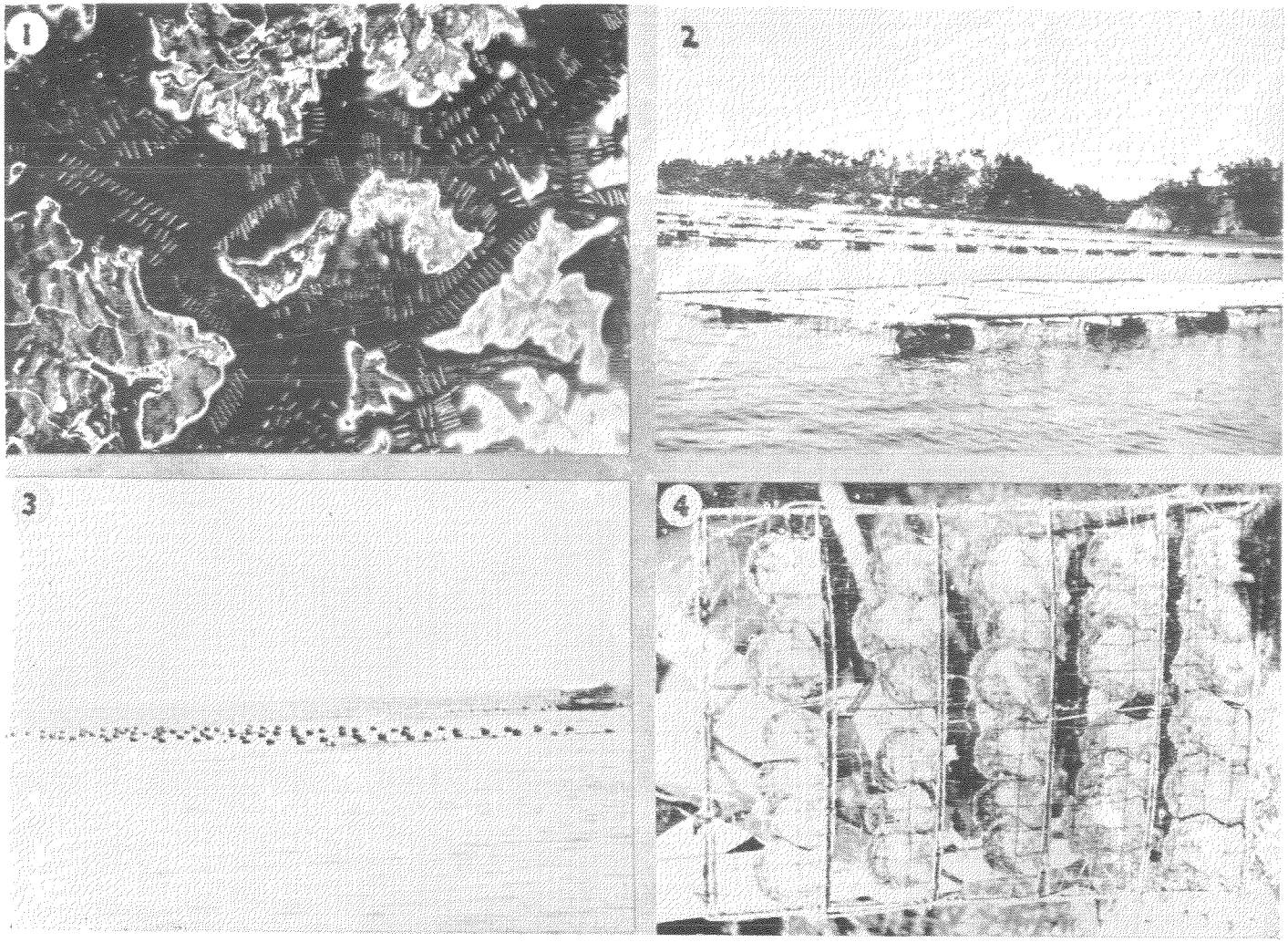
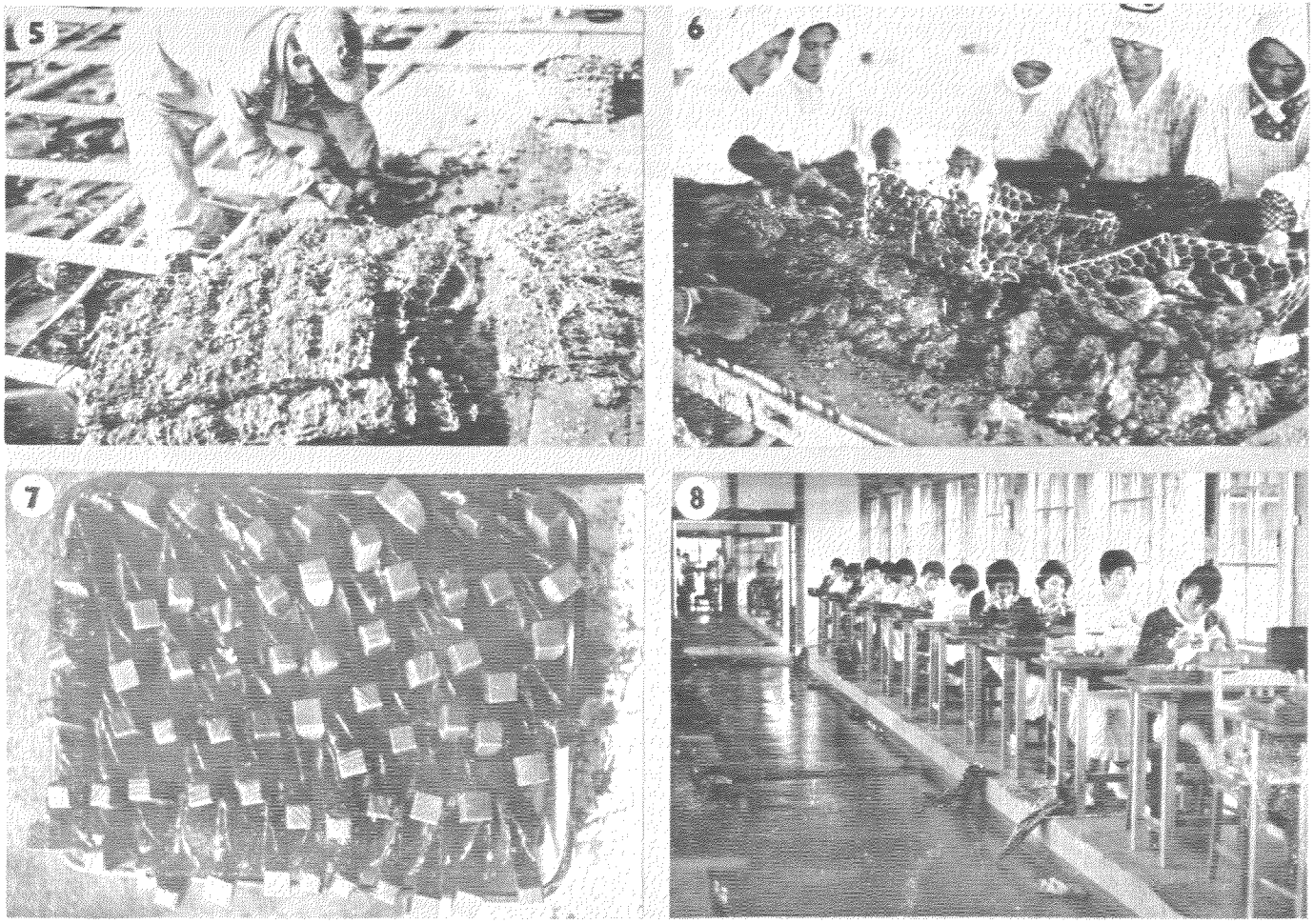
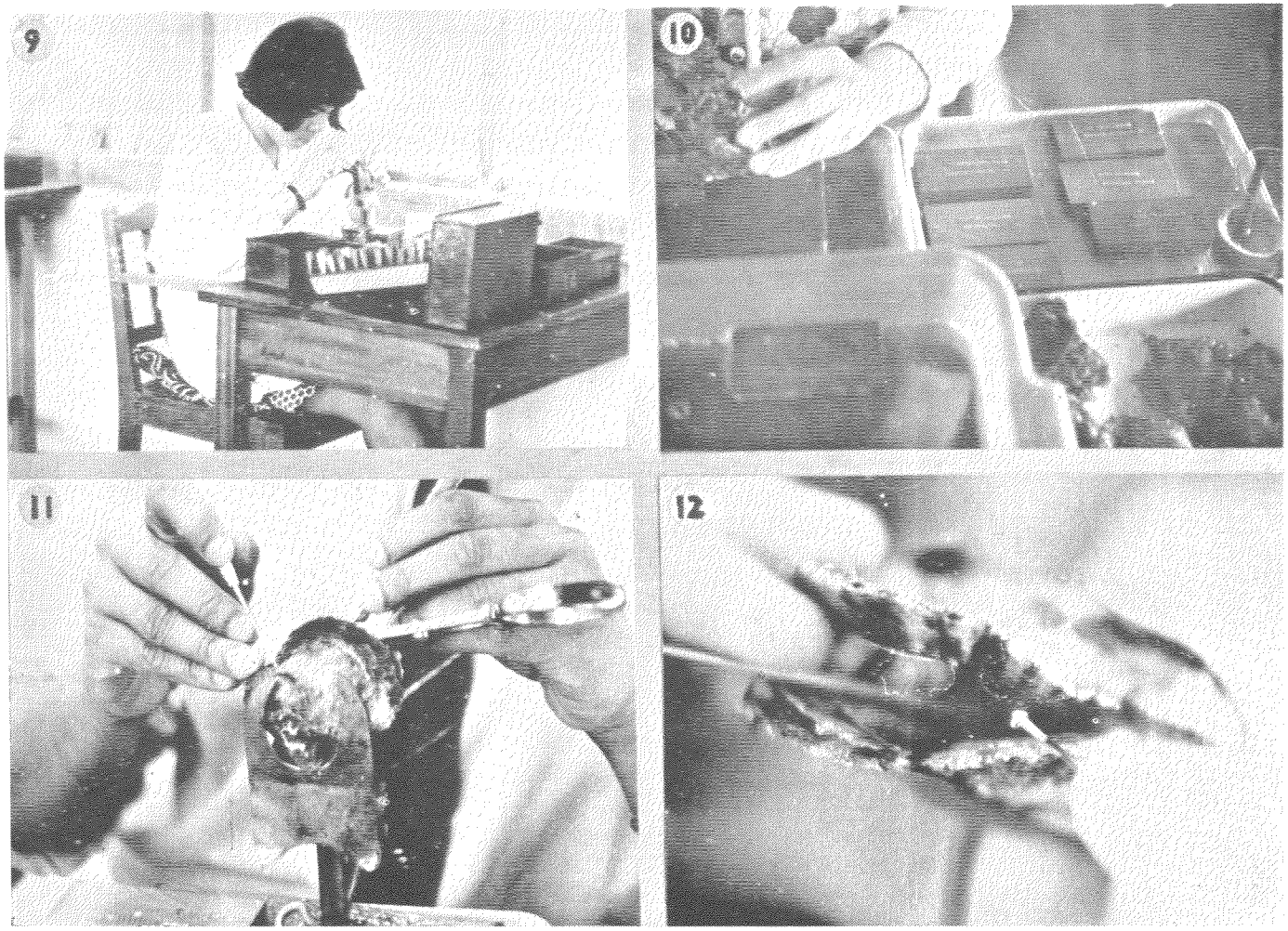


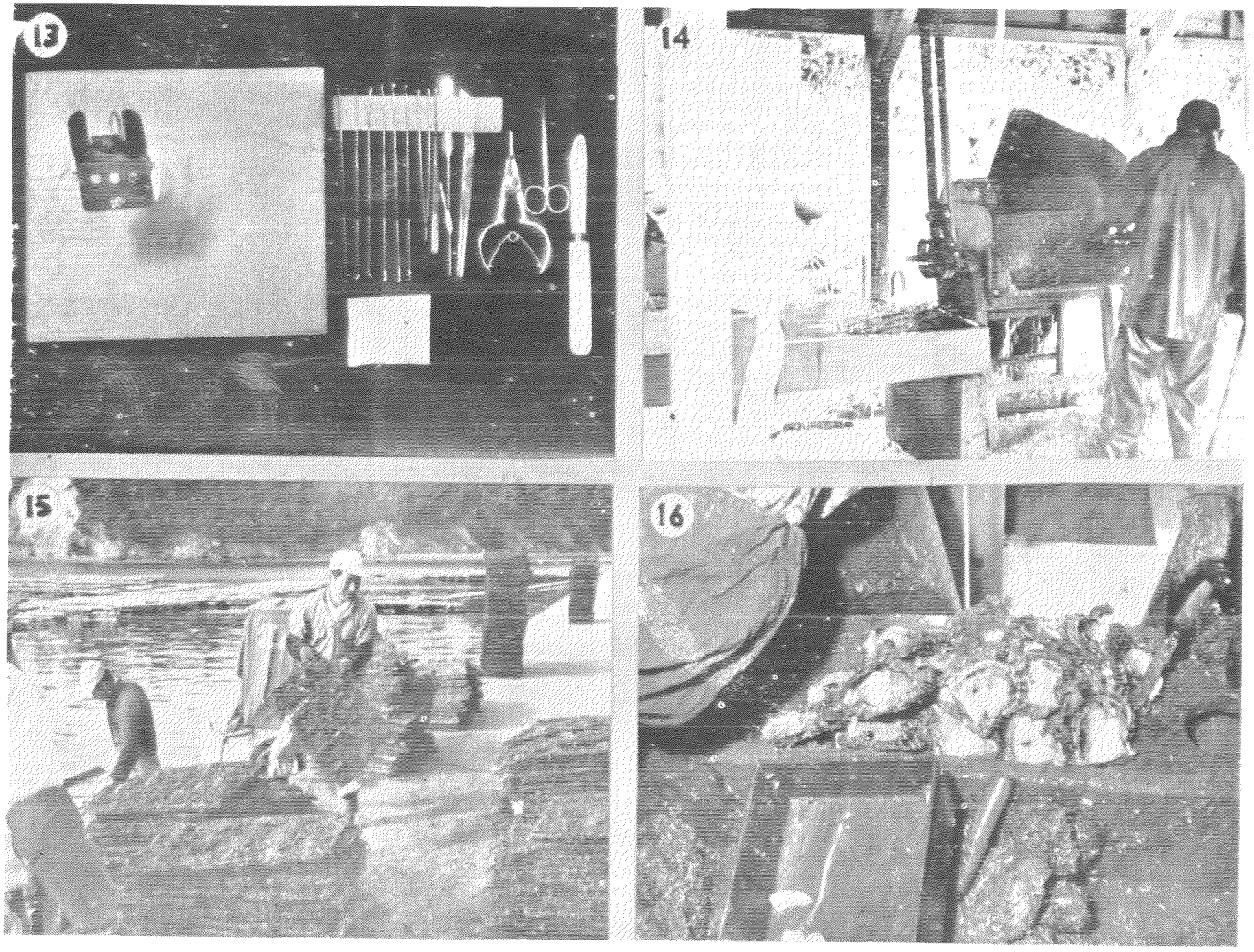
FIGS. 1–4. Pearl culture in Japan. 1. Aerial view of the pearl culture farms in the Aego Bay. 2. Wooden rafts. 3. Synthetic rafts. 4. Pearl oyster net with oysters arranged.



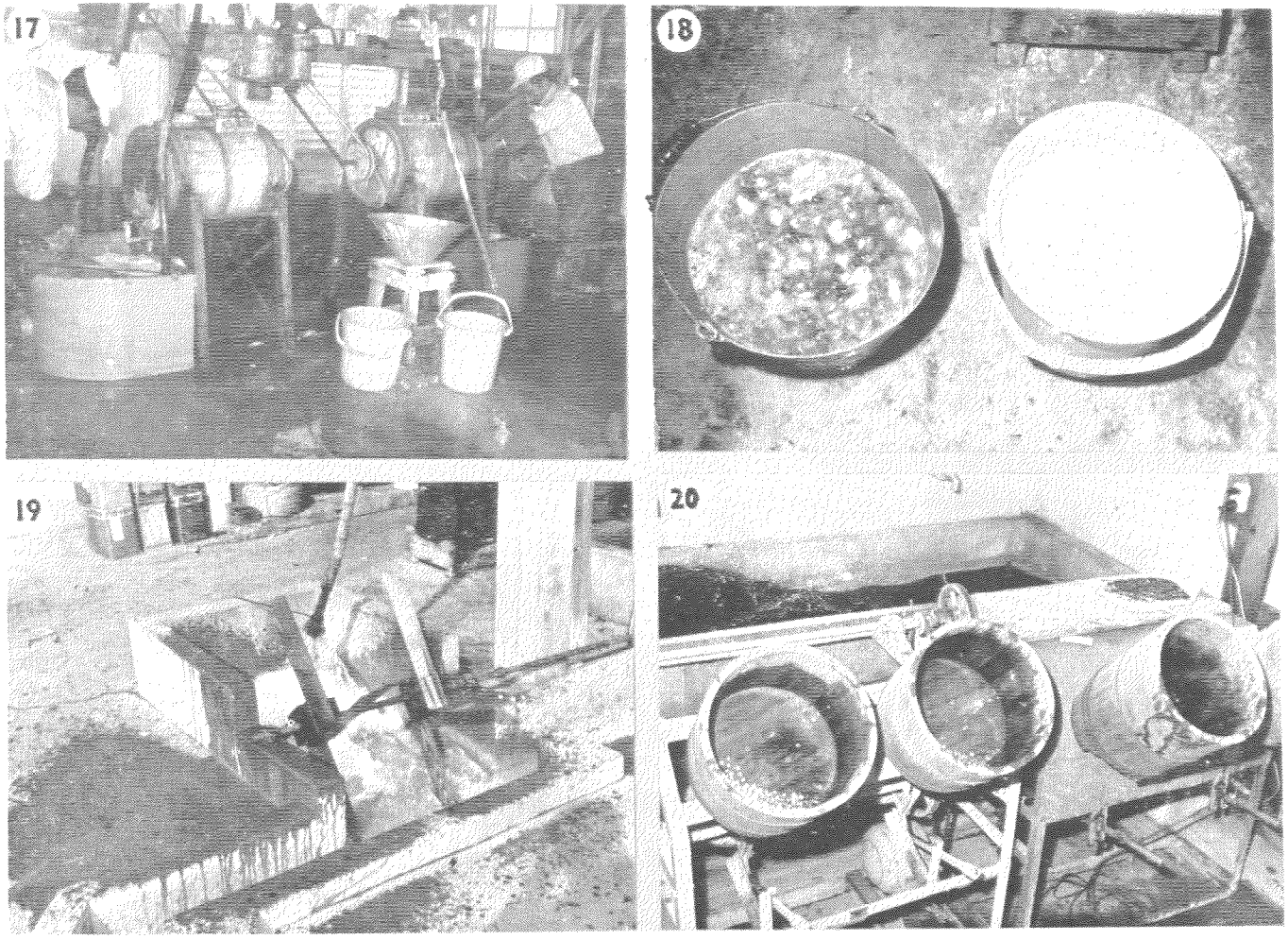
FIGS. 5–8. Pearl culture in Japan (*continued*). 5. Lifting the pearl oyster nets for cleaning. 6. Cleaning the oysters. 7. Pearl oysters prepared for the operation. 8. Nucleus implantation laboratory.



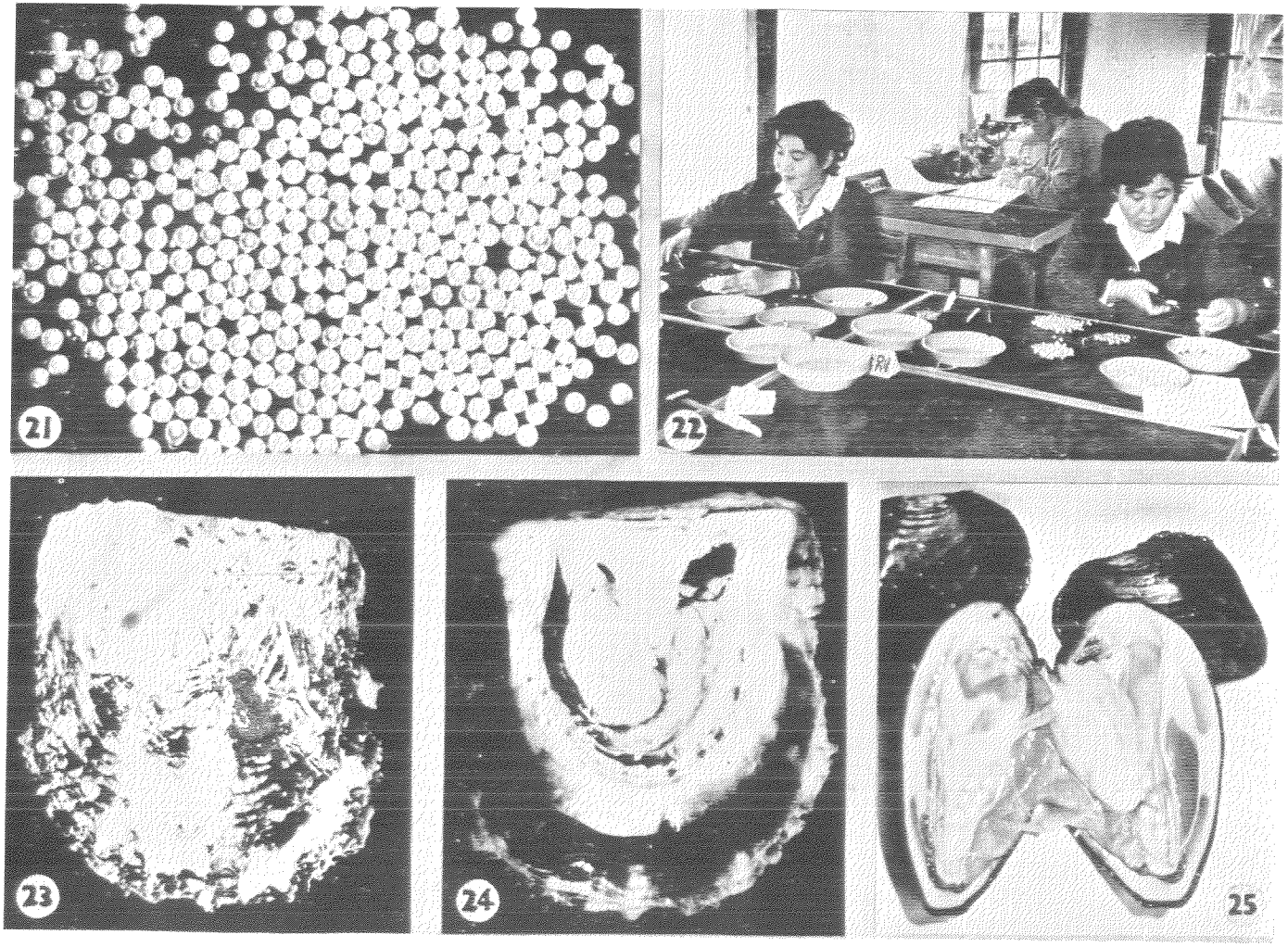
FIGS. 9–12. Pearl culture in Japan (*continued*). 9. Technician at operation. 10. Preparation of mantle pieces for grafting. 11. Position of the oyster on the stand at operation. 12. Mantle piece insertion.



FIGS. 13–16. Pearl culture in Japan (*continued*). 13. Tools used in operation. 14. Material repair shed. 15. Gathering pearl oyster nets for pearl collection. 16. Shucking the meat of the oysters.



FIGS. 17–20. Pearl culture in Japan (*continued*). 17. Revolving drums for separating pearls. 18. Oyster meat in slack lime. 19. Washing pearls with neutral soap water. 20. Collecting cultured pearls.



FIGS. 21–25. Pearl culture in Japan (*continued*). 21. Pearls collected. 22. Sorting of pearls. 23. Japanese pearl oyster *Pinctada martensii*, outside view. 24. Oyster with cultured pearls *in situ*. 25. Japanese freshwater mussel *Hyriopsis schlegeli* from Lake Biwa with cultured pearls *in situ*.

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