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REPORT OF THE RESEARCH ON THE POSSIBILITY OF MARICULTURE IN SRI LANKA

JAPAN INTERNATIONAL COOPERATION AGENCY

Tokyo, Japan

March, 1975

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Foreword

The Japan International Cooperation Agency has the pleasure of presenting the report of research on the possibility of mariculture in Sri Lanka, by Prof. Yutaka Uno and Dr. Ryogo Yuki who were dispatched under the Colombo Plan to Sri Lanka by the Overseas Technical Cooperation Agency (the present Japan International Cooperation Agency) at the request of the Government of Sri Lanka to the Government of Japan.

The experts stayed in Sri Lanka from March 14 to March 31, 1974 and successfully completed the research on fisheries in lagoons and possibility of mariculture in these waters in the country, including discussions and interviews with the authorities concerned, and collection of information and data with whole-hearted cooperation of the counterpart personnel of the Government of Sri Lanka.

Finally, on behalf of the Japan International Cooperation Agency, I wish to express my sincere gratitude to the Government of Sri Lanka for the generous cooperation and assistance rendered to the experts during their stay in the country.

March, 1975

Ushimaro Okuno

Ushimaro Okuno
Director, Expert Assignment Department
Japan International Cooperation Agency

- C O N T E N T S -

Research on the Possibility of Mariculture in Sri Lanka

Prof. Yutaka Uno,
Tokyo University of Fisheries

Dr. Ryogo Yuki, Director,
Mariculture Center of Hokkaido, Japan

Preface

Research on fisheries business in lagoons in Sri Lanka was undertaken from March 14 to March 31, 1974, at the request of OTCA, and the possibility was studied on the mariculture in these water basins. The research was carried out by the following members.

Japan:

Professor Yutaka Uno, Tokyo University of Fisheries
Dr. Ryogo Yuki, Director, Mariculture Center of Hokkaido.

Sri Lanka:

Mr. E. G. Gunewardena, Secretary of Ministry of Fisheries
Dr. A. S. Mendis, Fisheries Research Station
Dr. T. P. Gunewardena ditto
Dr. G. H. P. De Bruin ditto
Mr. J. J. Grero ditto
Mr. J. Sripathy, Brackishwater Fisheries Station, Negombo

The research was performed in conformity with the schedule described in Table 1 and Fig. 1 by the guidance of Dr. Gunewardena, Dr. De Bruin, Mr. Grero and Mr. Sripathy of Sri Lanka. Concerning the previous arrangement with the researchers of Sri Lanka, fisheries statistics as well as the fisheries affairs, many informations were obtained from Mr. K. Inoue, fisheries statistician of FAO. We express our sincere gratitude herewith for his kind assistance.

Although the period of research this time was a limited one, the research covered almost all of lagoons and estuaries except the south-eastern shores of

Table 1. Research sites in Sri Lanka

Item / Location	Research site	Date	Remarks
Panadula and Kalutara	Lunawa Lagoon, Bolgoda Lake Lalutara and Bentota ganga	Mar. 17, 1974	anguilla and prawn fisheries
Colombo	St. John's Fishmarket	Mar. 18	sampling
Negombo	Brackishwater Fisheries Stn., Pitipana and Negombo Lagoon	Mar. 18	hydrological and biological observations
Chilaw, Puttalam and Kalpitiya	Chilaw fishmarket and Puttalam Lagoon	Mar. 19-20	sampling and hydrological obs.
Trincomalee	Inner harbour, Koddiyar Bay and Lake Tamblegam	Mar. 20-21	hydrol., obs. snorkel diving and sampling
Mullaittivu and Kokkilai	Nanthi Kadal and Kokkilai Lagoon	Mar. 22	hydrol., biol. obs. and prawn fisheries
Mannar	Silavatturai fishing centre and offshore Kallar	Mar. 23	hydrol. obs. and snorkel diving
Jaffna and Delft	Kalundai salterns, Cey-Nor Development Project and Delft channel	Mar. 24-26	sampling hydrol., biol. obs. snorkel diving
Kalutara	Bentota Bridge	Mar. 27	hydrol. obs. and diving
Matra and Hambantota	Rekawa Kalapuwa Malala Lewaya	Mar. 28	hydrol. and biol. obs.
Colombo	St. John's fishmarket	Mar. 30	sampling

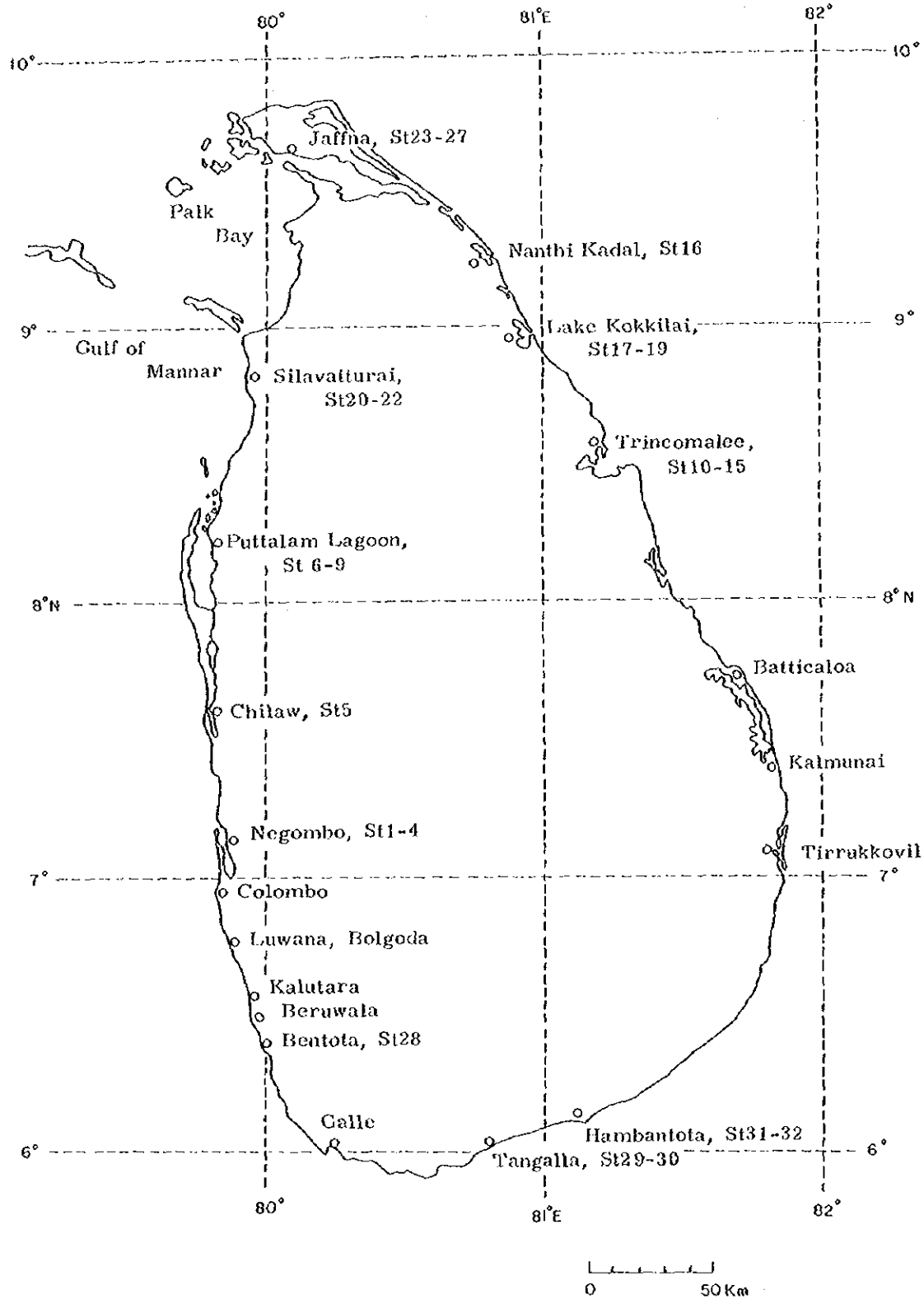


Fig. 1. Showing the research sites in Sri Lanka

Sri Lanka. As is stated in Figure 1, research on fishing products at 32 points, as well as the measurement of water depth, water temperature, salinity, specific gravity, pH value, dissolved oxygen content was performed, and at the same time, survey of bottom condition and fauna and flora was effected by means of snorkel diving.

I . Result

1. Negombo Lagoon (Fig. 2)

This lagoon is one with water area of 32.95 km^2, and the deepest portion thereof is located at the bottom of lagoon, where the water depth is 6 feet. The bottom of the lagoon is, as shown in Fig. 3, simple in form and, on the whole, it is a tray-shaped lagoon. The soil of almost all bottom portions is sandy mud or mud itself except that the entrance part is sand. Research was made at four points shown on Fig. 2. St 1 on the open sea at the entrance of lagoon consists of sand bottom where the sea-weed or other animal or plants are scarce, and only the fish-groups of Abudefduf saxatilis and Xesurus scalprum may be observed in the piled-up stones (Fig. 4-1. 2.). St 2 on the inner side of Pitipana Bridge consists of muddy sand bottom, where Zostera form vegetations. The area from St 1 to St 2 is the entrance channel, and is more shallow than one meter excluding the central part of water channel. In this shallow area, brushpiles are set as is shown in Fig. 4, and small prawns are caught (Fig. 4-3).

Brush pile is the round shelter composed of brush and piles, approximately 10 m in diameter, where the juvenile or adolescent Penaeid prawn gathers during the daytime. Once in a fortnight, this shelter is surrounded with the net to catch the prawns. In March, Penaeus indicus of 10 cm or so in body length are caught. In St 2 - St 4, the Zostera colonies are spotted. At St 4, Halophylla are the dominant species, exhibiting that it is the water area where the influence of fresh water is predominant. The result of hydrological observation is as shown in Table 2.

Table 2. The oceanographical observations on Negombo Lagoon

St	Time	At. °C	Dp, m	WT. °C	sp. gr.	Salinity	pH	O_2	Saturation
					(σ=15.0)	°/ooCl		ppm	%
1	11:35	32.5	S *	31.0	18.75	14.15	8.10	6.3	92.1
			B 2.5	30.7	26.80	19.96	8.25	6.3	98.9
2	12:10	34.1	S	31.0	16.88	12.79	7.50	5.5	79.4
			B 2.5	30.7	17.47	13.22	7.60	6.4	92.4
3	13:30	33.2	S	31.8	14.82	11.30	7.70	6.5	92.3
			B 1.2	32.1	18.10	13.68	7.70	6.5	94.4
4	16:40	32.2	S	33.5	12.72	9.78	5.90	11.0	SS
			B 1.3	33.2	16.24	12.33	6.10	12.5	SS

* S, surface; B, bottom.

At the four stations, the water temperature changes within the range of 30.7 - 33.5°C, showing almost no difference between the upper and the lower strata.

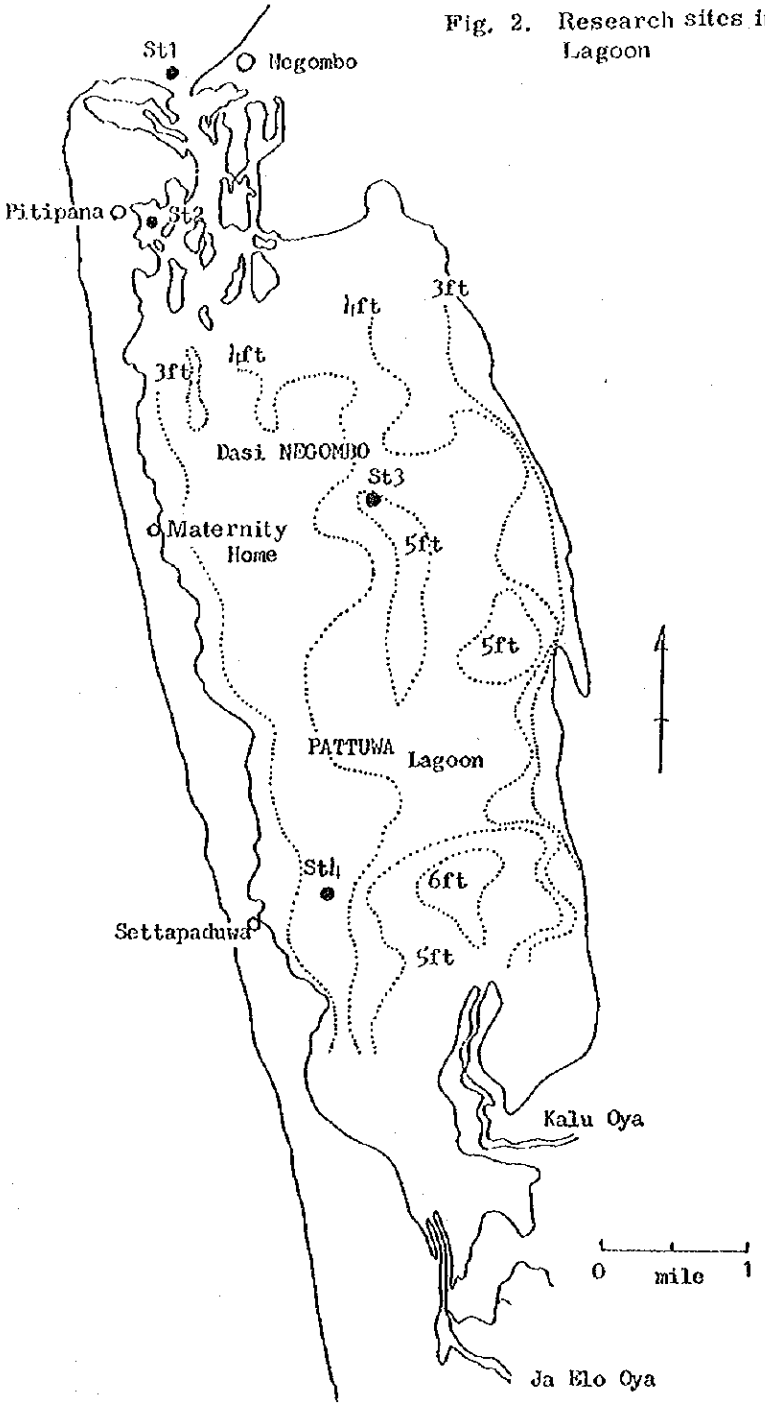


Fig. 2. Research sites in Negombo Lagoon

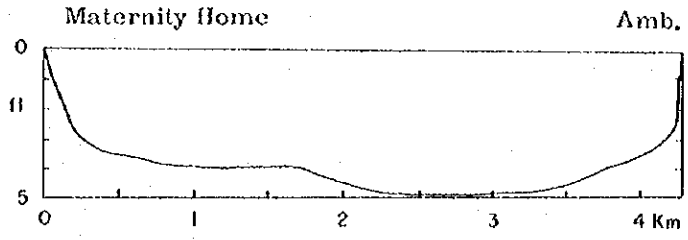


Fig. 3. Bottom profile of Negombo Lagoon, Maternity-Amb.

On the contrary, salinity value falls down from St 1 which is located near the open sea, to the inner part of the lagoon. At St 1, a big difference is seen between the upper and lower strata, the former stratum being 14.15‰ Cl, and the lower, 19.96‰ Cl. From this fact, it is to be known that, because of the clear presence of salinocline in even shallow waters of depth of 2.5 m, no vertical mingling of water mass is effected. The difference of salinity in vertical strata exhibits lesser inclination as the lagoon is reached more inside thereof. In each station, high salinity water occupies the lower part.

As the species suitable for aquaculture in this lagoon, there are prawns, crab, milkfish and mugil. Of these kinds, prawns are the most productive, embracing abundant kinds. As for the kinds, there are Penaeus semisulcatus, Penaeus monodon, Penaeus indicus, Metapenaeus dobsoni and Metapenaeus elegans; these kinds have their habitats respectively suited for them. It is said that Penaeus indicus makes the entire area of lagoon as their habitat; Penaeus monodon, deep water area; and Penaeus semisulcatus, shallow waters; but the details thereof are not clear.

These prawns move into the open in March and April after their full growth. During this period, large adults are caught with gill net at the mouth areas of lagoon. De Bruin (1971), on the basis of seasonal change of prawn fishing amount in lagoon, infers that Metapenaeus dobsoni, Penaeus semisulcatus, Penaeus indicus also move seasonally. With these prawns, similarly as Penaeus japonicus (Yatsuyanagi et al, 1955), Penaeus plebejus (Dakin, 1958), Penaeus duorarum (Hughes, 1967), Metapenaeus macleayi (Ruello, 1973), their hatched larvae oviposited in the open sea gather in the lagoon or estuary, and after growing in these water area, again move out into open sea, where they grow fully. When considering the production of prawns in the lagoons of Sri Lanka, the clarification of life history of each kind in relation to their habitat poses the fundamental problem.

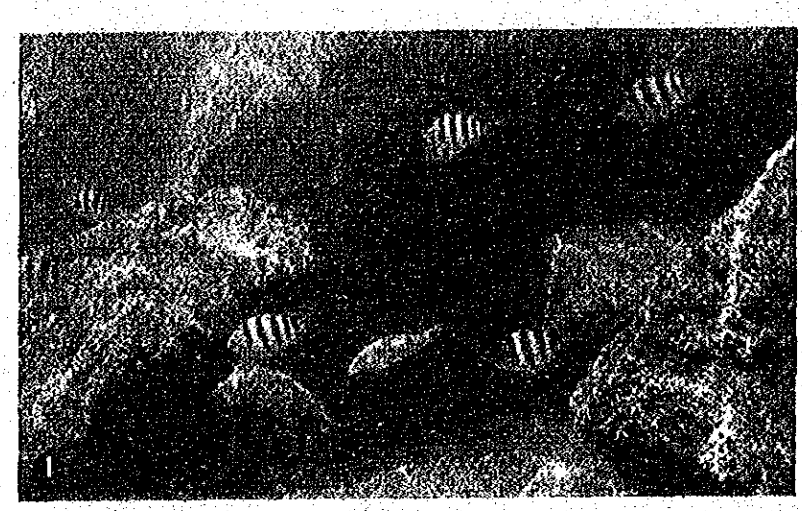
As for crab, mud crab (Scylla serrata) is the chief kind, and is caught with baited traps principally in the lagoon; this kind is large in size and has delicious

taste. Since the growth thereof is considered to be very quick, it is considered a creature suitable for future aquaculture. The clarification of its life history is indispensable.

As for fish, Chanos chanos and Mugil cephalus are the major kinds. The importance of the former was already pointed out by Pillai (1965). Further, Ramanathan (1969) reported that, in the mouth areas of the lagoon, an abundance of milkfish fry could be caught in mud pools during March-May. Accordingly, how to produce in the lagoon on a large scale would be the problem of study in the future.

Although the milkfish live chiefly on algae, it is widely known that they are the so-called bio-compound, and in such areas as Taiwan and Indonesia, pond culture of a high standard is carried out (Ling, 1962). There are many points which remain unclarified concerning the ecology of parent fish, especially breeding, migration and feeding habits. According to Kafukuo (1974, personal information), the distribution of parent fish of this kind covers extremely extensive area such as Hainan Island; Kagoshima (Japan), Mexico, Australia, Taiwan, Sri Lanka and Kenya. Because its fry may be captured in natural water area, and being herbivora and its growth is fast, it is drawing world-wide attention as a kind suitable for pond culture.

In Sri Lanka, its fry is caught on Mannar, Puttalam and Negombo lagoons, and, as adult fish shown in Fig. 5 is caught, it is a good location for carrying out the fundamental study of its ecology chiefly on the oviposition period.



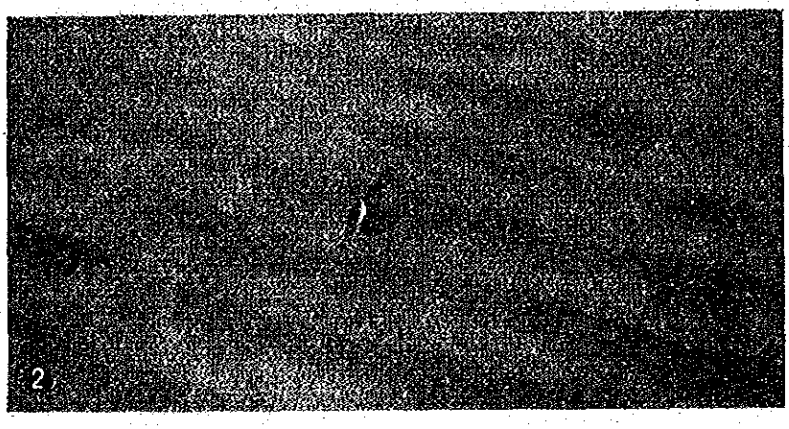


Fig. 4 Underwater photographs of Negombo Lagoon

1. shelter of crushed rock
2. wave sand at St 1
3. brush pile shelter for prawns

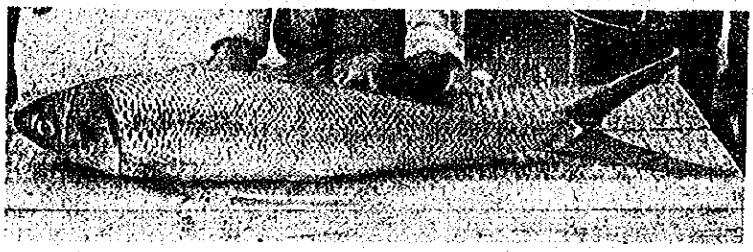


Fig. 5 Adult of Milk fish, Chanos chanos at Tila

2. Puttalam Lagoon (Fig. 6)

This is a large-size lagoon with water surface area of 229.57 km^2, leading to Dutch Bay (84.74 km^2) and Portugal Bay (49.50 km^2) by a channel of which breadth is 0.2 mile. As is indicated in Fig. 6, observation was made at St 6, 7, and 8 (mouth areas of the lagoon) and at St. 9 (interior of the lagoon). The result is as

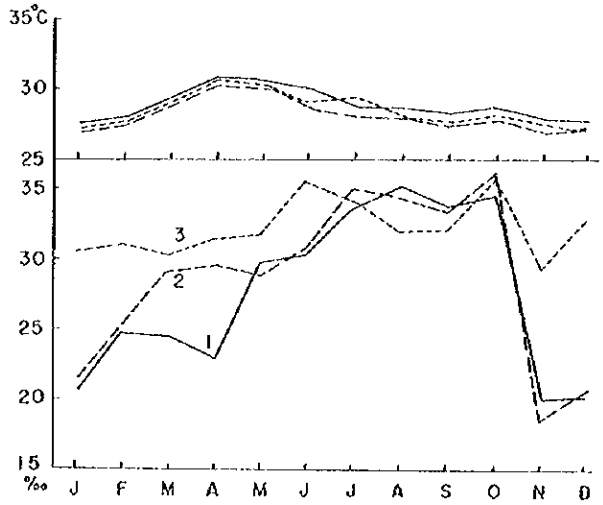


Fig. 7 Monthly surface temperature and salinity at three locations on Puttalam Lagoon from June 1960 to May 1961.
1, 2 and 3 represent Puttalam Lagoon, Dutch Bay and Portugal Bay towards Pallugaturai, respectively. (Durairatnam, 1963).

shown in Appendix I. The water temperature at those four points changed between 29.3 - 30.9°C, with scarcely any difference between the upper and lower strata. The salinity showed difference ranging from 22.70 - 24.43‰Cl at St 6, 7 and 8, with hardly any difference between the upper and lower strata; but at St 9 in the innermost part of bay, sea water of high saline concentration is found to exist in the lower stratum. Dissolved oxygen content shows saturated condition at the mouth area of lagoon, while at the innermost part of bay, low value is observed

The deepest part is 4 to 5 m near St. 7, and the bottom soil is almost sandy mud. More vegetation of Zostera is seen in shallow water areas. Owing to lack of detailed data on hydrological survey of lagoon, the topography of lagoon bottom is not available, prohibiting the calculation of fundamental movements of lagoon waters by which the productive potential of lagoon may be inferred.

There is the detailed report by Durairatnam (1963) on the hydrological conditions of sea areas including Puttalam Lagoon, Dutch Bay and Portugal Bay.

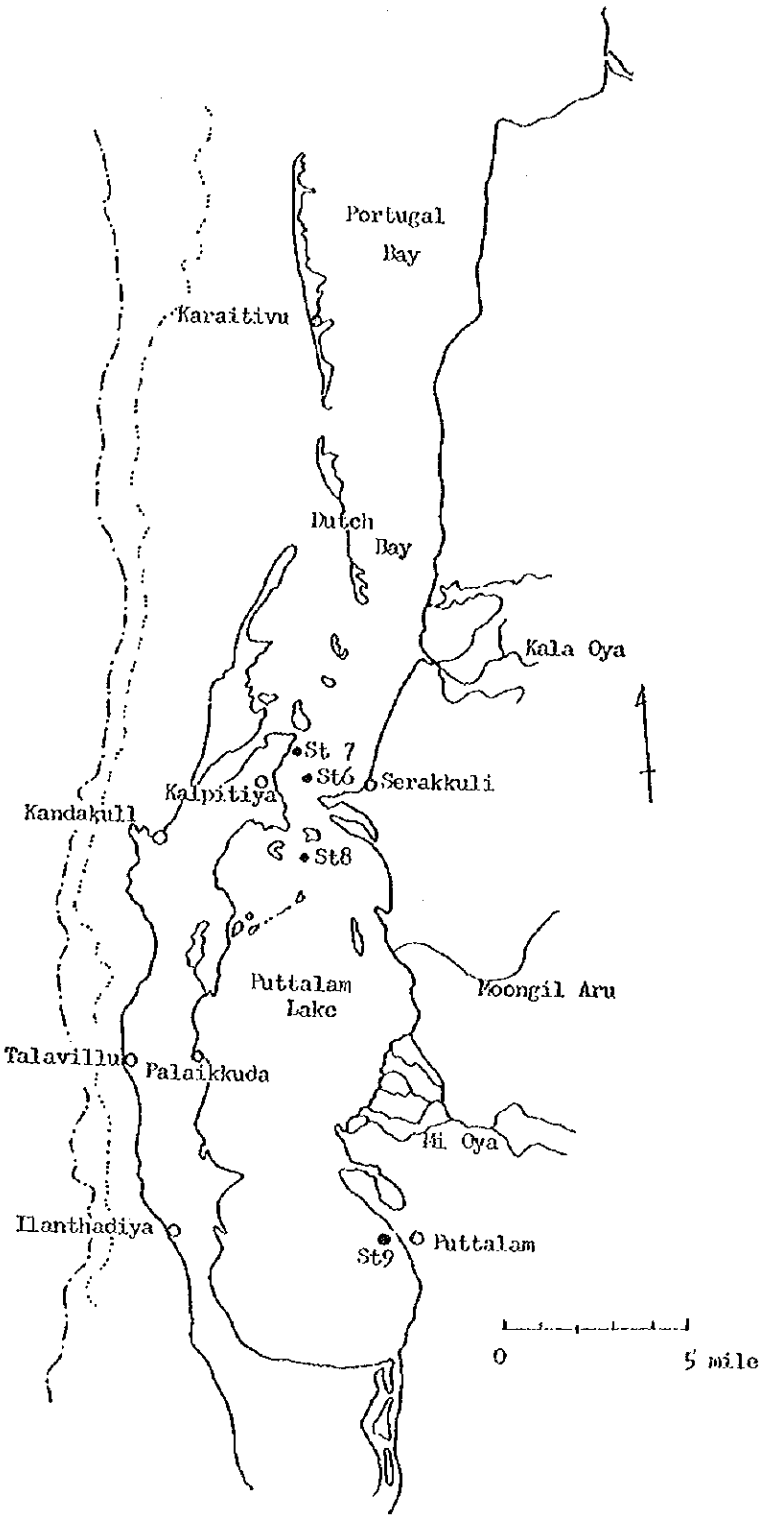


Fig. 6. A map of Puttalam Lagoon showing the research sites

Monthly variation of the temperature and salinity of these sea areas is as shown in Fig. 7. These 3 sea areas exhibit nearly the same changes, the peak of water temperature in April being 30.4 - 30.8°C, and after that, the temperature falls down gradually until 27.2 - 27.8°C in the period of October through January. The salinity begins to rise in Dutch Bay and Portugal Bay from March-April, showing the maximum value during May-October of south-west monsoon months, and shows the lowest value during November to February period which is the north-west monsoon season. It is said that the highest value during the period of May and October is because during this season, the south-west wind blows violently, the open sea water from the south of Arabian Sea running into the lagoon, and the evaporation of sea water is the most abundant. The plankton amount shows the maximum value twice, in May-June and October. This is due to the nutrient salts brought from Kal Aru and Pomparippu Aru. Of the phytoplanktons, diatom which is the prey of bivalves is profusely found. As the result, many favourable aquaculture grounds for oyster raising are found in this sea area.

Of shellfish, lobsters, prawns, and mud crabs live in abundance, and good fishing ground are found for lobster in Ilanthadiya region, prawns in Serakkuli region and mud crabs in Palaikkuda region, respectively. The fry of Chanos chanos may be caught, in great abundance (Ramanatham, 1969).

Puttalam region is a favourable sea area which may be used as aquaculture ground, including the ocean portion. It is necessary, simultaneously with the ecological survey on the above-mentioned marine animals, to perform the oceanographical survey of the lagoon, thereby to establish the comprehensive production plan. Especially, in view of the extensive area of this water area as compared with Negombo region, the production by means of large scale and efficient productive techniques, not the existing small scale cultivation, may be expected.

3. Trincomalee Region (Fig. 8)

This region consists of three water areas of Inner harbour, Lake Tamblegam and Koddiyar Bay, and faces the west shores of Sri Lanka Island.

As is stated in Fig. 7, survey was made *in Cod Bay (St 10), Malay Cove* (St 11), Great Sober Is. (St 12), Lake Tamblegam of Periathumunai (St 14), Gangal in the inner part of Koddiyar Bay (St 15) and Coral Cove (St 13) along the shore of the Indian Ocean.

St 10, St 11 and St 12 are sea areas situated inside the Inner harbour, where the inflow of rivers is scarce, the salinity concentration is high and with abundance of oceanic organisms. The sea-bottom of St 10 (Fig. 9-1) is rock bed where small rolling stones are scattered, and where the big colony of sea urchin, Diadema setosum is found. On the bottom of rock bed, a great many oyster shell remains are to be seen, and it is considered that there was a big development of oyster. These areas are said to be the site to collect the tropical fish for enjoyment such as Thalassoma and Abudefduf sp. St 11 is located at the entrance of Malay Cove, and is the sea area where the shore is deep. The place is attended with sharp slope, where big rolling stones are abundant; sea bottom where water is more deep than three meters is the sand bottom. Crassostrea sp. are sticking profusely to the big size rolling stones. In this sea area, lion fish, Pterois sp. Pinna, Spondylus and Lopha and the like are found in great abundance, and big size fish are also observed. Divers catch fish in this sea area by spear fishing.

St 12 is located at the entrance of Sober Creek, and the sea-bottom is rock. To the rock bottom in the water depth of 4 meters, a great many of Crassostrea sp. are settled (Fig. 9-2, 3). Massive corals, Porites sp. are scattered on the sea bottom which is 4 meters or more deep. The French Pass on the west side of Great Sober Island is the point where it connects with Malay Cove, and because of the location of water pipe line and causeway, no thoroughfare is offered to vessels. Therefore, the whole sea area may be available as oyster culture bed .

St 14 is at the mouth areas of Lake Tamblegam, and its salinity at the time of survey was 19.5‰Cl, but the lake was, on the whole, shallow, being 2-3 ft. only. It is considered that, in the rainy season of October-December, the water therein will almost entirely become fresh water. When the change of plankton in Kinnyai Channel at mouth area of this lake is studied qualitatively, green algae increases during April and July, reaching the maximum in August. It decreases from October-December, and again begins to increase from January. Accordingly, the water colour changes from green in April-July, to light blue in October-December.

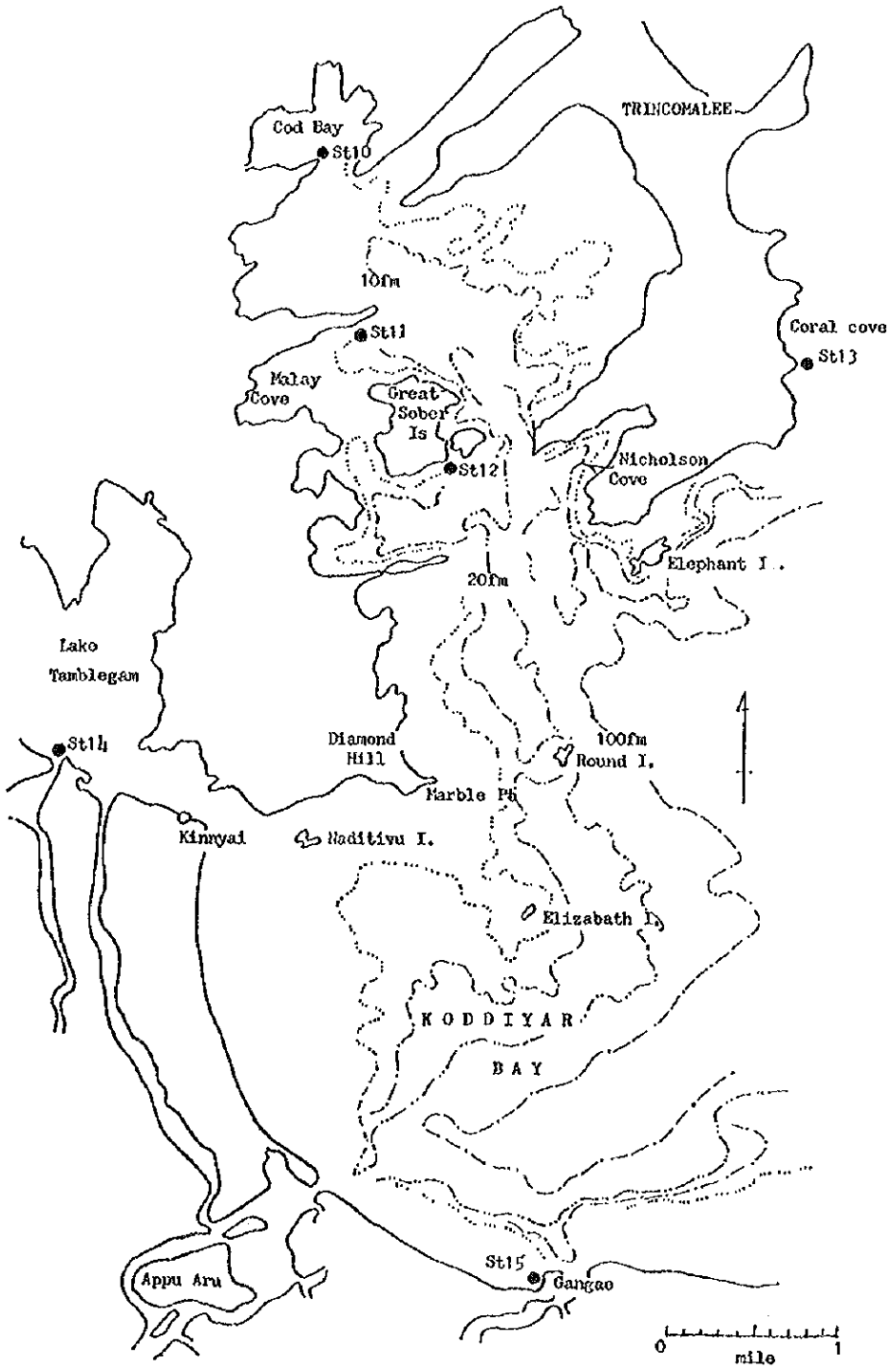


Fig. 8. A map of Trincomalee region showing the research sites

In this sea area, window pane oyster, Placuna placenta was raised profusely, and from 1953 - 1955, there was a catch of 22 - 51 million of them annually. According to Pillai (1965), oyster beds were overwhelmingly devastated by the flood in 1957, and as the result of inundation, brown coloured silt covered the bed, by which death of population in bulk occurred, and there was no spat-fall at all until 1959. At the time of the survey by the authors, no harvest could be made from these oysters, and only the shell remains of oysters which died in bulk in 1957 were seen piled on land (Fig. 10). Needless to say, this shell is the fisheries resources which could be exported as the material for window pane in Philippines, and the more detailed biological survey thereof is required for propagating this species, and, first of all, the detailed research of standing crop of population in this sea area should be commenced.

The bottom area (St 15) of Koddiyar Bay is the major production area of Gracilaria confervoides which is the material of agar-agar. The ecological survey of this sea-weed in this sea area is performed by Durairatnam (1965). In case of this species, sea-weed bed is located at sand bank as far as 4 feet of water depth and usually, grows more luxuriantly over 1.5 fm or more. Its fertility season is from June-August, and during this period, tetrasporangia and carposorangia are formulated. The September-October period witnesses the maximum growth rate, and plants are either buried in the sand, or obliterated during north-east monsoon period. Those cast upon the shore during this season are gathered and dried. Of the material collected during June-October red ones are of superior quality as the material for agar-agar. The months during which maximum yield of agar-agar from plants is seen is from September to October.

Since Appu Aru, Koddiyar Aru and Valvachar Aru empty themselves into Koddiyar Bay, the nutrient salts are included in abundance and this causes the seaweeds to grow well. Though the sea area with water depth of 4 meters or less is considered favourable ground for oyster culture beds as well, more detailed survey is deemed necessary because of possible damage which may be inflicted upon facilities for cultivation in north-east monsoon period.

The sea area fronting to the Indian Ocean outside Trincomalee Bay has high transparency, with full salinity all the year round. St 13, Coral Cove presents its representative seabottom spectacle of the open sea character, and there live Acanthurus, Lutianus, Cryptotomus, Pomacentridae and many other rock fish (Fig. 9B).

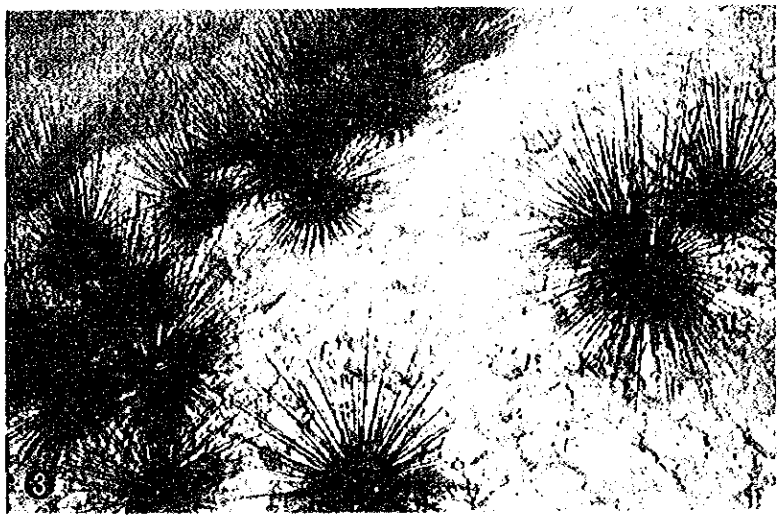


Fig. 9-A Underwater photographs in Trincomalee region

1 Colony of sea-urchin Diadema setosum on the bottom

at St 10, 2, 3 and Crassostrea sp at St 12

Fig. 9-B Underwater photographs in Trincomalee region

4 School of fish Acanthurus triostegus and Caesio sp ?

5 Caesio sp and Abudefduf sexatilis

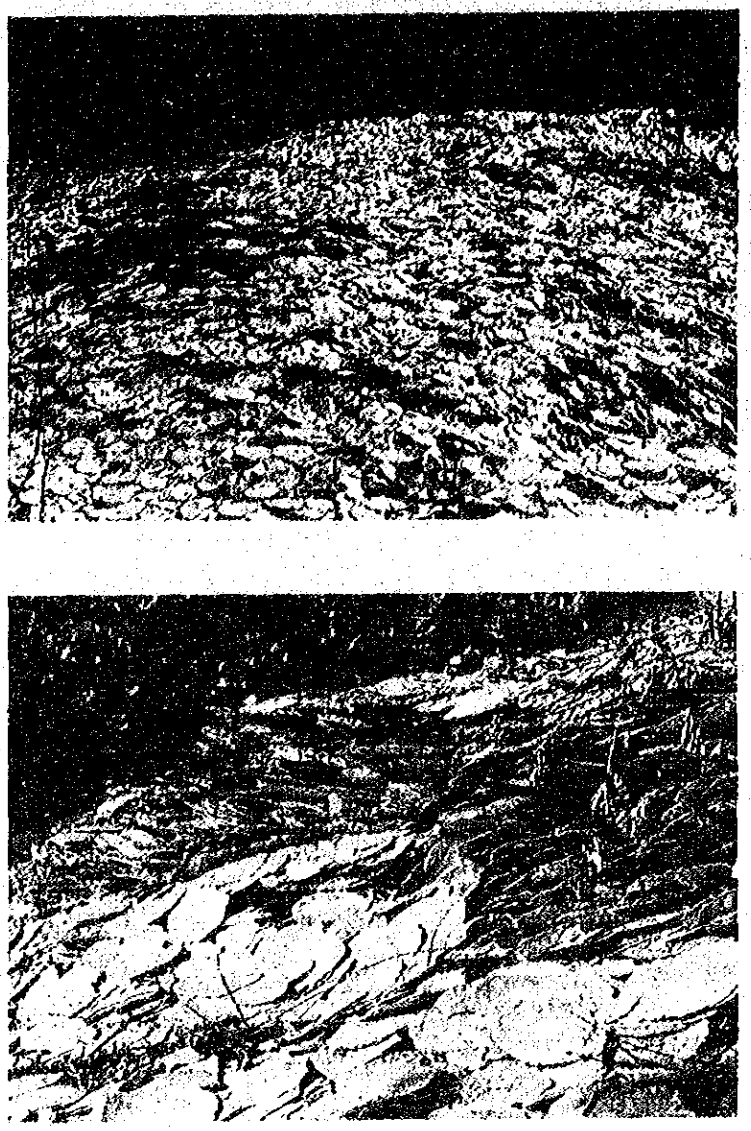


Fig. 10 Shell remains of window pane oyster Placuna placenta during the bulk

4. Sanctuary Lagoon Region (Fig. 11)

As is shown in Fig. 11, survey was made on Nanthi Kadal and Kokkilai lagoons. Nanthi Kadal lagoon connects with the open sea at Arichael district in the rainy season only. There is a bridge, shown in Fig. 12, on lagoon side of mouth areas, and at the point, the water depth is very shallow being 1 - 2 feet, and the flowing of salt water into the lagoon is extremely small. As the result, the water inside of the lake tends to become fresh water, and Telapia is increasing, while marine prawns are decreasing. Lake Kokkilai Lagoon, on the contrary, is connected with the open sea by a channel of 2.5 m in depth, 80 cm in width, and because sea water flows into the lagoon throughout the year, high salinity concentration of 17.89‰Cl is observed even at the center of the lagoon (St 19). During the monsoon period and also at the time of flood tide, silt suspends on the lagoon surface, and the water colour turns into brown. Except the monsoon season, the lagoon water is agitated and looks brown in colour only at the time of flood tide. The bottom soil consists of sand at the mouth of lagoon (St 17), rock at St 18, and mud at the center (St 19). On the rock bottom near St 18, there lives the spat of Crassostrea sp. in great abundance. Sea water flows into this lagoon all the year around, and the lagoon water is well agitated. As shown in Fig. 13-1, small fish of brackish water and sea water origin live there in multitudes, and also the producitivity of crabs and prawns that live in them is considerable. Migrant fishermen gather there for fishing during February and October, the number thereof being approximately 300, consisting of 175 households. Outside the lagoon, they fish tunas and dolphins, chiefly by means of gill net. Inside the lagoon, they fish during night penaeid prawns chiefly by such means as small size skated nets with wings and a cod end, cast net or by grabbing with fingers. This year, there was especially great many catch of prawns. The most favourable catch amounts to 100 lbs/day/person or thereabouts. As about 100 fishermen are engaged in fishing each night, it is estimated that there is 10,000 lbs of catch one night during the best prosperous season, but no detailed statistical data thereon are available.

In this district, there is Nanthi Kadal lagoon which scarcely opens to the open sea all the year round, and Kokkilai lagoon which opens to the open sea throughout the year, and the latter is the area of high productivity. Considering the life history of prawns, the fact that lagoon is connected with the open sea always has a significant meaning. Generally speaking, penacid prawn spawns in the open sea, and the hatched larvae move to lagoon area where salinity concentration is low, and after growing into juvenile, adolescent, subadult in the lagoon, again go out into open sea, become adult, and when fully grown-up, spawn (Burkenroad, 1934; Yatsuyanagi et al, 1955; Idyll et al, 1964; Kurata, 1972).

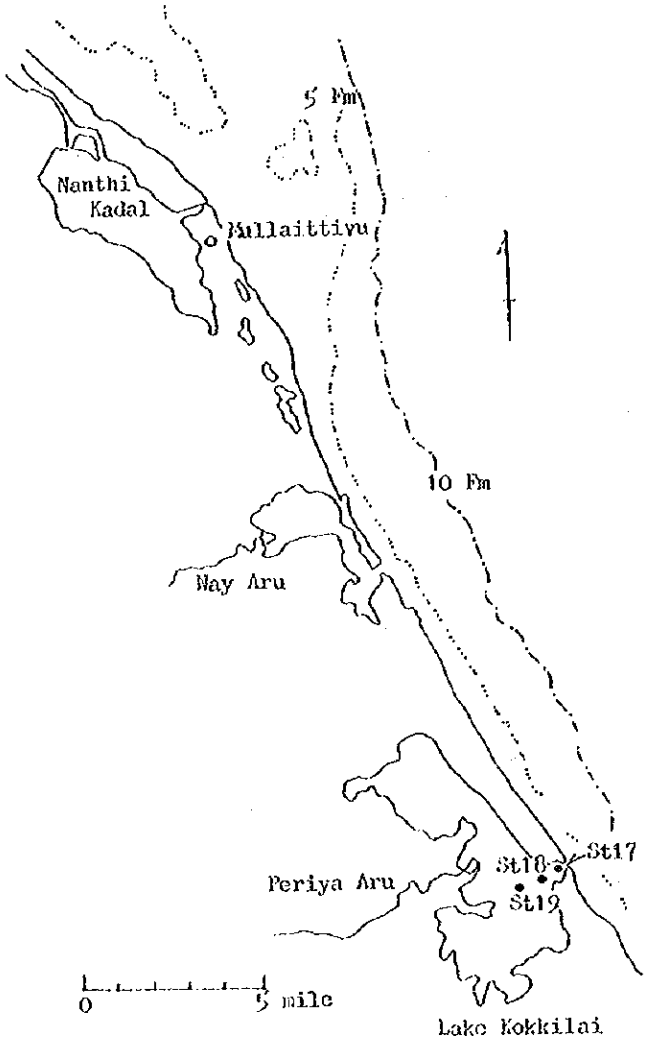


Fig. 11. A map of Mullaittivu and Kokkilai Lake, showing the research sites.

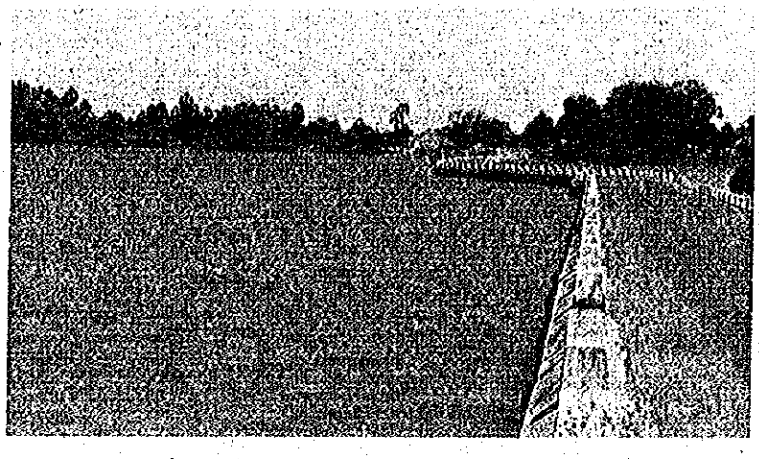
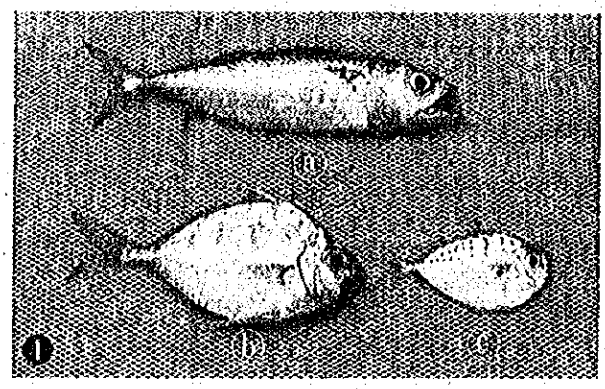


Fig. 12 The bridge throwing the channel in the mouth area of Nathi Kadal



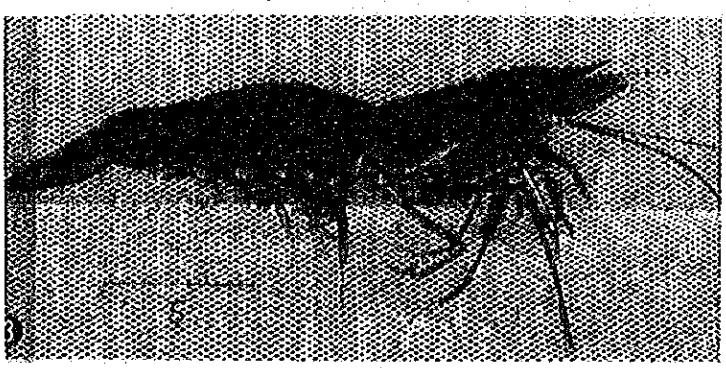


Fig. 13 Crab and prawn at Kokkilai lagoon

1a. Rake-gilled mackerel, Rastrelliger kanagurta

b. Trachinotus russelli

c. Slender barred pony fish, Secutor insidiator

2. Mud crab, Scylla serrata with a baited fish

3. Karuvandu issa Penaeus monodon

4. Cast-net for prawn

5. Selecting Karuvandu issa by size at fish market

The free connection of lagoon with the open sea insures the population recritment of prawns. On the other hand, tidal current, through agitating the water mass in the lagoon, improves the physio-chemical environmental conditions of prawns, giving them their habitats of favourable conditions. As the terms of raising the productivity of prawns in a lagoon, it is important to fix the mouth part of the lagoon, thereby enabling the flowing of the open sea water thereinto, and at the same time, to construct a creek within the lagoon, thereby to introduce sea water into the recess of the lagoon. It is considered that this is the fundamental problem for the development of prawn fisheries in lagoons of Sri Lanka.

5. Mannar Region (Fig. 14)

As is shown in Fig. 14, research was made at 2 points in Kal Aru estuary (St 20 and St 21) as well as offshore Kondachchi (St 22). The areas of St 20 and St 21 are the estuary where Kal Aru flows into, and, similarly as the bottom areas of Koddiyar Bay, Gracilaria lichenoides grow richly there (Durairatnam et al 1954; Fig. 15-1) and the areas also abound in spiny lobsters (Panulirus sp.). St 20 and 21 are sandy bottom mixed with shell remains as is shown in Fig. 15-1. and is dotted with rocks. Off the coast of Kondachchi, coral reef grows in profusion, and Montipora sp. is predominant (Fig. 15-2, 3). St 22 is a coral reef which is nearest to the beach, where live Porites sp., Acropora and Montipora. This sea area has high transparency, and nutrient salts are not so prevalent as in the case of shallow water. To the contrary, shallow water from Kallar to Silavatturai is rich in planktons, and, as stated before, sea-weeds grow luxuriantly there. It is considered that the location will serve as favourable nursery beds for pearl and oyster.

As for pearl oyster, Pinctada vulgaris, there has been good fish grounds from olden times around Gulf of Mannar, which had world-wide reputation. Unfortunately, we could not make a survey this time, but could study the samples kept at the Fisheries Research Station; it is a kind with close affinity with Japanese pearl oyster, Pinctada martensi in its size and morphology. It is considered that, using it as a material, application of Japanese pearl culture techniques may be possible. In regard to the population of this species, there are a number of reports. As for recent studies, there is a report by Sivalingam in 1961. This species had been caught in great abundance until 1925. In 1908, when the fishing there was at its height, as many as 125 boats gathered in these waters and caught oysters. With 1925 as the last year, pearl oyster fishing ceased to be engaged owing to the decrease of population. On the basis of population survey in 1955, such amount of population as to justify fishing was estimated, and in 1958, 4.5 million pieces of pearl oysters were caught by dredge fishery.

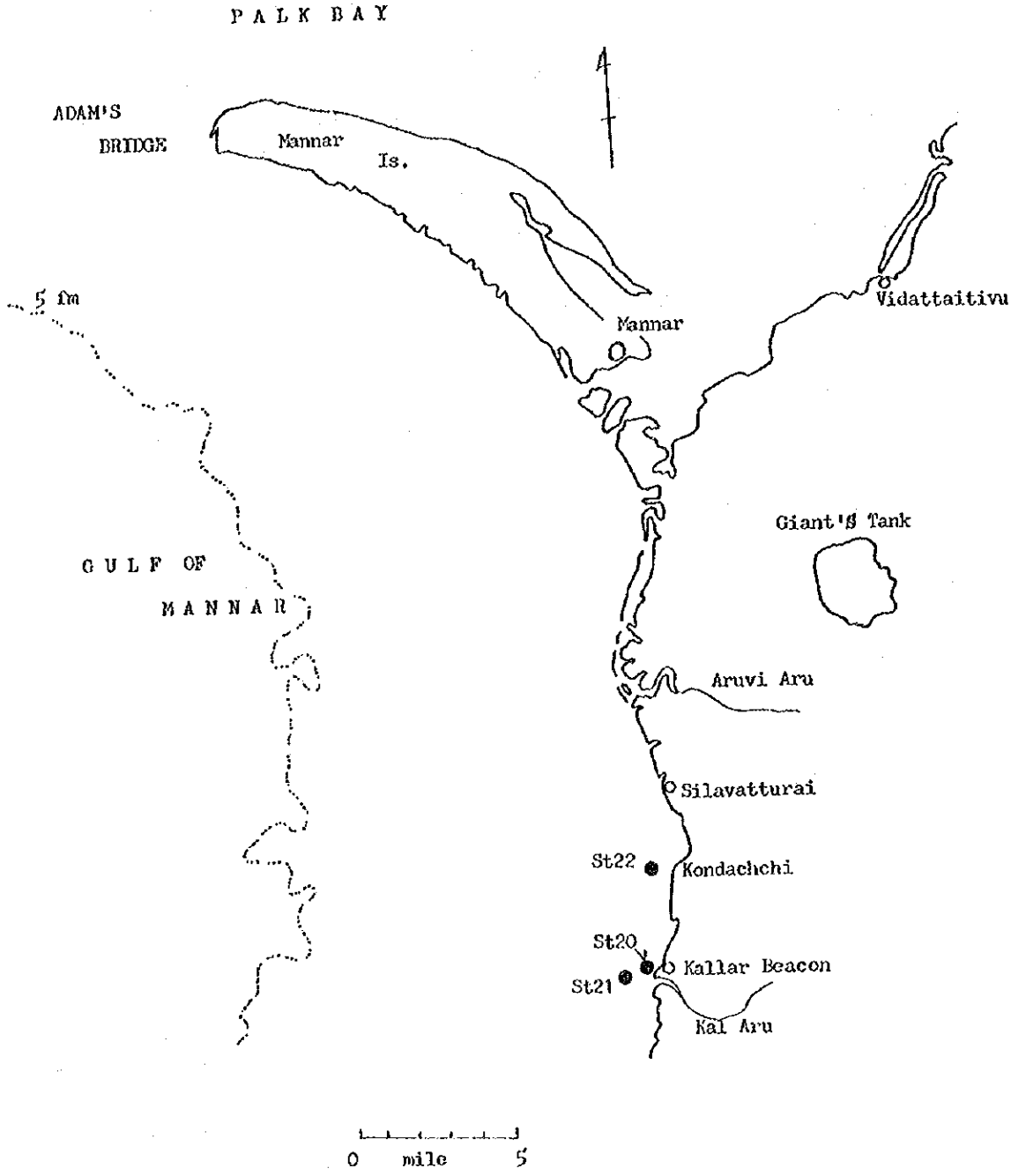


Fig. 14. A map of Mannar region

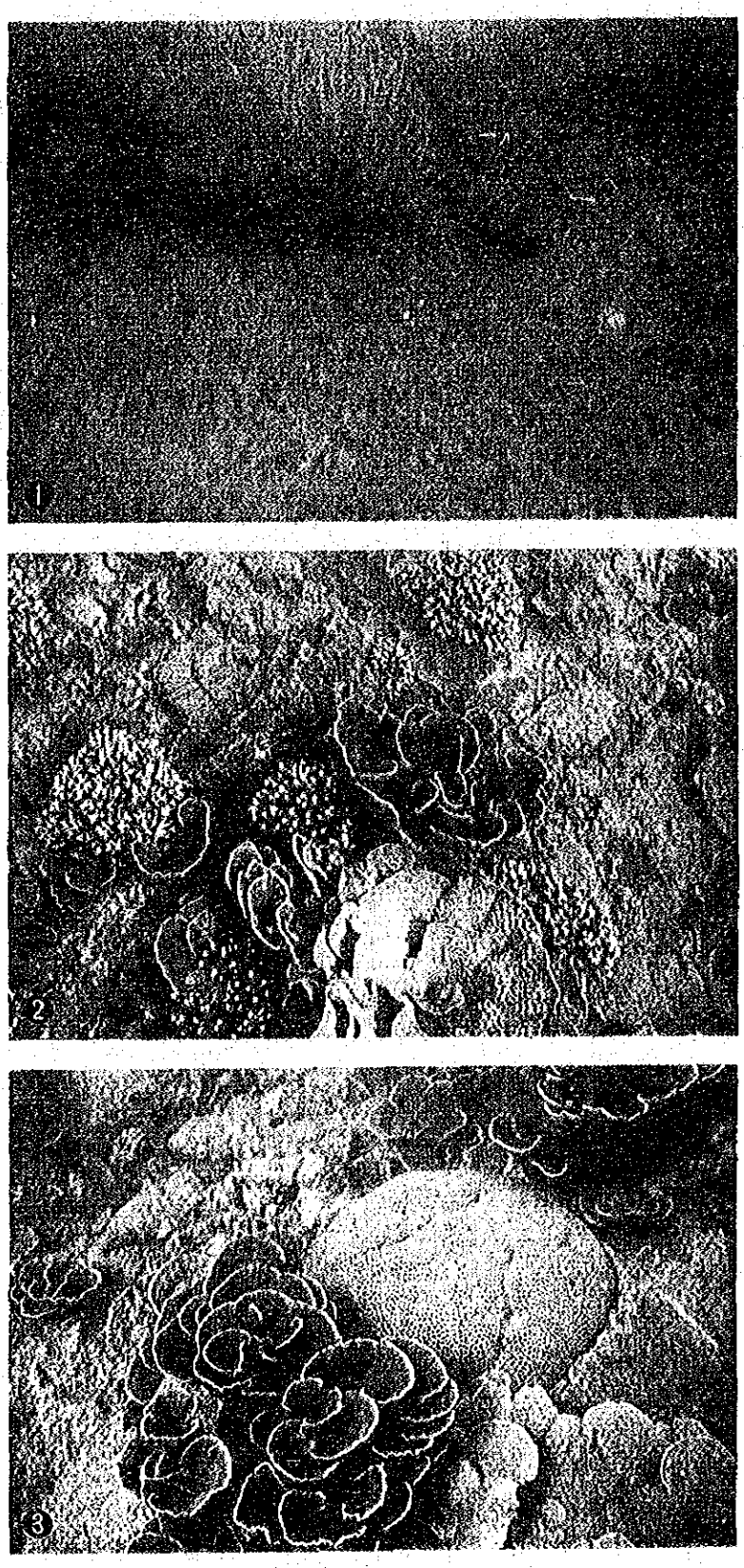


Fig. 15 Underwater photographs of Kal Aru estuary (st.21) and offshore Kondachchi (st.23).

1. Gracilaria lichenoides on the sand bottom of st.21
2. Coral bottom of Montipora and Acropora, offshore Kondachchi
3. Montipora and Porites

In future, this fishing will continue by fishing management; but, on the other hand, it is considered necessary to introduce Japan's high technique of pearl oyster culture for pearl production, in order to efficiently make use of this population. It is a plan having enough possibility to catch seed oyster for pearl culture in Mannar fishing ground, and to use the shallow waters from Kallar to Silvatturai as nursery beds. On such an occasion, consideration should be paid that the bivalve to be used as seed oyster should not be those caught by means of dredge fishery, but those caught by more careful method of catching, for example, to catch by the use of divers. After all, the detailed survey of resources and fishing ground development, not for fishery but for cultivation, is desirable.

6. Jaffna Region (Fig. 16)

As is shown in Fig. 16, research was made at 4 points around Delft Channel.

St 24 is situated off the coast of Karaitivu, where water is 4 m deep, and bottom soil is sand. The transparency is extremely low, and no macro bottom fauna was collectable. St 25 is located at the intermediate point of Nayinativu and Analaitivu, with water depth of 5 m, and sand-mud bottom. At this point also, as in the case of St 24, no benthos was collectable. St 26 is located outside the port of Delft Island, and Sargassum sp., Gracilaria lichenoides, Padina and Codium could be observed.

In this sea area, the remains of coral are scattered, as is seen in Fig. 16, and also Tegula (Gastropoda) live in great abundance. St 27 is located off the coast of Pearl Bed, where sand bottom continues from the point of water depth of 3 m to the beach. Upon the remains of coral, colonies of new Acropora and Montipora are scattered. There also live Crassostrea sp., Turbo, Tegula, etc. In point of fish, Abudefduf, Acanthurus and Thalassoma were observed.

St 26 and 27 are in the Delft Channel, where tidal currents are fast and sea weeds, Gastropoda and nutrient salt are rich. Punkutivu, Pearl Bed and the sea area of Delft channel which faces Delft Is. are considered to be favorable as nursery beds for aquaculture. The annual variation of salinity concentration and temperature at surface water of Jaffna Lagoon is as shown in Fig. 18 (Sachithananthan, 1969). Minimum temperature of Palk Bay is observed in February, and maximum temperature in May. The temperature changes within the range of 24.0 and 30.0°C. As in the case of other points in Jaffna Lagoon, maximum temperature of Kayts channel is observed in April and minimum in December. Salinity is, generally speaking, very high from May to August and low from October to December. Salinity changes very much with the range of 13.04 ~ 38.6‰Cl in the Kayts channel of the lagoon entrance and in the

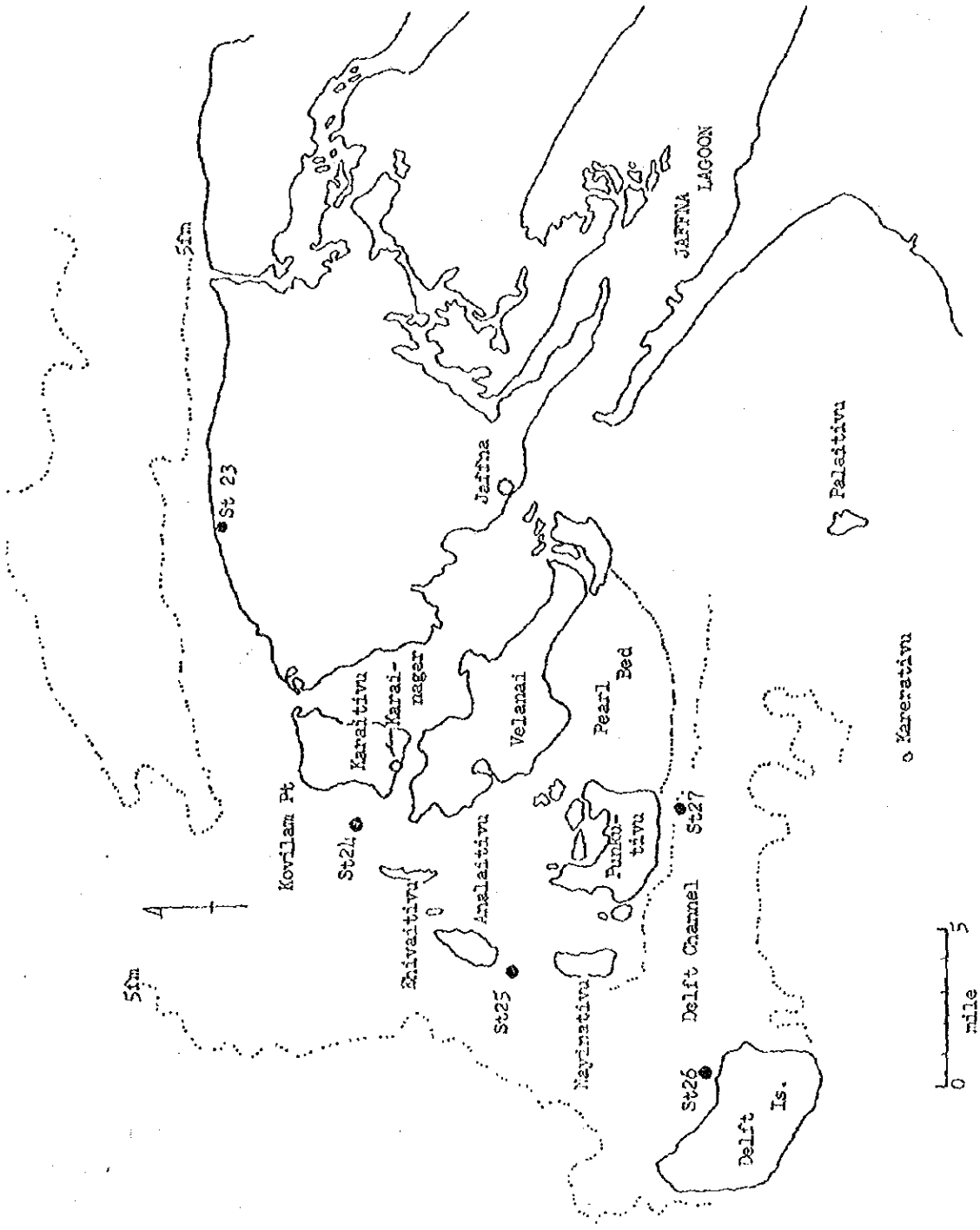
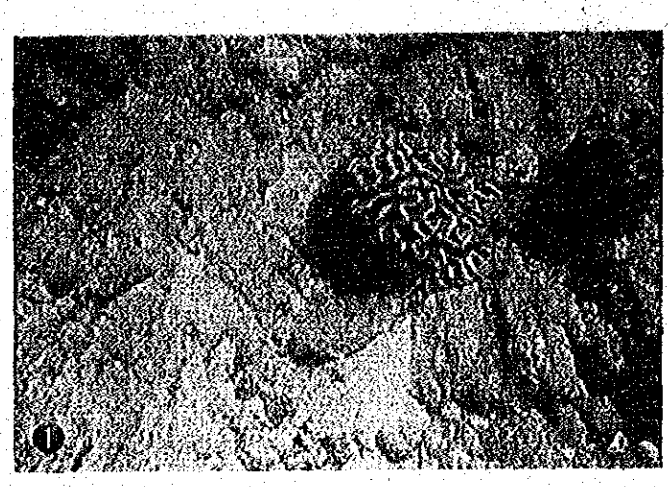
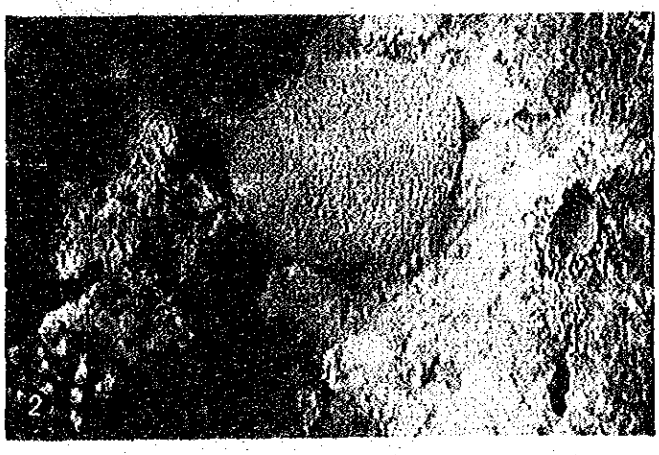


Fig. 16. A map of Jaffna region showing the research sites





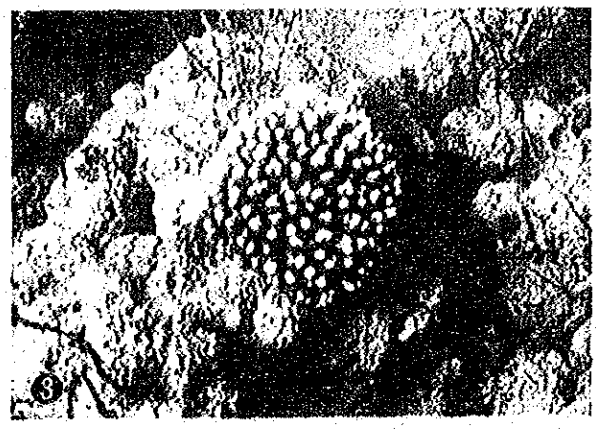


Fig. 17 Underwater photographs of corals on the old coral reef offshore Pearl Bed, Jaffna

1. Leptoria sp 2. Massive coral Polites 3. Acropora

lagoon. On the contrary, salinity of Palk Bay off Myliddy which is on the outside of the lagoon changes less with the range of 28.39 ~ 36.06‰ Cl.

In the lagoon water area in Sri Lanka, the change in salinity is considerable owing to the influence by the two monsoons (the North-East monsoon and the South-East monsoon). Especially in the case of North-East monsoon, which begins in mid-October, is attended by violent rain. The rainfall value is the greatest during November - December, and a great quantity of fresh water flows into the lagoon. Rainfall becomes the least during January-March. It again increases from April, and fresh water begins to flow into the lagoon. It is on account of this that the change of precipitation amount has big influence on the salinity fluctuation.

Jaffna Lagoon which shows low salinity concentration in rainy season, also registers high salinity in dry season, and because of exceedingly great range of change latitude, it is not a favourable area for nursery ground of oyster which is originally

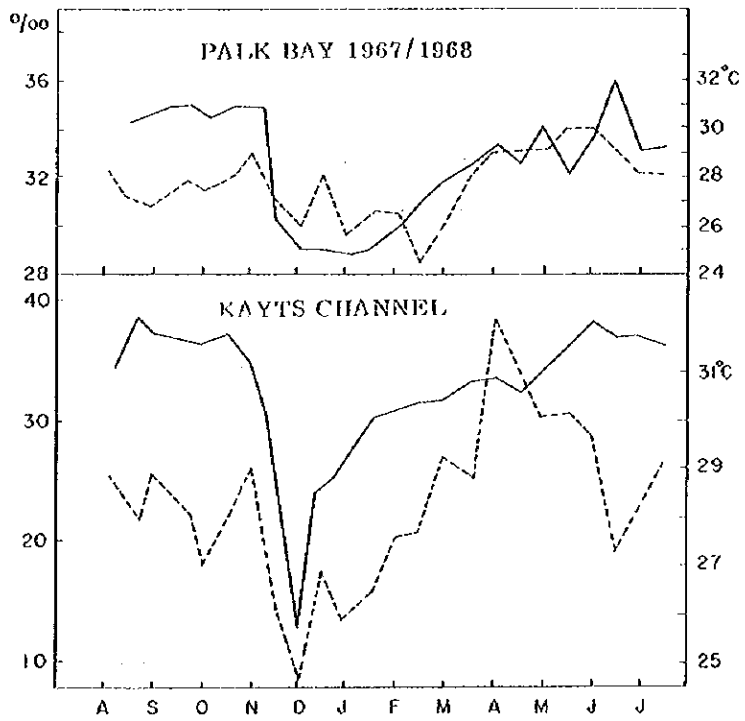


Fig. 18 Seasonal variation of the temperature and salinity of the sea surface in the Jaffna Lagoon (Sachithananthan, 1969).

euryhaline animal, not to mention pearl oyster adapted for open sea. In view of these points it may be said that the sea area which has less change of salinity concentration and temperature and rich in nutrient salts, namely the sea area including Palk Bay, especially the waters in Delft Channel, may be said as combining the favourable conditions. Attention should be paid here that the selection of sea area should be to find out the area where the cultivation facilities are well protected from damage in monsoon season especially during south-west monsoon period.

In Jaffna sea area, the chank, (Gastropoda) Xancus pyrum, is caught in a great quantity. Its shells are exported to Bangladesh as material for shell works, while sea cucumbers are exported to Hong Kong, etc., in dried form (Fig. 19). These creatures are commercially important animals, and more detailed survey on their biology and ecology is required. The dried sea cucumber, when valued in Japan, may not be called high-class product. It is necessary to study the processing method in future.

In Karainagar, there are the facilities of Cey-Nor Development Project established by the Norway Charity Fund, where the prawns and lobsters are processed by quick-freezing. Although this freezing facility is a modern establishment (Fig. 20), it requires some hours for conveyance from catch to works, and their freshness somewhat lost, and the result is that, though the freezing process is excellent, production of refrigerated items possessing superior quality sufficient for export may not be secured. In order to guarantee their good quality, high class aquatic products to be exported as raw fish should be produced by freezing process, preserving freshness by use of chill cars.

7. Kalutara Region

Survey was made on the spot near Bentota bridge where oysters live, but after observation by means of snorkel diving for 30 minutes, no oyster could be caught. According to Pillai (1965), Bentota oyster is reported as edible oyster and attention thereon paid, but as yet there is no detailed report. It is said that in rivers within this region, glass eels (elva or transparent eel juvenile) go up the stream, but similarly as the case of oyster, no report thereon is available. Macrobrachium rosenbergi, fresh water prawns are caught in rivers of Kalutara region, but unfortunately the authors had no opportunity to obtain the materials. This species is one of the biggest freshwater and brackishwater prawn in the world, and study on mass production of seed prawn and cultivation are being advanced in such countries as Japan, Malaysia, Thailand, India, France, U.S.A., and England, and the technique of mass production is being established. The study of the ecology for aquaculture of

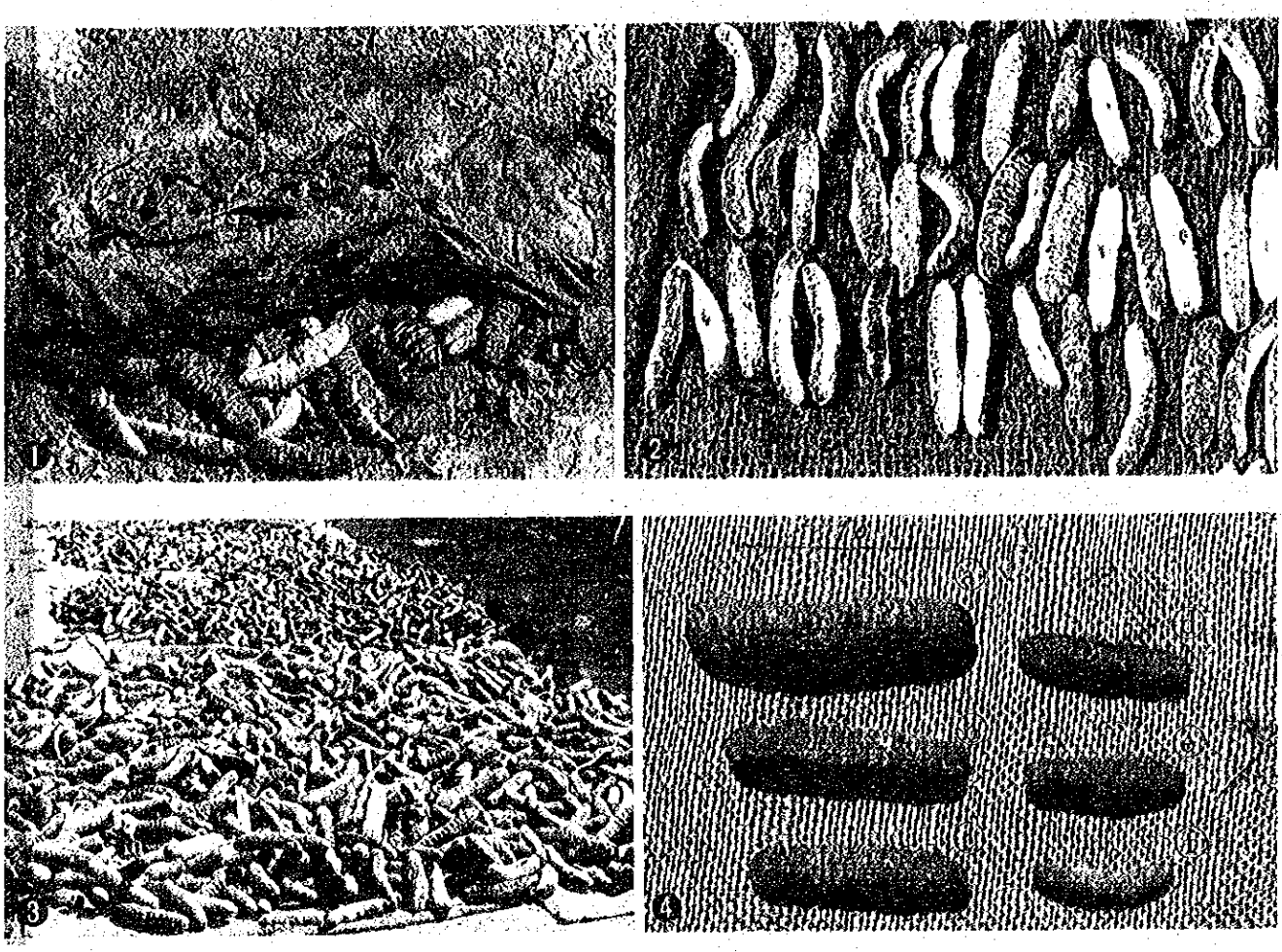


Fig. 19 The process for beche-de-mer at Jaffna region

1. burying under the ground for 24hrs after 1st boiling
2. dried materials with calcareous powder after 2nd boiling
3. last dry after 3rd boiling
4. grades by size: a 1st, b 2nd, c 3rd, d 4th, e 5th, f 6th class

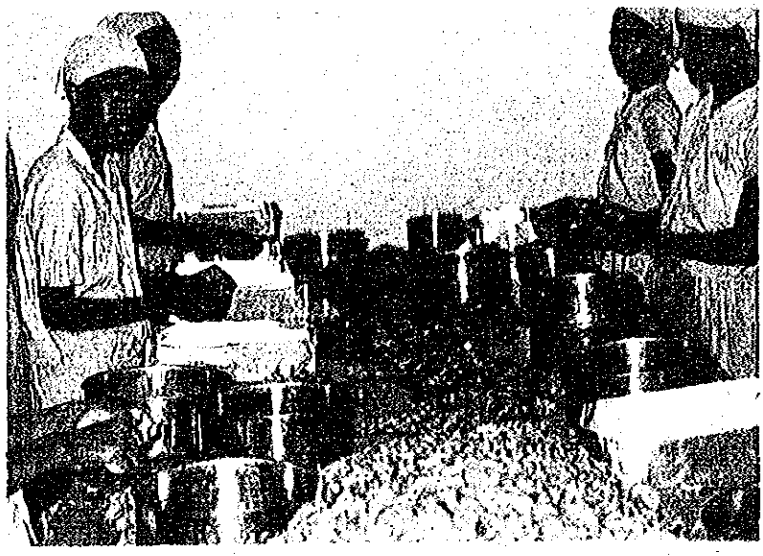


Fig. 20 A processing prawns for freezing at the factory, Cey-Nor Development Project, Jaffna

this species should be carried out in Sri Lanka.

8. Matra and Hambantota Region (Fig.21)

As shown on Fig. 21, 3 points were surveyed in Rekawa Kalapuwa and Karagan Lewaya. Rekawa Kalapuwa (Fig. 21 A) is the lagoon with water area of 3.24 km^2, the deepest part thereof being 5 feet. As the kinds of catch, there are prawns (Penaeus monodon and Penaeus indicus), milkfish, Chanos chanos, 8 inches in body length, Leiognathus sp., Caranx sp., Telepia mossambica, Etroplus suratenis, Mugil cephalus, Anguilla sp. and so on. The major product is prawn, which is caught during the rainy season of June - July. Principal fishing implements are cast-nets, and has efficiency of 5 lbs/man/day during the best season.

Karagan Lewaya, the mouth of which is made narrower by road construction, is connected with the open sea by a tube of only 50 cm in diameter, and in the dry season, it is dried up. Accordingly, the flowing of sea water decreases, and the productivity therein has declined.

Malala Lewaya (Fig. 21 B) connects with the open sea by opening its mouth 3-4 times during rainy season. Prawns and mugil are caught, but the increase in catch thereat may not be expected unless the introduction of open sea water is realized.

II. Consideration and Conclusion

Survey was made for 3 weeks on the shallow waters and brackishwaters along the shores of Sri Lanka Island, especially around the lagoons. From the point of view of survey period, it was a pre-survey, but the result showed the presence of creatures of aquacultural possibility, such as prawns, pearl oyster, milkfish and mangrove crab. It is considered fundamental that, these creatures should be produced more increasingly by the extensive utilization of spacious lagoon water area, rather than to apply intensive culture method such as pond culture and cage-net culture as in Japan.

Discussion will be made as to the point on which attention should be concentrated for the above purpose. It may be generally said that shallow water zone of Sri Lanka, especially lagoon and mangrove areas has abundant nutrient salts carried from the rivers, and the plankton and small creatures to be the feed of above-mentioned commercially important species, is richly found, and therefore, is the area suitable for the breeding, growth, and survival of these edible fish and shellfish. This fact may be understood by the study of the temperature, salinity concentration and plankton in respective lagoon and shallow waters effected by

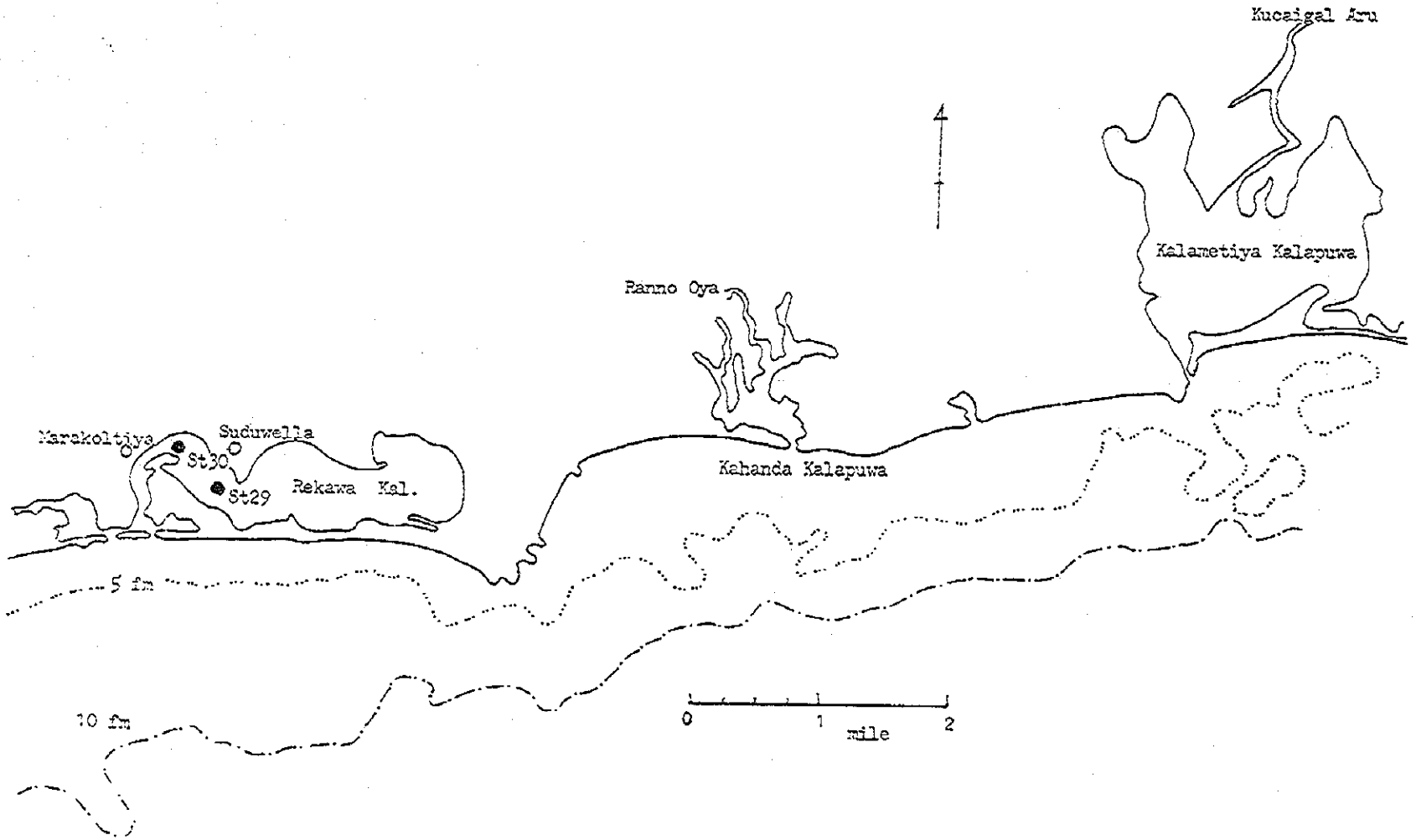


Fig. 21 A. Matra and Hanbantota region showing the research sites.

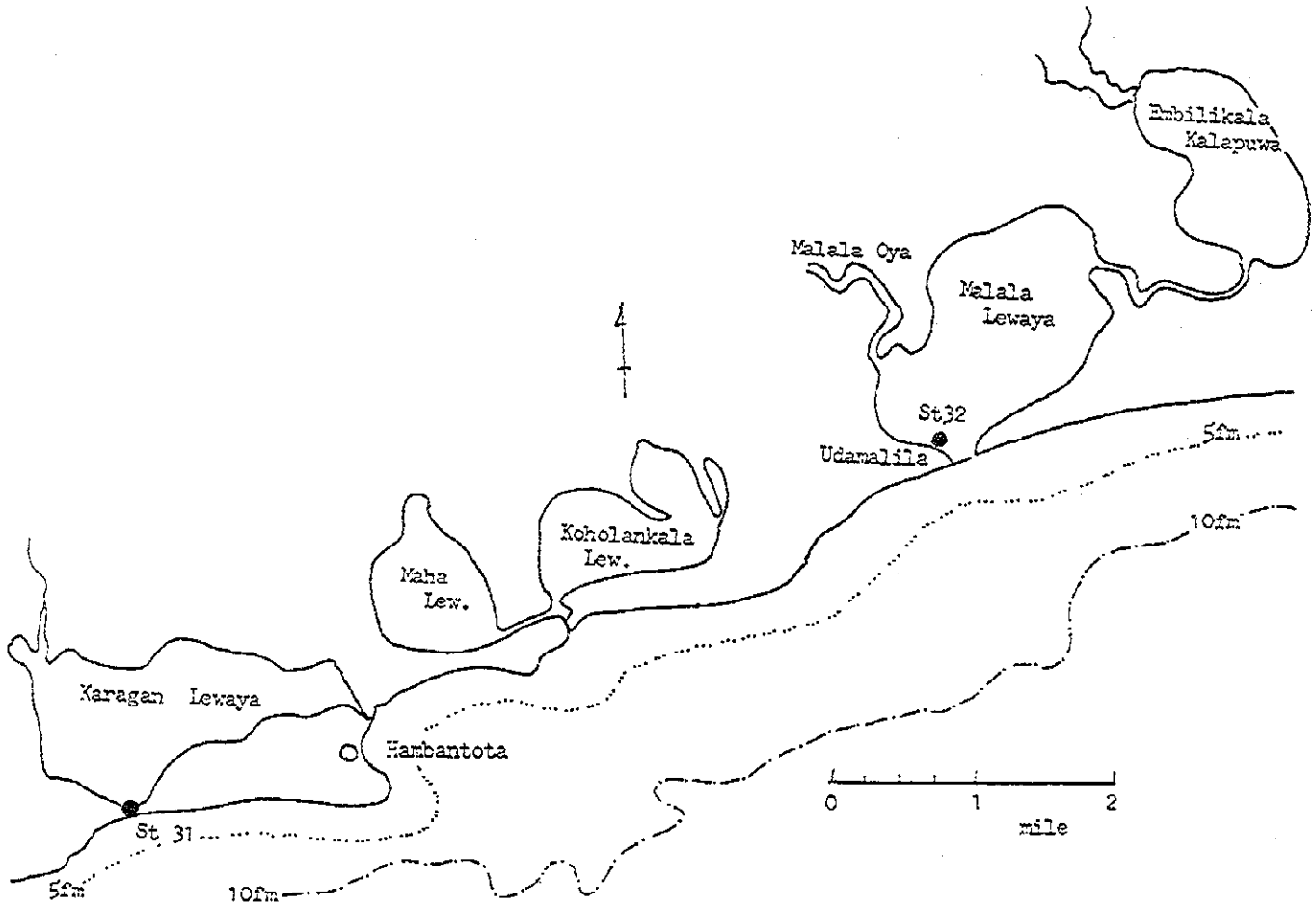


Fig. 21 B. A map of Hambantota region.

Durairatnam (1963), Durairatnam et al (1964) and Costa et al (1969), but there is no such detailed research on inorganic phosphate, organic phosphorous, nitrite, nitrate, silicate, chlorophyll, plankton as the recent study which deals chiefly on nutrient salts such as the research on Vellar-Coleroon Estuarine by Krishnamurthy et al (1973). Moreover, the environmental conditions towards the creatures in lagoons and estuaries are closely related with the meteorological conditions. It is necessary therefore, in attempting the aquacultural development, to clarify the characteristics for environmental conditions for respective lagoons.

The fact that the production in lagoons is closely related with rainfall is as stated by Ruello (1973). The information on the meteorological conditions in Sri Lanka, especially rainfall, is available in detail.

According to Ekanayake (1972), as is shown in Table 3, Fig. 22-23, the annual rainfall variation in Negombo, Colombo, Kalutara, Galle, Hambantota and Tangalla located in south-west to south part of Sri Lanka Island represents a bimodal curve. There are two peaks of rainfall during April-June and September-December. On the other hand, for Jaffna, Mullaittivu, Trincomalee and Batticaloa, the curve is one in which there is a peak during September-December. Even in the case of lagoons with nearly the same amount of precipitation, the above-mentioned environmental conditions differ according to the size of rivers flowing thereinto, and the violence of monsoon, giving each lagoon its own characteristics.

The movement of water in the lagoon containing the inflow of the open sea water in lagoon affects the productivity therein considerably. As stated before, the lagoon with high productivity of commercially important fish has the well-established mouth enabling the flowing-in of open sea water all the year round. The movement of water mass from open sea in the lagoon is predominantly determined on the basis of bottom topography of the lagoon, flowing-in of open sea water, tidal range, the amount of flowing-in of fresh water, etc. The details of hydrological survey in the lagoons in Sri Lanka are hardly available except the Negombo Lagoon. It may be said that the foundation for discussing the water exchange in lagoon and for establishing the construction plan to improve the exchange is totally non-existent. At any rate, it is clear that the fisheries productivity in lagoon connecting with the open sea all the year round is high, and that the productivity of lagoon connecting only in rainy season is low. It is considered important for the increase of production of living marine resources, to establish the opening part of lagoon, thereby to make it opening all the year around and to enforce the construction work to improve the exchange of water as seen from the point of view of hydraulic engineering. On the other hand, it has been already mentioned from the point of biology, that the flowing-in of water serves to increase the production of prawns, and it is important to clarify the

Table 3. Monthly average rainfall for the standard period 1931-60 at Sri Lanka (Ekanayake, 1972)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Jaffna	3.80	1.35	1.18	2.76	2.47	0.64	0.65	1.24	1.87	9.59	16.19	10.50	52.34
Delft	2.62	0.99	1.17	2.21	1.70	0.22	0.31	0.84	1.11	7.39	12.68	8.64	39.88
Mannar	3.44	1.32	1.75	3.48	1.94	0.19	0.28	0.63	0.93	6.60	9.56	7.97	38.09
Kalpitiya Saltern	2.89	1.67	2.70	4.47	2.64	0.39	0.48	0.34	0.96	5.94	9.30	6.45	38.23
Puttalam	2.88	1.80	2.99	5.42	3.89	0.91	0.67	0.84	1.39	6.34	10.04	6.04	43.71
Chilaw	2.54	2.10	3.90	8.41	6.75	3.02	1.98	1.80	2.64	9.88	10.30	4.62	57.94
Negombo	2.33	2.30	4.41	10.29	10.94	6.29	3.99	3.26	4.38	12.08	12.20	4.73	77.20
Colombo	2.93	3.39	4.20	9.39	11.39	7.33	4.70	3.97	4.79	12.13	12.15	6.15	82.52
Kalutara	4.45	3.98	5.84	12.22	15.79	9.78	6.66	5.98	7.88	15.42	13.48	8.24	109.72
Galle	4.45	4.56	4.59	9.94	11.90	8.67	6.72	7.04	7.06	14.02	12.69	7.31	98.95
Hambantota	3.97	2.30	2.61	4.29	4.76	2.17	1.70	1.66	1.79	4.95	7.38	4.76	42.34
Tangalla	3.04	1.73	2.40	5.33	8.33	4.92	2.74	3.64	4.07	6.36	7.30	4.32	54.18
Batticaloa	10.99	7.02	3.34	2.85	1.23	0.73	1.49	2.43	1.88	7.01	11.23	16.92	67.12
Trincomalee	8.55	3.38	2.19	2.84	2.51	0.70	1.66	3.38	2.36	7.44	11.88	13.52	60.41
Mullaittivu	4.96	1.85	1.15	2.78	2.42	0.60	1.50	2.66	2.86	8.32	15.56	13.04	57.70

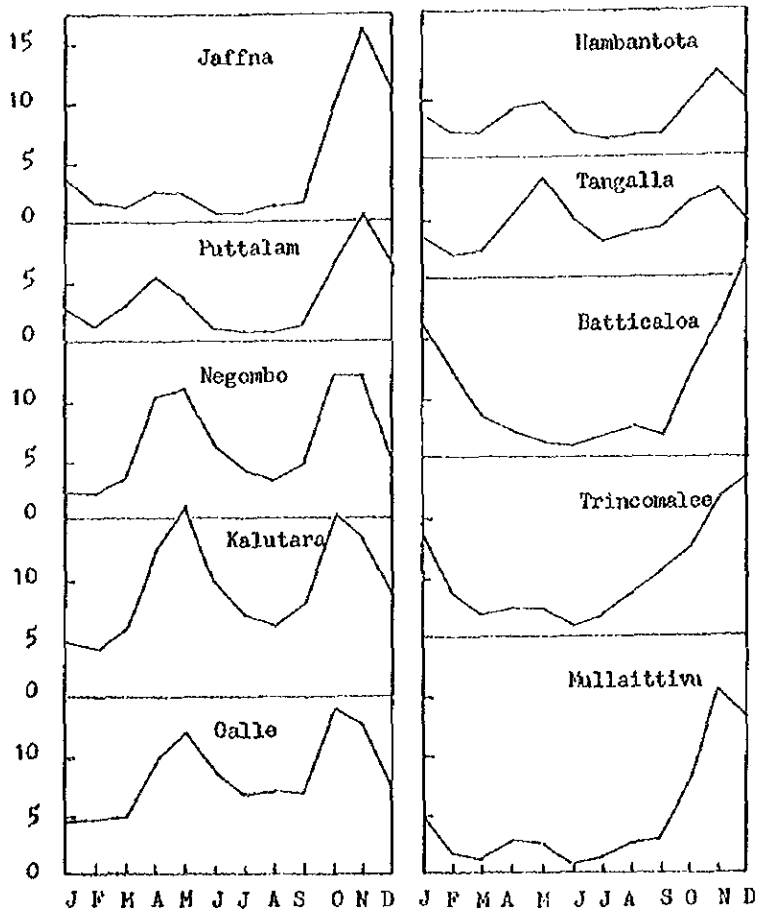


Fig. 22. Diagram showing monthly rainfall for the standard period 1931 - 60 (Ekanayake, 1972)

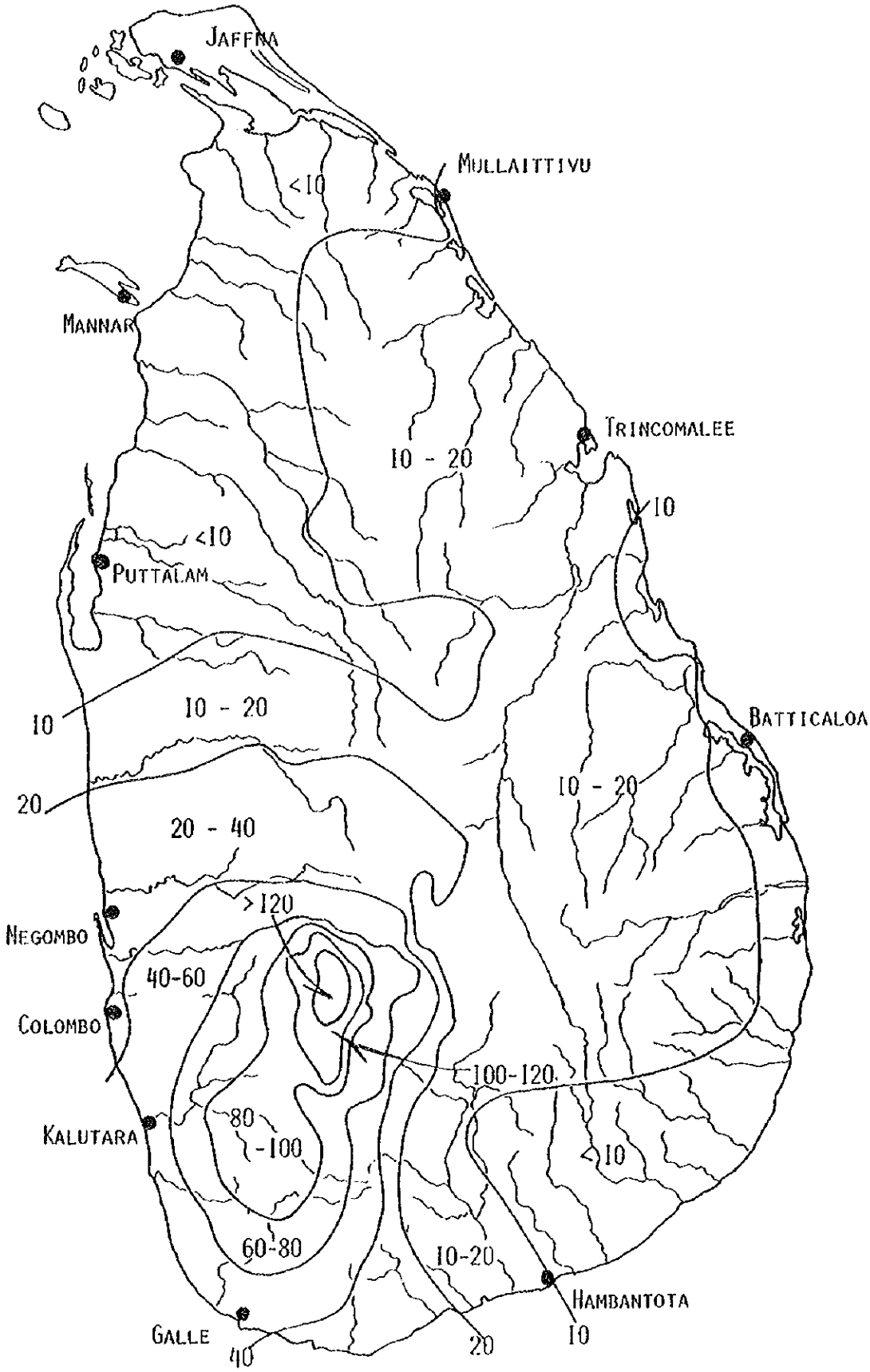


Fig. 23. Showing S. W. monsoon average rainfall, May-Sep. (1931-1960) (Ekanayake, 1972). Unit: inches

life history of Penaeus monodon and Penaeus indicus, which are the commercially important prawns, in the lagoons in Sri Lanka. In the case of these prawns, similarly as Penaeus japonicus, their adults grow into maturity in the open sea and spawn. The hatched larvae move and gather as they grow into lagoon and estuary areas, and passing each stage of juvenile — adolescent — subadult, go out again into the open sea where they grow into adult. In each stage, they have their particular habitats, but no survey is obtainable in the case of lagoon in Sri Lanka thereon. It is important to clarify at least the details for breeding season, life cycle relating to habitats, migration, etc., concerning Penaeus mondon, Penaeus indicus, Metapenaeus monoceros, Metapenaeus elegans and Metapenaeus dobsoni.

According to Berg (1971), the survey result is obtained that much population of prawns in the sea area in Sri Lanka is found on the coast of Palk Bay, Mullaittivu, Batticaloa regions. It is therefore necessary to clarify, first of all, their ecological characteristics in lagoons, chiefly in lagoons of Negombo, Puttalam, Mullaittivu, by means of the above-mentioned ecological study.

For aquacultural exploitation of penaeid prawns in Sri Lanka, as is stated above, it is better to apply the extensive method. It is thought preferable, through securing lagoon mouth as well as improving the movement of lagoon water by irrigation works, thereby elevating the productivity of the lagoon as a whole, to increase the population and then to catch. The hydrographical survey and ecological research to enable these will become indispensable. When the growth and survival inside lagoon as well as the population recruitment of prawns from the open sea is made known, and when the variation in population is available, still higher stage of production, for example, the establishment of prawn hatchery will be made, and will make mass production of juveniles, and after stocking lagoons with them, catch them on a fixed plan, that is, in other words, the system of recruiting resources creatures artificially and then to harvest, the so-called "sea-farming" will be considered in future. The system such as this will be more possible in the lagoon which is a semi-closed sea area. Recently, the possibility of sea-farming is becoming apparent by stocking the Seto Inland Sea, Japan with the seed prawns of Penaeus japonicus in bulk (Hasegawa, 1973).

Good examples of extensive culture of prawns are seen mostly in various south-eastern countries of Asia. The example of pond culture in Singapore (Hall, 1962), shrimp farming in Thailand (Teinsongrusmee, 1970), paddy field prawn fishery in India (Menon, 1954; Gopinah, 1956) are these. These examples make efficient use of water areas, availing themselves of the ecology of the seed prawns which gather in estuary, mangrove area and lagoon, and may be called an efficient extensive culture.

For the population of pearl oyster Pinctada vulgaris, since sufficient amount for use of pearl culture may be obtained as referred to already, because its nursery bed exists, it is necessary to plan in detail how to introduce pearl culture technique of Japan.

As for oyster, it has been confirmed that there is a good abundance of adult and spats in Negombo and Kokkilai lagoons. These have been assumed as Crassostrea cucullata or a similar species, and it is considered that spat collection in the nature may be possible. For this purpose, it is indispensable to perform the ecological research such as the spawning season of oyster in Sri Lanka, and the distribution of larvae in the open sea. For the time being, it may be possible to introduce the spats of Japanese oyster, Crassostrea gigas. As a cultivation method, it is desirable to adopt the rack method suited for shallow waters, and to begin with any one of the Negombo, Puttalam, Kokkilai lagoons, or of Palk Bay, shallow waters of Mannar, Dutch Bay, Portugal Bay, Kokkiyar Bay, Trincomalee Bay, etc. As for milkfish, experiment thereon has already been made in Negombo Brackishwater Fisheries Station, and its bright future is known (op. cit.). In future, production planning should be established upon full deliberation of the future demand for this fish.

The suitable locations for creatures mentioned above are stated in the following table.

Table 4. Shallow waters and lagoons suitable for sea farming in Sri Lanka

Locality	Area (km^2)	Feasible area (km^2)	Suitable species	Remarks
Negombo L.	32.95	15	Oyster, prawns, milk-fish	The entrance open throughout the year
Puttalam	229.57	80	Prawns, oyster, milk-fish	Ditto
Dutch Bay	84.74	20	Oyster	-
Portugal Bay	49.50	15	Oyster	-
Mannar coast	386.45	200	Pearl oyster, oyster	-
Delft channel (Punkutivu)	47.33	10	Pearl oyster, oyster	-
Delft Is	17.99	15	Pearl oyster, oyster	-

Locality	Area (km^2)	Feasible area (km^2)	Suitable species	Remarks
Nanthi Kadal	41.54	5	Prawns	Open during wet season
Kokkilai L.	55.79	20	Prawns, oyster	Open throughout the year
Batticalao L.	100.73	25	Prawns?	?
French pass	0.56	20	Oyster	-
Bottom of Koddiyar Bay	12.79	8	Oyster	-
Rekawa Kalapuwa	3.24	1	Oyster	Open throughout the year

In the next place, the authors' opinion on the fisheries in Sri Lanka will be given as follows.

Generally speaking, after fishing and preserving freshness with proper means, fisheries resources which are treated through appropriate processing procedure are distributed to consumers as foodstuff. No need to say that when distributing fresh fish to consumers as food, even when processing is done, unless the system for keeping freshness, for example the cold chain system, is established, it will never be a wholesome product even though the processing facilities are perfect. This situation may be well understood in the above-mentioned case of Cey-Nor Development Project.

The imperfection of facilities for keeping freshness in Sri Lanka may be well understood by the experience of bad odour in St-John's fish market in Colombo City. In the case of fishing products, not only fresh fish, but also when preparing chilled, cured, frozen and canned items, unless attention is paid to the preservation of freshness, no good products will be prepared (Fig. 24). What the authors here want to stress is that, the development of lagoon fisheries is not limited to simply increasing production through the introduction of superior cultivation technique, but it is a comprehensive improvement planning which covers distribution and management of products.

The coastal fish production of Sri Lanka in recent years is as stated in Table 5. Of the 89,760 tons for the year, prawns attain to 2,451 tons. The greater portion of this amount is considered to be much deteriorated in freshness when it is carried to the market. Assuming that the increase in production may be expected through the introduction of new techniques in future for the lagoon fishery, the preparation

Table 5. Coastal Fish Production in 1973, excluding Deep Sea Fishing and Inland Fisheries (Ton)

D. F. E. O. Division	Seer	Poraw	Blood Group	Shark & Skate	Rock Fish		Shore Seine		Prawn	Others	Total
					Large	Small	1	2			
Negombo	258	168	3,177	10,352	233	108	144	1,014	434	98	15,986
Colombo	107	133	131	2	246	17	33	456	277	17	1,419
Kalutara	148	44	1,484	709	169	14	127	312	0	2	3,009
Galle	87	146	1,294	126	206	77	103	393	36	93	2,561
Matara	60	106	2,258	507	317	74	671	633	54	88	4,768
Hambantota	169	173	2,704	405	459	60	18	72	94	238	4,392
Jaffna	1,351	1,683	1,514	1,977	3,999	3,072	1,342	5,500	478	1,417	22,332
Mannar	331	1,367	586	1,088	313	564	1,044	4,488	73	226	10,080
Mullattivu	38	102	43	144	32	138	184	483	195	37	1,396
Trincomalee	295	812	1,570	570	1,218	677	633	3,073	72	119	9,039
Batticaloa	72	243	1,249	214	169	301	113	653	233	791	4,638
Kalmunai	93	227	446	73	138	266	141	1,530	48	604	3,566
Puttalam	496	438	2,033	802	293	549	251	1,600	505	207	7,174
Total	3,506	5,638	18,489	16,967	7,795	5,919	4,803	20,207	2,451	3,985	89,760

of facilities for preservation of freshness is a matter of urgent necessity.

Various problems of the lagoon fishery exploitation have been so far discussed, the summary of which is given as follows:

I. The system of aquaculture in lagoons and shallow waters

a. It is desirable to develop extensive culture in wide and spacious water areas where the productivity is high, and to establish sea-farming in the future;

b. As living resources, prawns, oyster, pearl oyster, milkfish may be counted;

c. To enforce hydrological survey which will be the foundation of extensive culture, as well as ecological research which will be necessary for sea-farming;

d. To establish a mouth to the open sea for the improvement of environmental conditions of lagoon;

e. To establish a system for distribution and management of fish products, especially for the preservation of freshness, simultaneously with the development of extensive culture, for example, to provide a certain number of freezing cars, thereby establishing the system to collect fish to a certain area where processing facilities are provided.

II. Research and Education

There are many superior researchers in Sri Lanka Fisheries Research Station who received education in advanced countries. This fact may be well understood from the reports of the Institute. The fact may be known that living marine resources are deeply studied from the biological point of view. Unfortunately, studies from the point of view of fisheries science which is a sphere of applied science, are extremely scarce. The authors were informed that in the near future, a research institute would be newly established, and they hope that an institute fitting to promote fisheries science will be completed. For the study of shallow waters, the following points should be considered.

a. Construction of a research boat sufficiently capable to study fishery and coastal oceanography in shallow waters;

b. Besides an institute which will be a centre of research, to completely equip branch stations which will enable them to study special features in each district. There is an existing station at Negombo, but the number of staff and facilities are not satisfactory. In future, at least two branch stations, one on the east and the other on the west coast, should be established which will be useful for fishery.

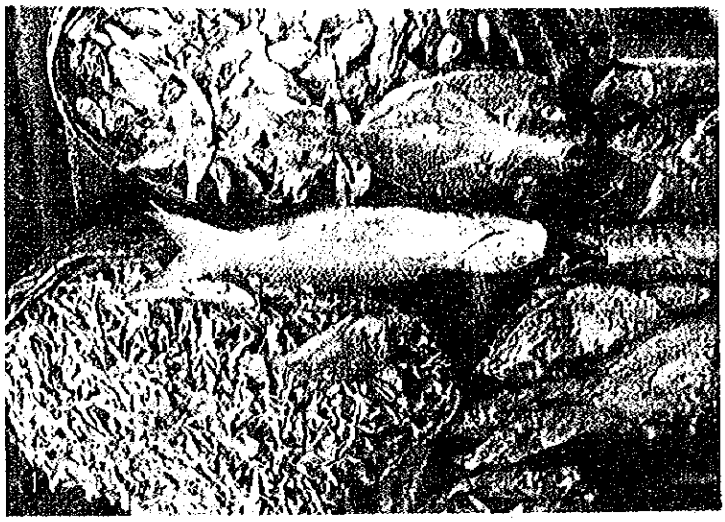


Fig. 24 The processing of salted dry fish at Puttalam region
1. Landing fresh fish 2. pre-treatment for dry 3. salted dry goods

c. Education

It is a matter of rejoicing to know that in Sri Lanka, the project of establishing a fisheries high school system is under way. The fisheries education and research in Japan date back to 80 years ago. In the early stage, research and education were advanced in a body. This is because development of new techniques by means of research demanded new talents. The present status in Sri Lanka is considered to resemble the early period of Japan in which the development of fishery activity was followed by the education. At any rate, the authors would like to propose the following items for education to promote production.

a) To send senior fishery researchers to advanced countries where they study empirical fishery technique for one year at least, by limiting research themes.

b) As themes of research, the following may be mentioned.

1) Coastal oceanographical research technique
2) Prawn culture and sea farming
3) Oyster sea-farming
4) Pearl culture
5) Fish farming

c) To dispatch junior researchers to universities or high-grade laboratories. At present, there are two ways in Japan. One is a technical cooperation program of the Government of Japan under the Colombo Plan which is a comparatively short period and the other is Japanese Government scholarship by which foreign research students can study in Japanese universities for one or two years.

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Appendix I

Result of the oceanographical observation on the lagoon of Sri Lanka during Mar. 18 to 28, 1974.

St.	Date & Time	AT °C	Dp m	WT °C	Sp. Gr. σ 15	Salinity o/oo Cl	pH	O2 ppm	Saturation %	Remarks
1	Mar. 18 11:35	32.5	S	31.0	18.75	14.15	8.10	6.3	92.1	Negombo Lagoon
			2.5B	30.7	26.80	19.96	8.25	6.3	98.9	
2	Mar. 18 12:10	34.1	S	31.0	16.88	12.79	7.50	5.5	79.4	
			2.5B	30.7	17.47	13.22	7.60	6.4	92.4	
3	Mar. 18 13:30	33.2	S	31.8	14.82	11.30	7.70	6.5	92.3	
			1.2B	32.1	18.10	13.68	7.70	6.5	94.4	
4	Mar. 18 16:40	32.2	S	33.5	12.72	9.78	5.90	11.0	SS	
			1.3B	33.2	16.24	12.33	6.10	12.5	SS	
5	Mar. 19 11:25	--	S	31.3	12.45	9.58	7.85	7.0	97.2	Chilaw Lagoon
			1.8B	30.8	16.40	12.44	7.85	6.1	87.5	
6	Mar. 19 16:05	--	S	30.9	23.87	17.85	8.00	7.4	SS	Puttalam Lagoon
			1.0B	30.8	23.77	17.78	8.00	7.5	SS	
7	Mar. 19 16:25	--	S	30.6	24.43	18.25	8.00	7.8	SS	
			4.0B	30.2	24.25	18.12	8.00	7.2	SS	
8	Mar. 19 17:10	--	S	30.1	23.11	17.30	8.00	8.0	SS	
			3.0	30.0	22.70	17.00	8.05	7.9	SS	
			6.2B	30.1	23.28	17.42	8.00	7.8	SS	
9	Mar. 20 08:20	--	S	30.0	17.01	12.89	6.80	5.5	79.4	
			1.5B	29.3	21.32	16.01	8.40	5.3	78.4	
10	Mar. 21 09:30	34.4	S	30.4	26.58	19.80	8.35	7.1	SS	Trincomalee Region
			4.0B	28.9	26.55	19.78	8.40	7.4	SS	
11	Mar. 21 09:55	35.4	S	29.9	26.35	19.63	8.38	8.1	SS	
			3.0	29.1	26.17	19.51	8.40	8.1	SS	
			6.0B	28.9	26.58	19.80	8.40	8.2	SS	
12	Mar. 21 11:30	34.2	S	29.1	26.54	19.77	8.43	8.2	SS	
			3.0	28.5	26.58	19.80	8.45	8.5	SS	
			8.0B	27.9	25.84	19.27	8.45	8.0	SS	

St.	Date & Time	AT °C	Dp m	WT °C	Sp. Gr. σ 15	Salinity o/oo Cl	pH	O_2 ppm	Saturation %	Remarks
13	Mar. 21 12:20	35.4	S	28.5	26.00	19.38	8.30	8.4	SS	Trincomalee Region
			5.5 B	27.9	25.81	25.81	8.30	8.3	SS	
14	Mar. 21 17:00	--	S	30.2	26.28	19.58	6.60	8.2	SS	
15	Mar. 21 18:30	--	S	29.2	21.31	16.00	6.60	--	--	
17	Mar. 22 17:20	--	S	29.9	26.43	19.69	8.10	8.2	SS	Sanctuary Lagoon
			2.4 B	29.6	27.27	20.30	8.15	8.0	SS	
18	Mar. 22 17:30	--	S	31.0	26.27	19.58	8.20	9.0	SS	
			1.4 B	30.3	27.93	20.77	8.15	8.4	SS	
19	Mar. 22 17:45		S	31.3	24.08	18.00	8.20	9.3	SS	
			2.2 B	30.8	23.94	17.89	8.15	9.4	SS	
20	Mar. 23 15:08	33.8	S	30.6	26.43	19.69	8.29	8.0	SS	Mannar Region
			1.5 B	31.0	26.62	19.83	8.25	8.2	SS	
21	Mar. 23 15:25	--	S	30.5	27.03	20.12	8.22	8.0	SS	
			3.0 B	29.9	26.83	19.98	8.20	8.0	SS	
22	Mar. 23 16;15	--	S	31.5	27.39	20.38	8.16	8.1	SS	
			2.0 B	29.9	27.71	20.61	8.20	7.6	SS	
24	Mar. 25 10:45	29.0	S	29.4	24.68	18.43	8.29	7.6	SS	Jaffna Region
			4.0 B	29.2	24.67	18.42	8.35	7.2	SS	
25	Mar. 25 11:50	36.4	S	30.0	25.01	18.67	8.39	6.9	SS	
			5.5 B	29.1	24.78	18.50	8.42	6.0	90.7	
26	Mar. 25 13:10	35.1	S	31.4	24.98	18.65	8.53	9.5	SS	
			3.0 B	30.8	24.14	18.04	8.46	8.0	SS	
27	Mar. 25 16:20	--	S	31.5	25.12	18.75	8.41	10.1	SS	
			2.5 B	31.2	24.36	18.20	8.51	8.7	SS	
28	Mar. 27	--	S	31.3	3.50	3.11	6.85	--	--	Bentota Region

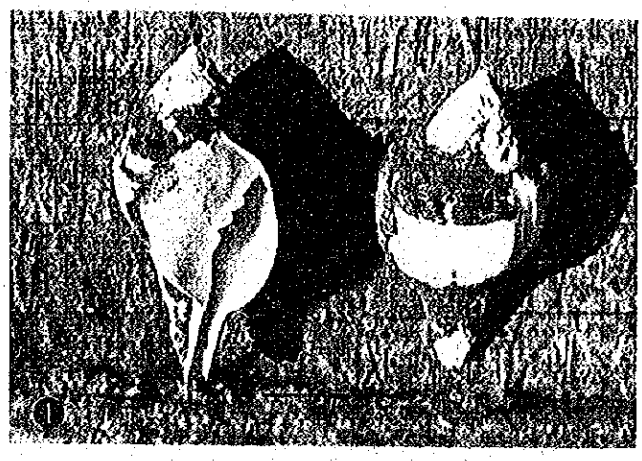
St.	Date & Time	AT °C	Dp m	WT °C	Sp. Gr. σ 15	Salinity o/oo Cl	pH	O_2 ppm	Saturation %	Remarks
29	Mar. 28 08:15	--	S	30.3	10.88	8.44	8.40	6.2	85.1	Rekawa Lagoon
			1.2 B	29.9	11.49	8.89	8.68	1.5	20.7	
30	Mar. 28 08:45	--	S	30.1	10.91	8.47	8.48	5.9	81.0	
			1.0 B	30.0	10.91	8.47	8.60	1.8	24.7	
32	Mar. 28	--	S	31.9	5.50	4.55	8.51	6.5	85.5	Malala Lagoon

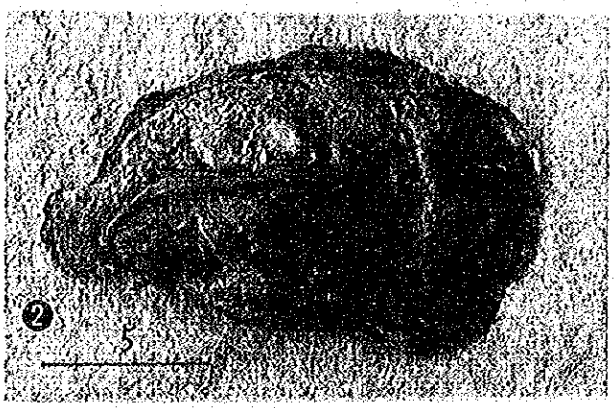
Appendix II

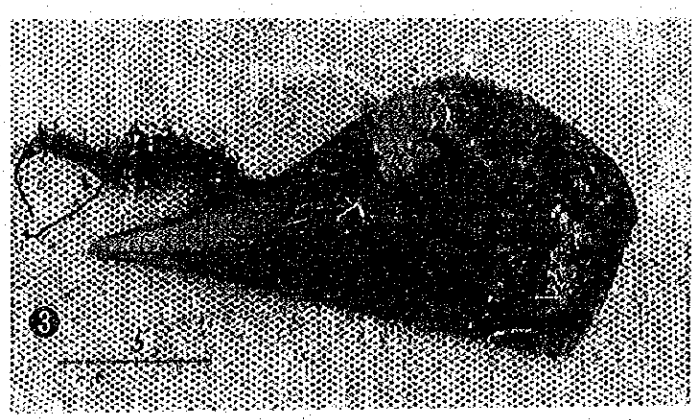
Photographs of marine animals in Sri Lanka

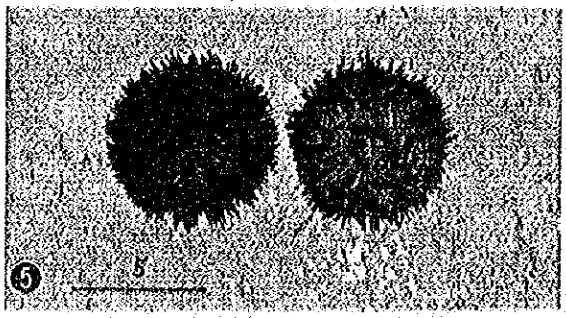
1. Xancus pyrum, Chank
2. Crassostrea cucullata?
3. Pinna sp
4. Diadema setosum
5. *Temnopleurus sp*
6. Echinothrix sp
7. Holothuria sp
8. Panulirus ornatus
9. Panulirus penicillatus?
10. Portunus pelagicus
11. Scylla serrata
12. Charybdis sp
13. Penaeus monodon
14. P. monodon
15. Penaeus indicus
16. Metapenaeus sp
17. Metapenaeus sp
18. Chiloscyllium indicum
19. Amphotistius imbricatus
20. *Amphotistius sp*
21. Amblygaster sirm
22. Macrura kelee
23. Amblygaster clupeoides
24. Sardinella albella
25. Sardinella melanura
26. Dussumieria acuta
27. Dussumieria hasseltii
28. Anchoviella commersonii
29. Nematalosa nasus
30. Chanos chanos
31. Chirocentrus nudus
32. Tachysurus subrostratus
33. Pseudarius jella
34. Plotosus canius
35. Ablennes hians
36. Ablennes hians
37. Tylosurus strongylurus
38. Hyporhamphus gaimardi
39. Exocoetus sp
40. *Trichiurus savala*
41. Sphyraena jello
42. Mugil cephalus
43. Sphyraena obtusata
44. Epinephelus bleekeri
45. Epinephelus fuscoguttatus
46. Variola louti
47. Cephalopholis argus?
48. Therapon jarbua
49. Psammoperca waigiensis
50. Apogon thermalis
51. Sillago sihama
52. Caranx sansum
53. Caranx carangus
54. Caranx sansun
55. Selar kalla
56. Selar crumenophthalmus
57. Lactarius lactarius
58. Selaroides leptolepis
59. Megalaspis cordyla
60. Chorinemus tol
61. Chorinemus tala
62. Kishinoella tonggol?
63. Indocybium guttatum
64. Coryphaena hippurus
65. Rachycentron canadus
66. Pristipomoides typus
67. Lutianus fulviflamma
68. L. rivulatus
69. L. fulviflamma
70. L. kasmira

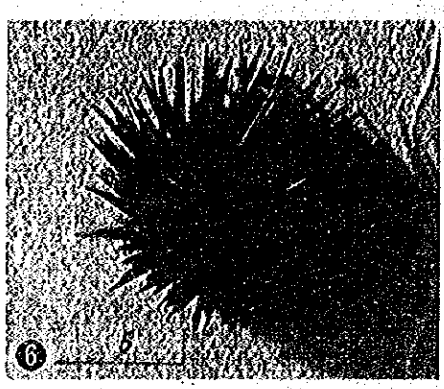
71. Leiognathus equulis
72. Gerres abbreviatus
73. Pomadasys maculatus
74. Scolopsis bimaculatus
75. Lutianus waigiensis
76. L. nebulosus
77. Rhabdosargus sarba
78. Acanthopagrus berda
79. Argyrops spinifer
80. Gaterin schotaf
81. Parupeneus macronemus
82. Upeneus tragula
83. U. vittatus
84. Drepane punctata
85. Scatophagus argus
86. Tilapia mossambica
87. Etroplus suratensis
88. Abudefduf sexatilis vaigiensis
89. Siganus vermiculatus
90. S. sp
91. Acanthurus gahm?
92. Cybium commersoni
93. Euthynnus affinis
94. Auxis thazard
95. Psettodes erumei
96. Pseudorhombus arsius
97. Triacanthus brevirostris
98. Pseudotriacanthus strigilifer
99. Lactoria cornuta
100. Nemipterus furcosus
101. Gnathodentex aurolineatus?

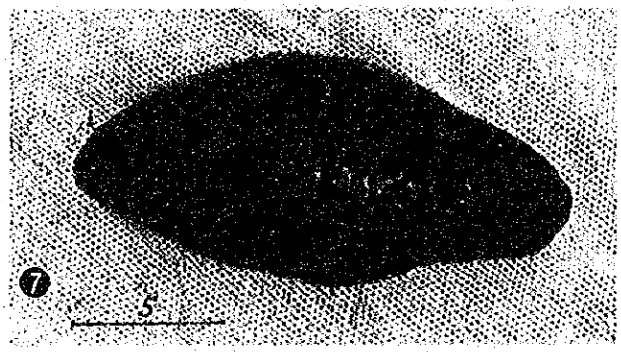


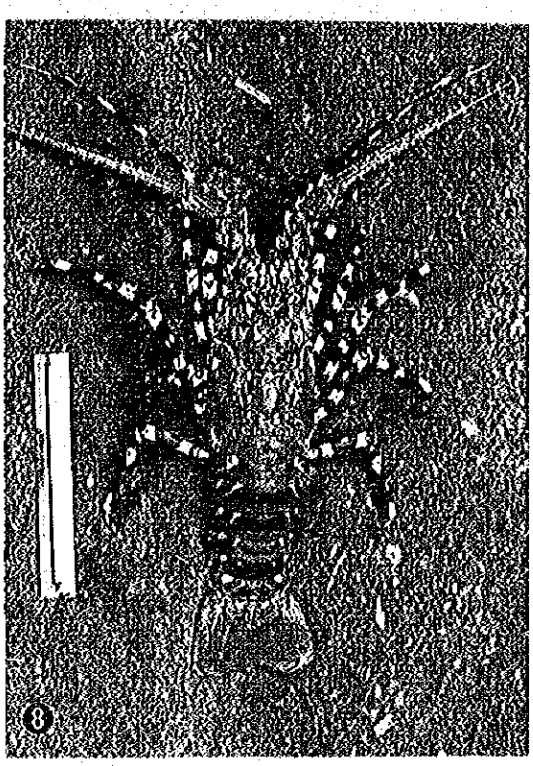












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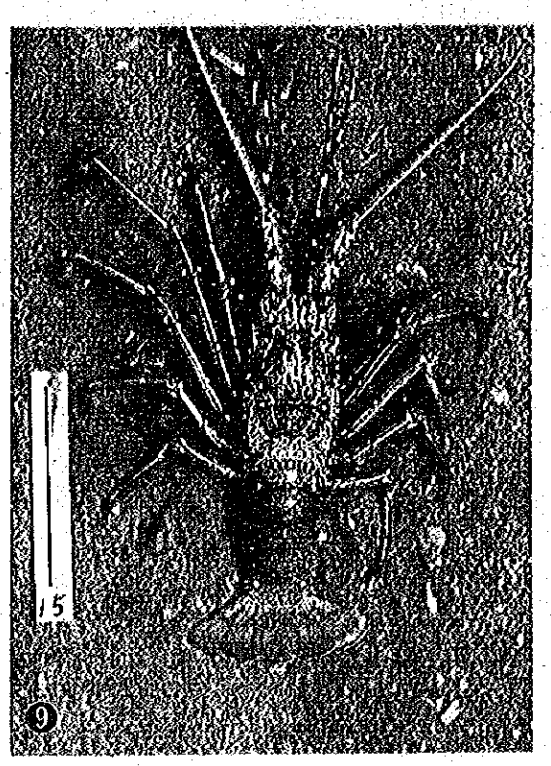

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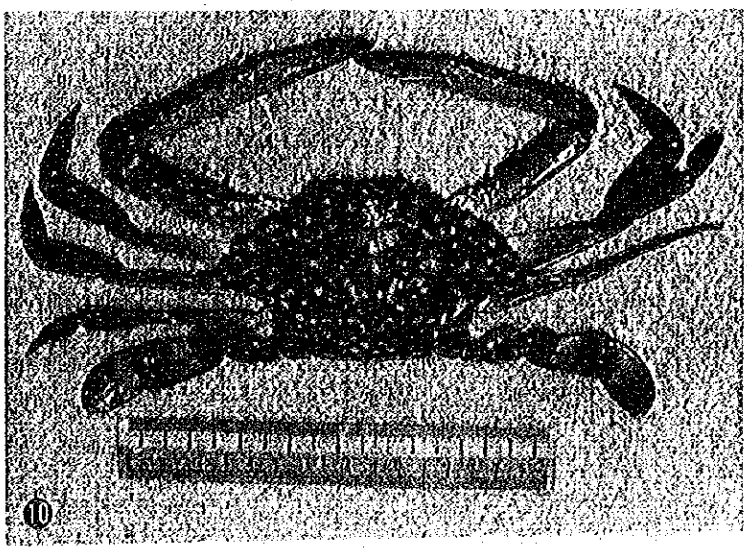

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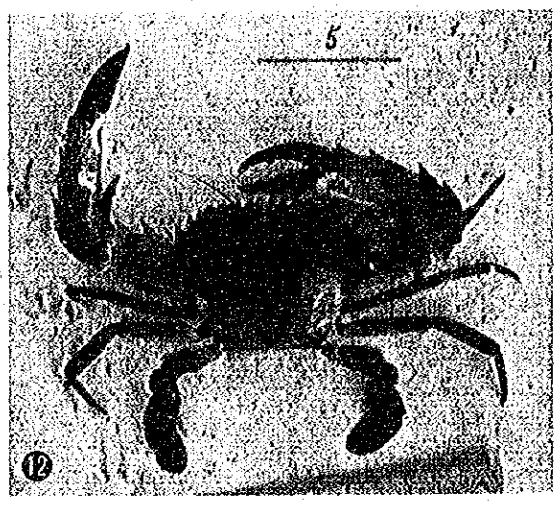

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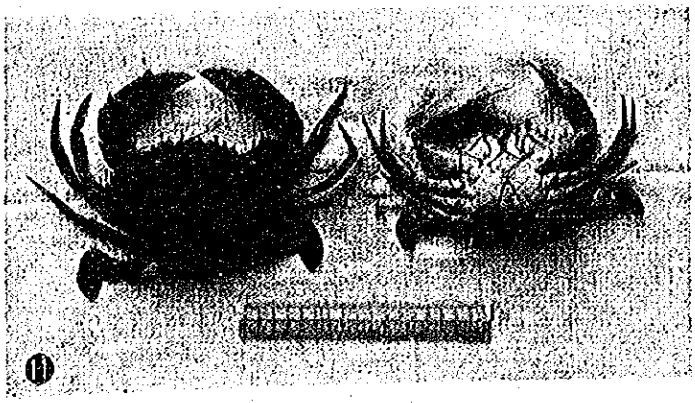

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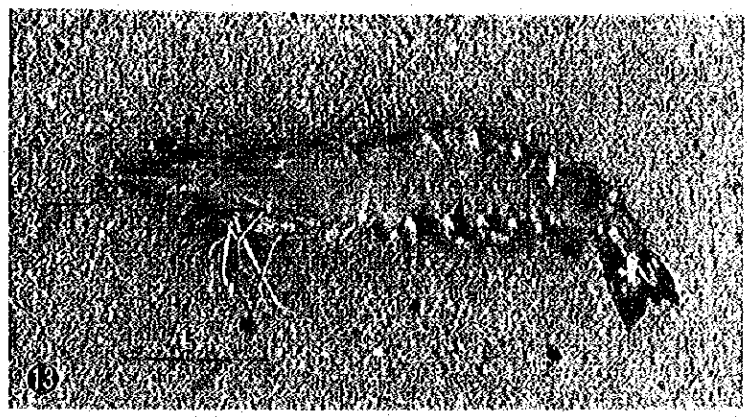

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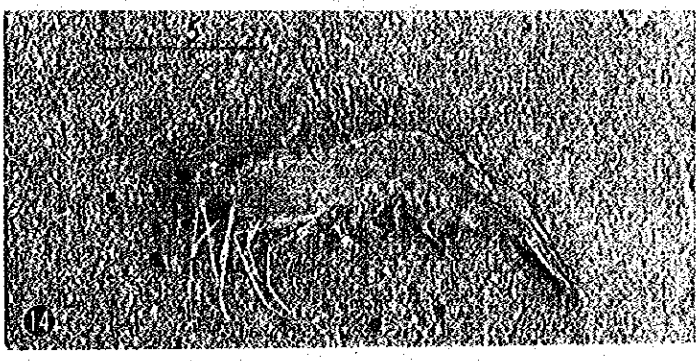

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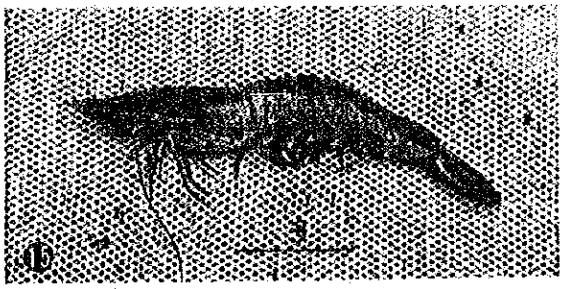

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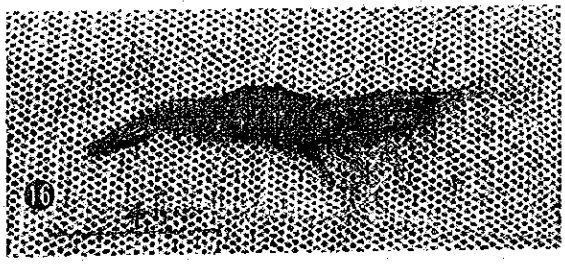

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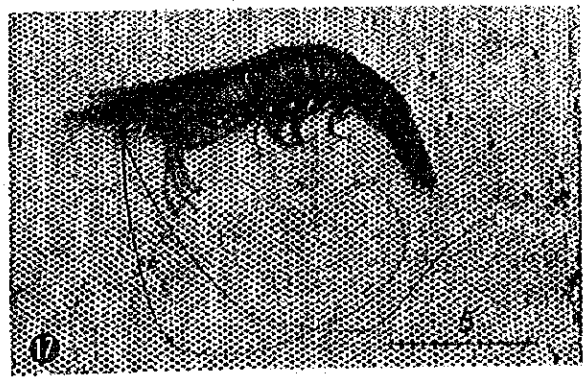

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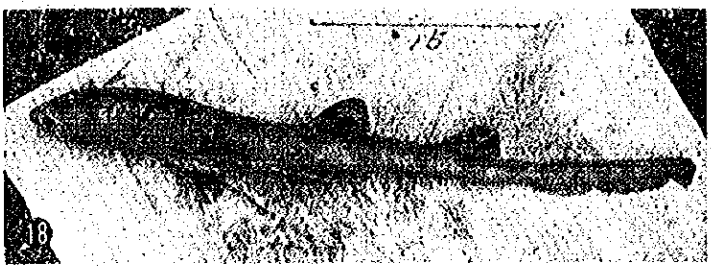

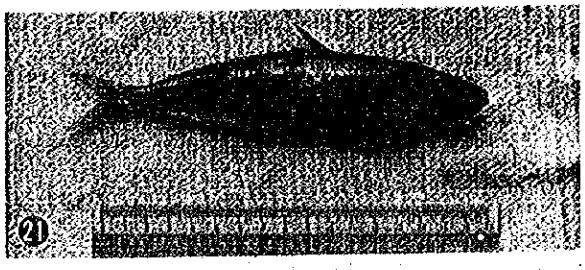

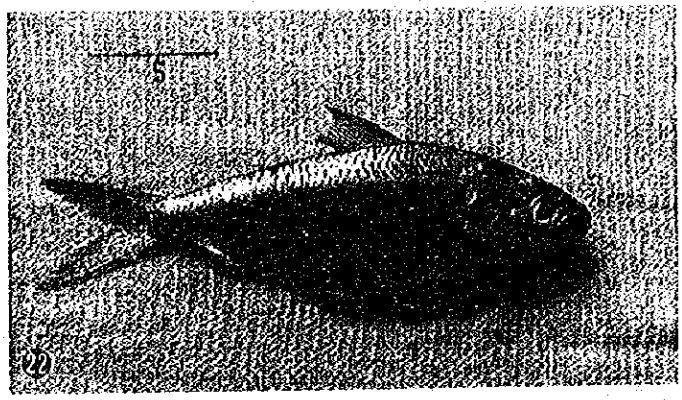

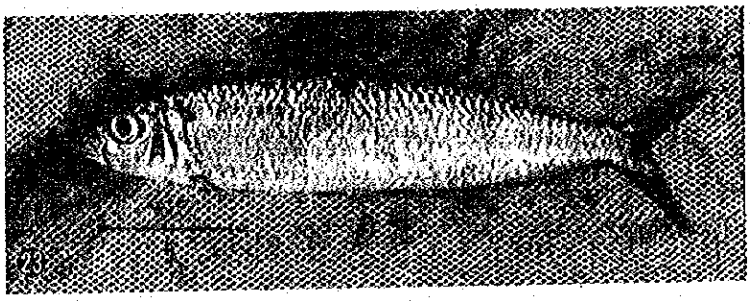

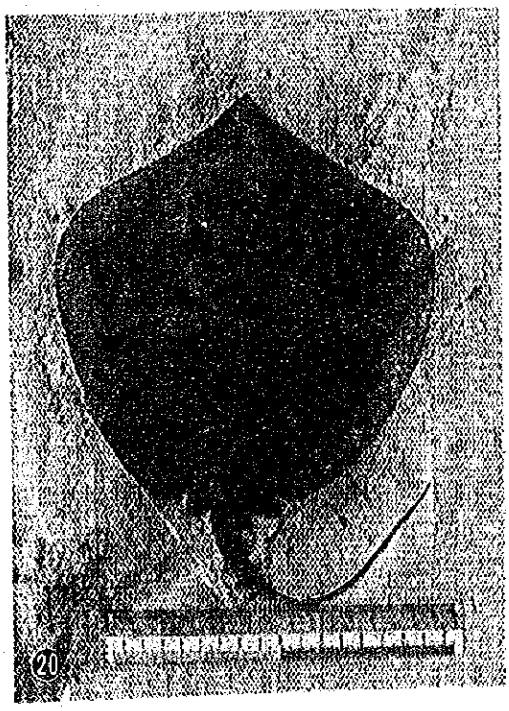

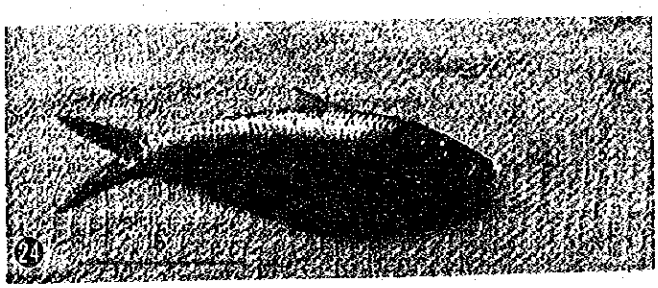

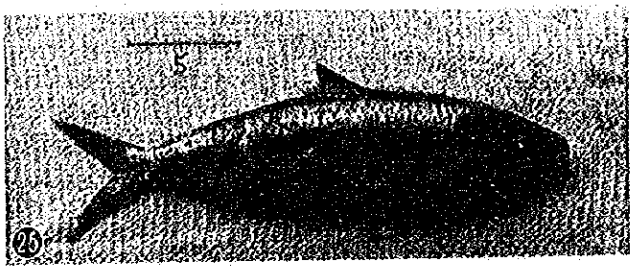

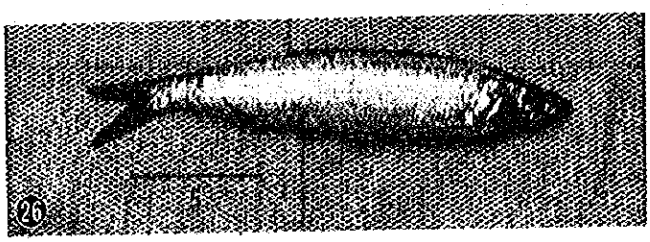

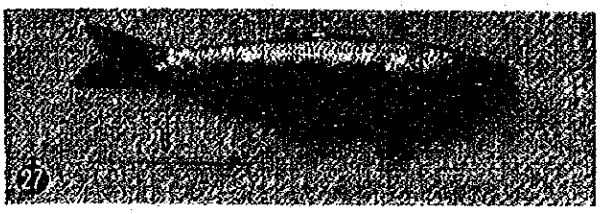
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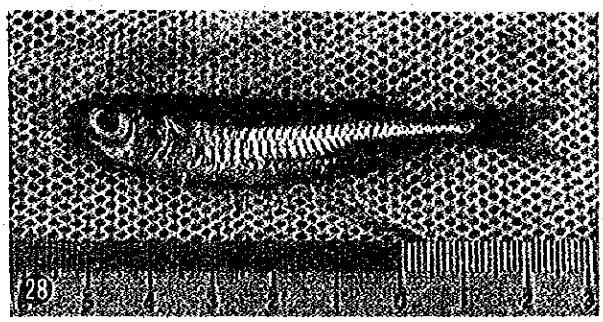
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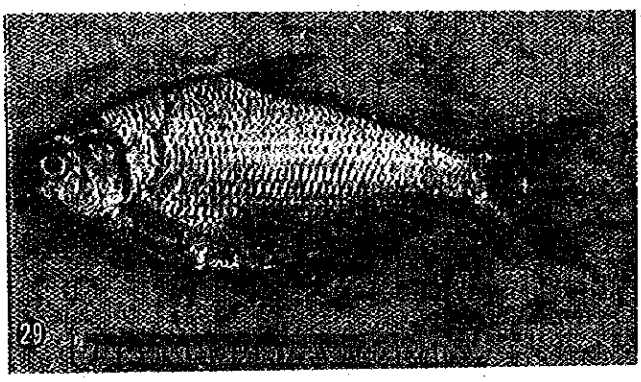
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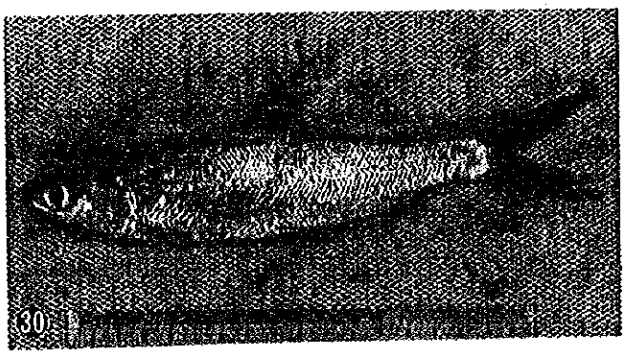
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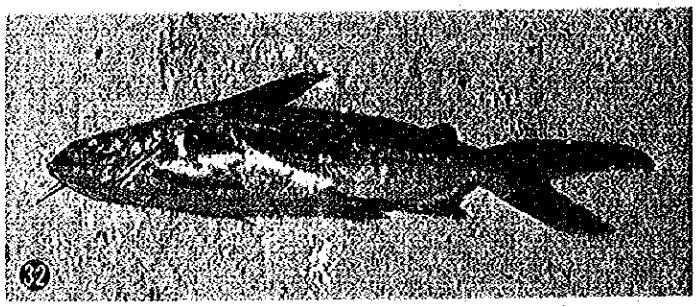
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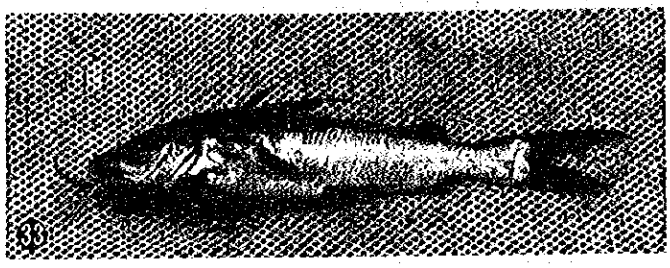
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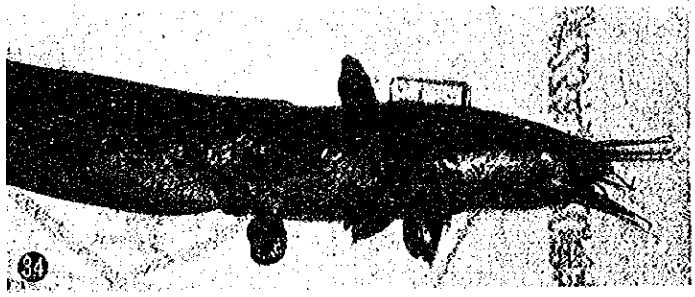
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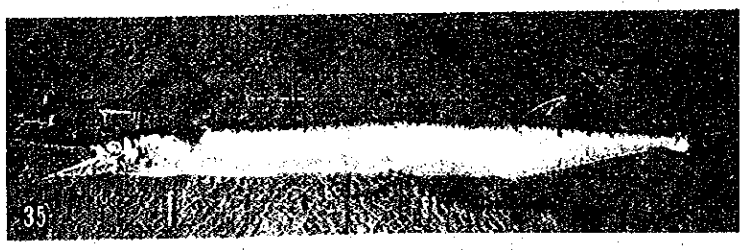
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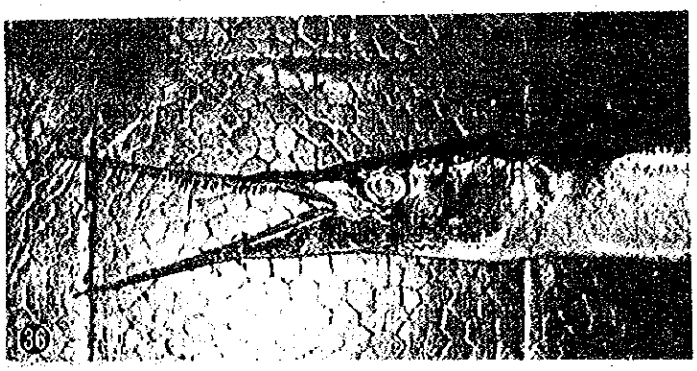
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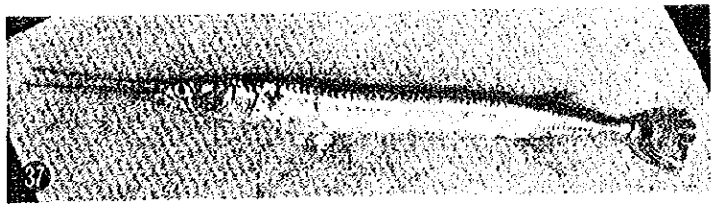
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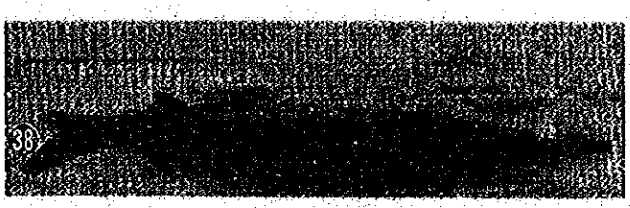
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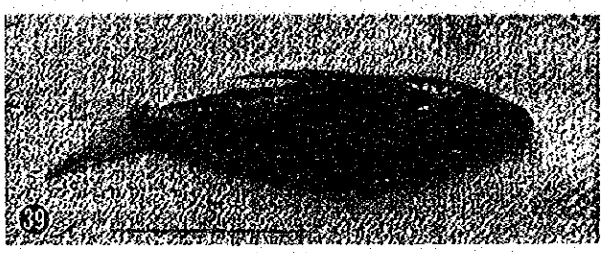
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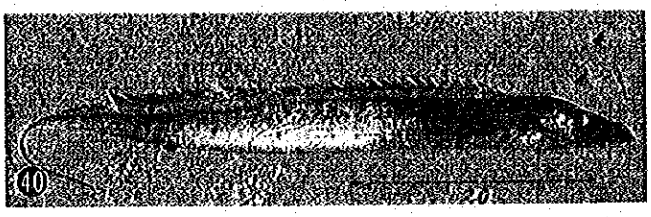
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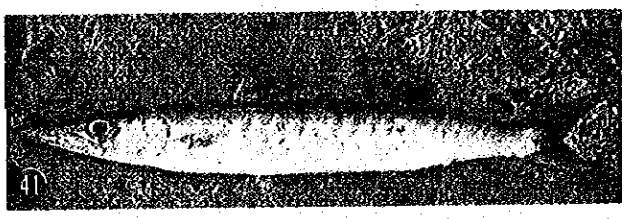
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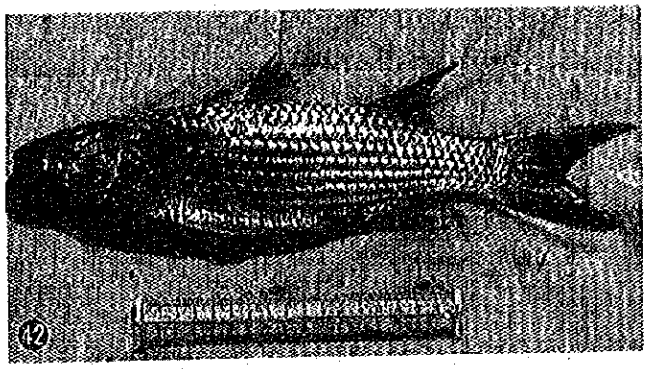
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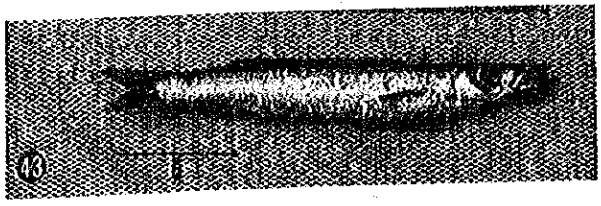
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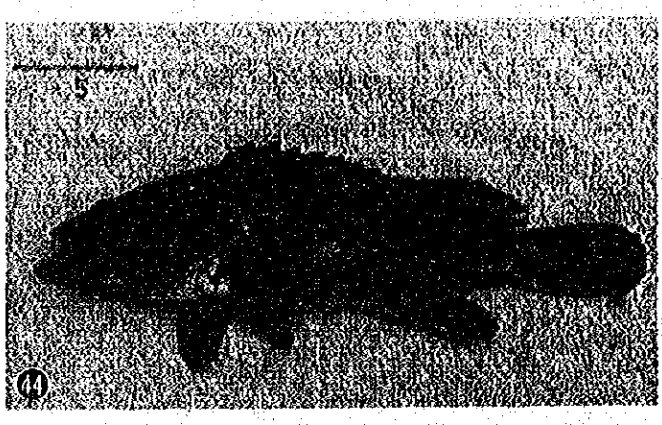
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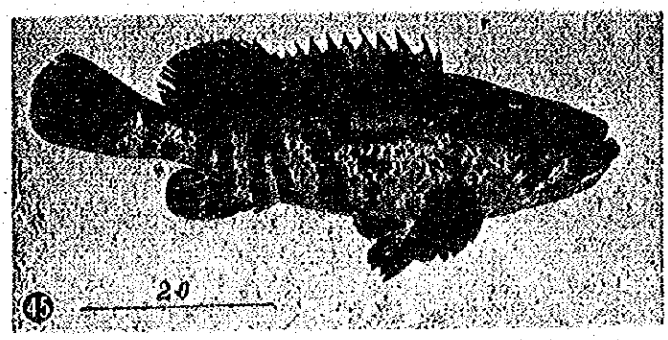
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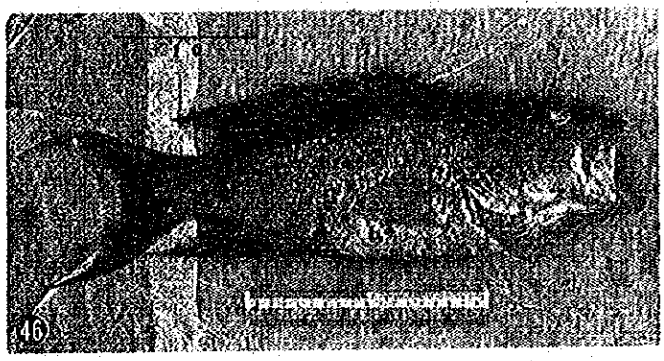
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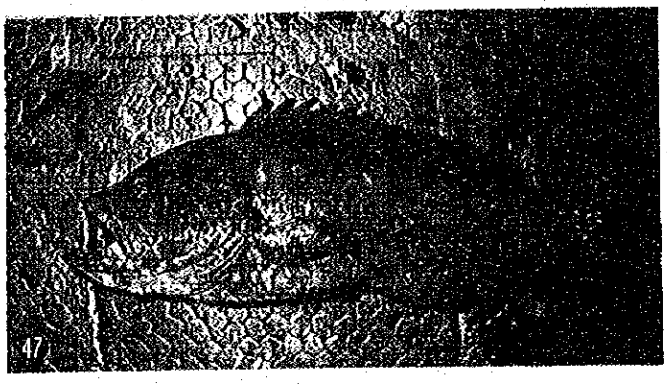
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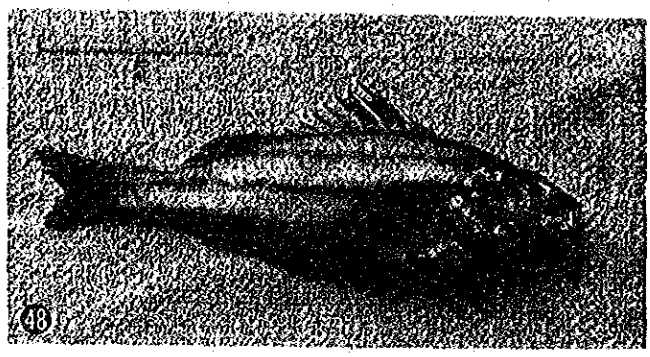
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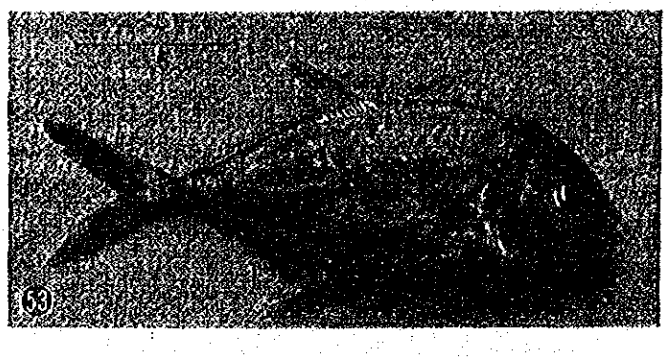
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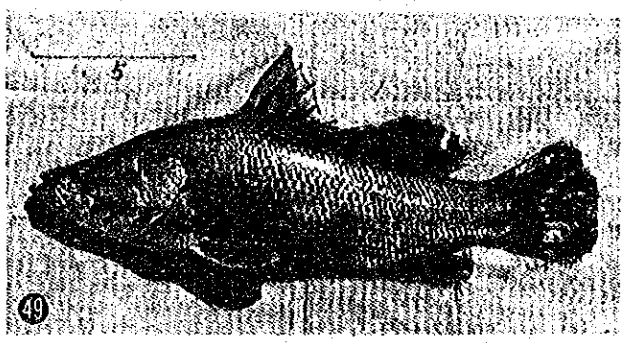
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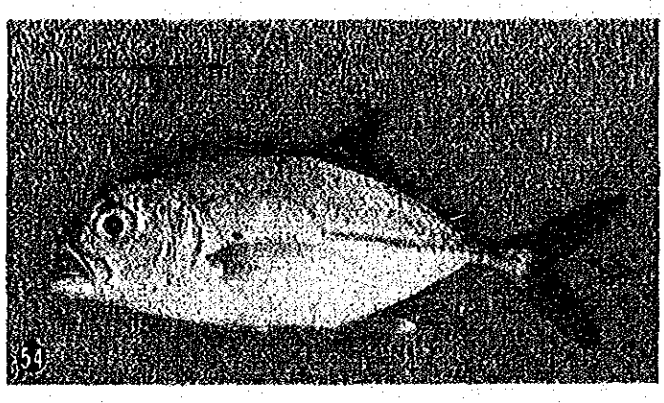
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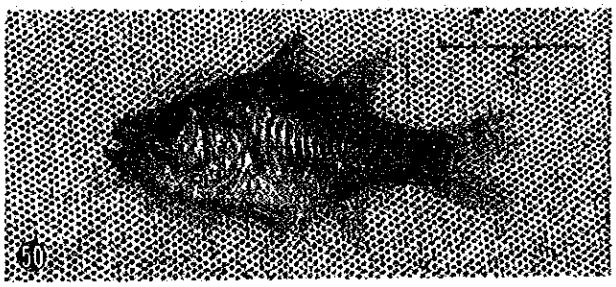
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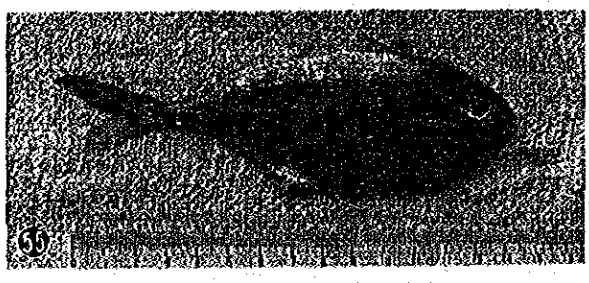
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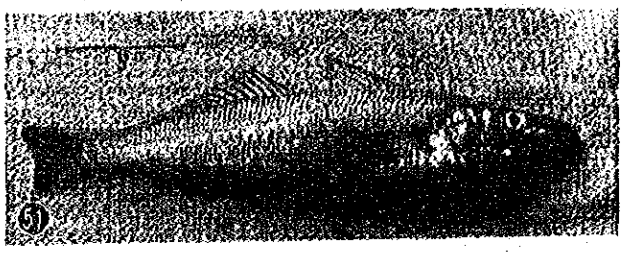
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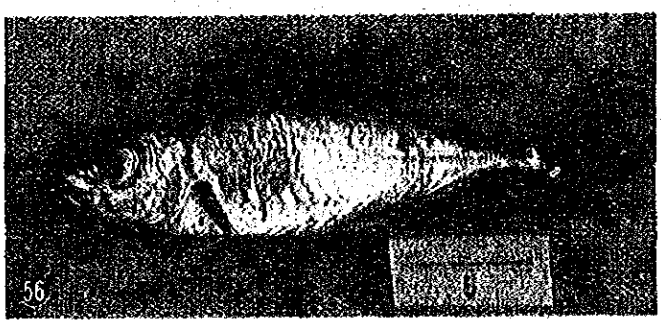
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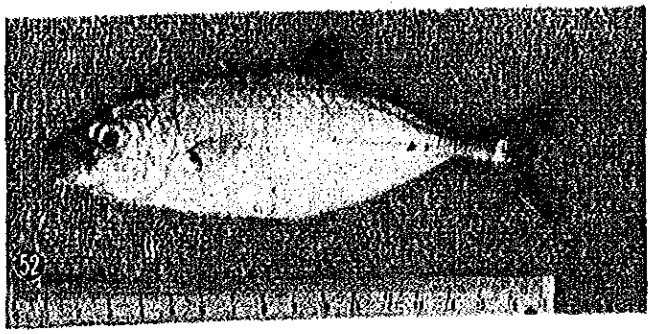
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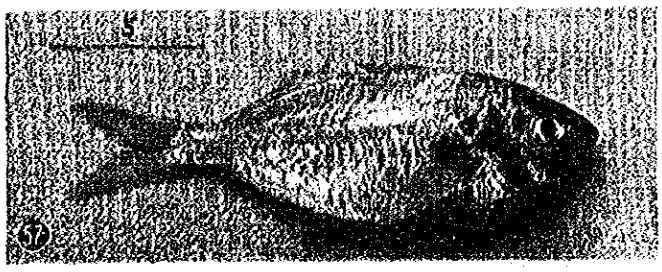
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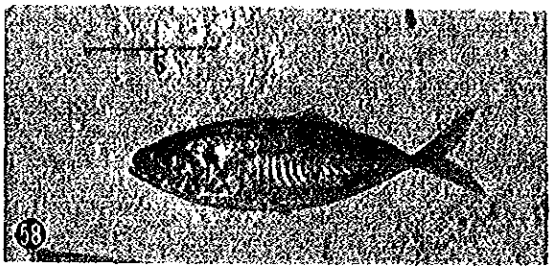
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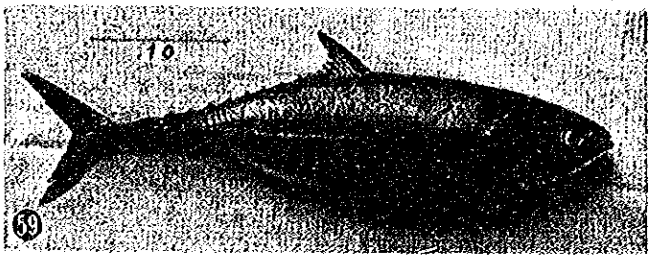
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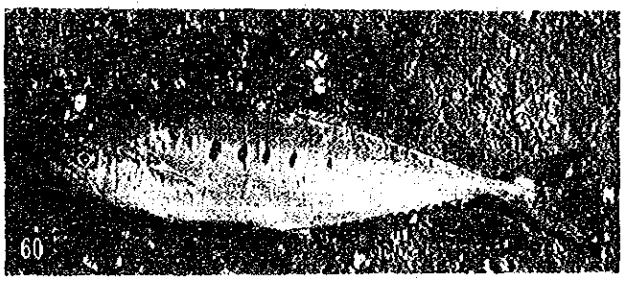
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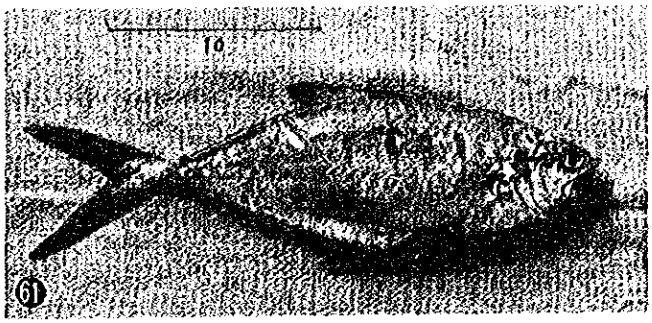
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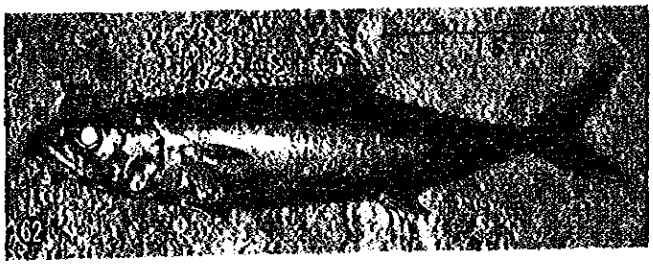
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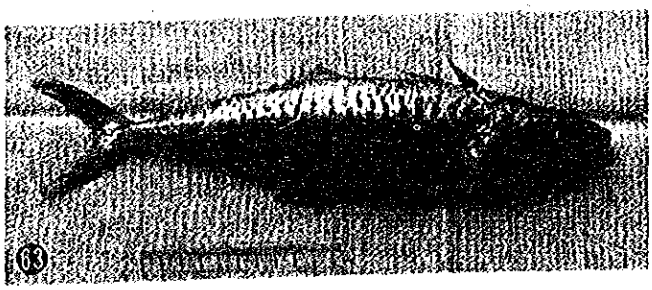
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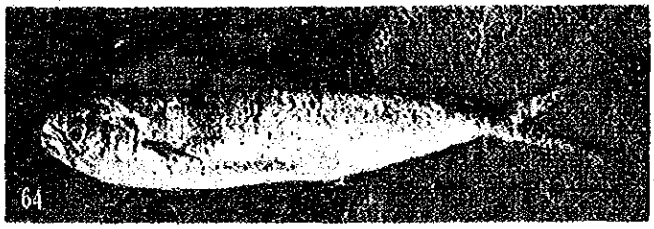
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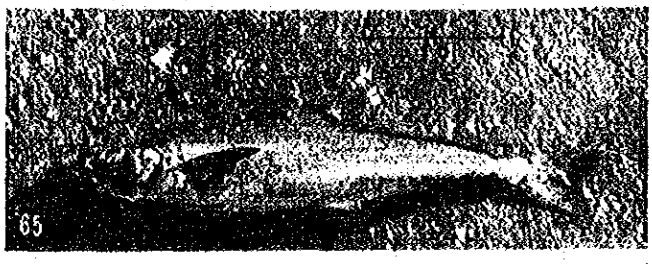
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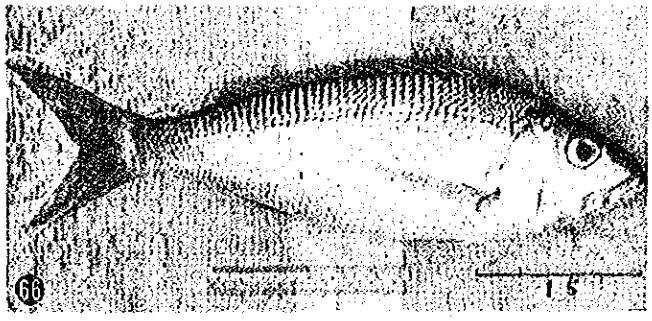
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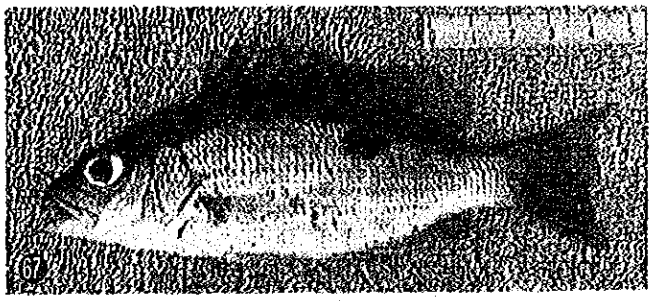
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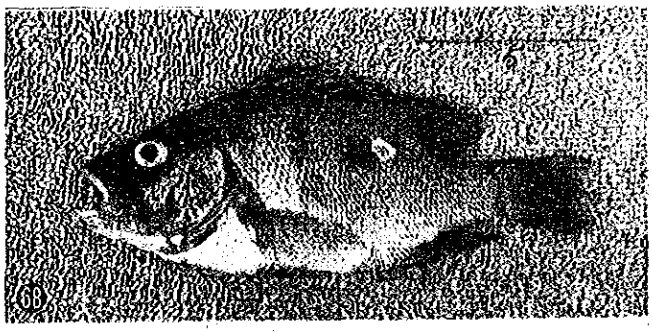
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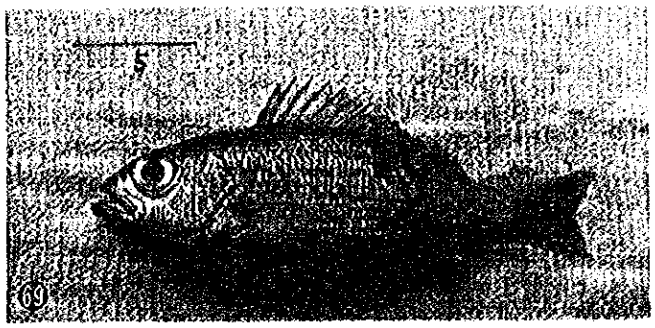
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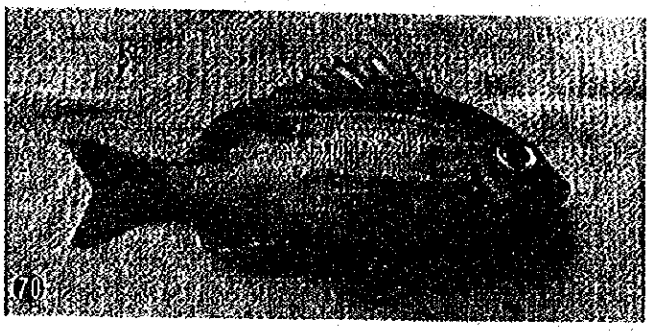

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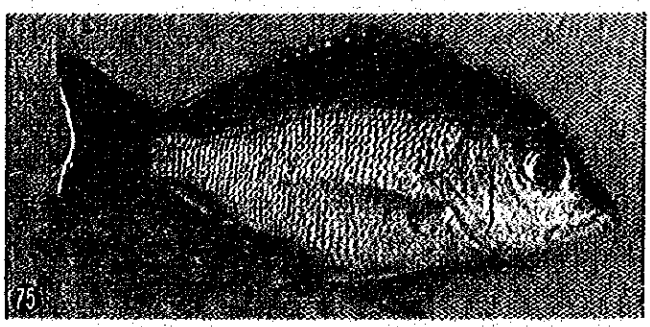

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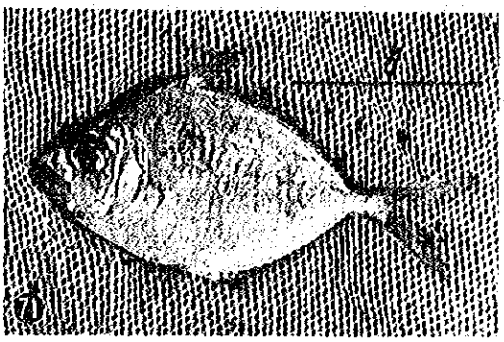

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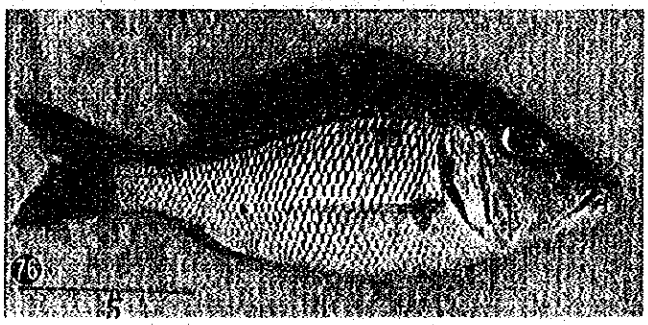

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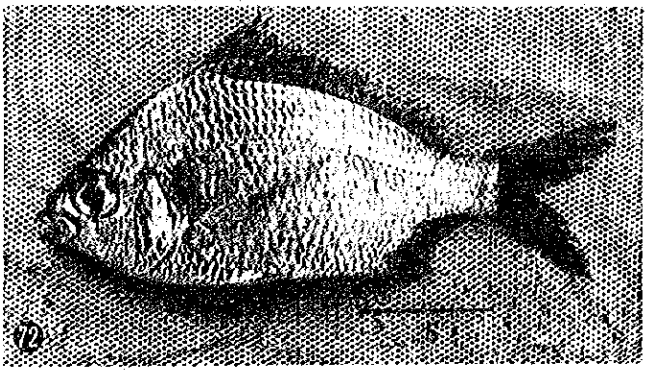

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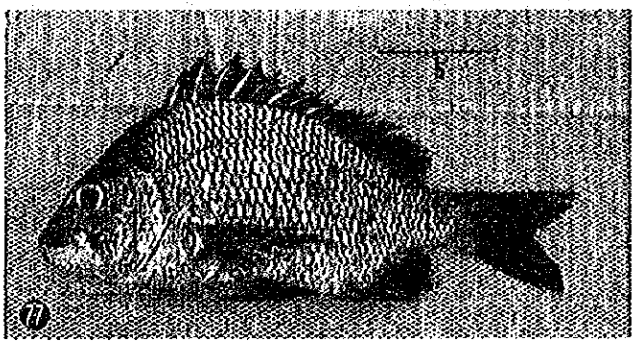

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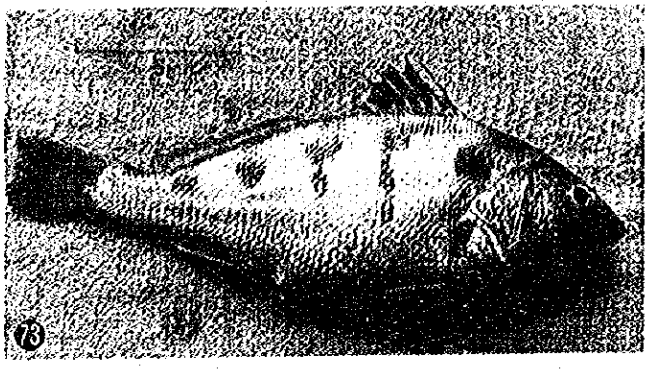

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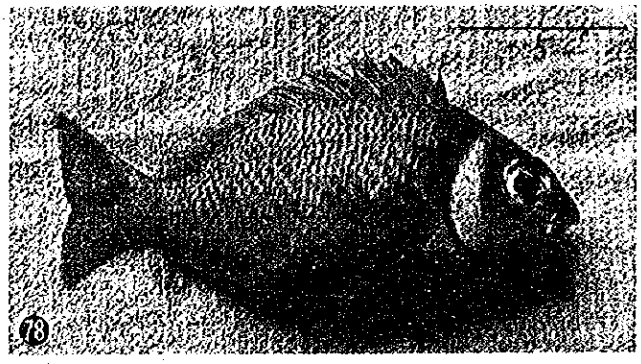

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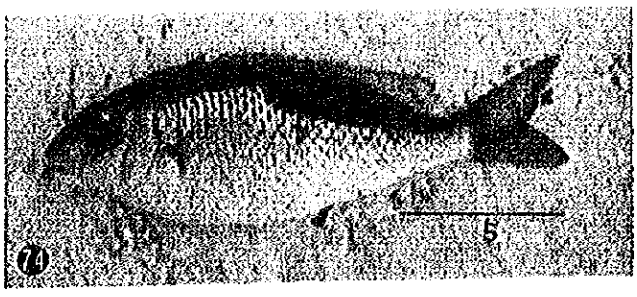

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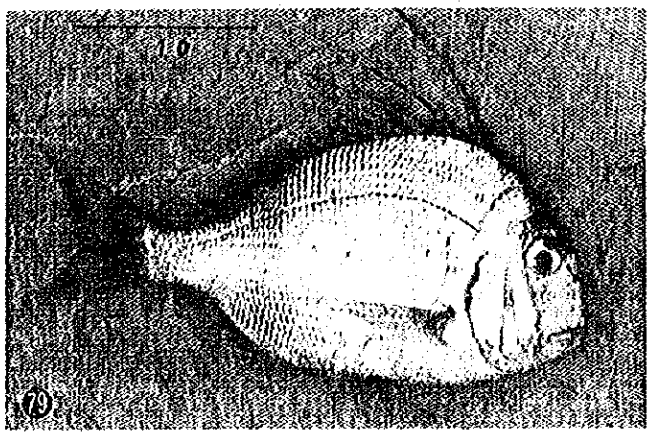

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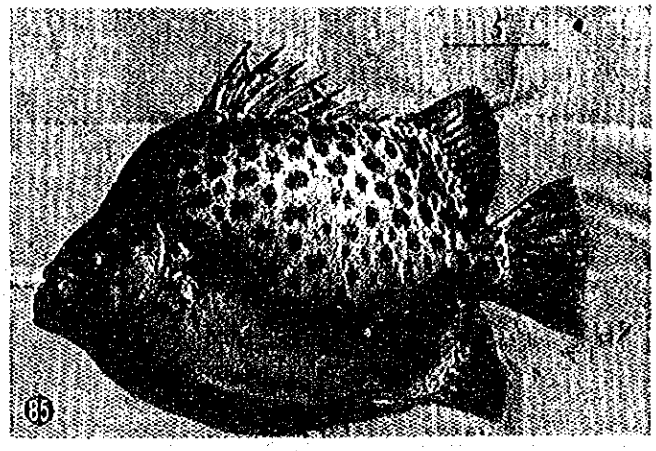
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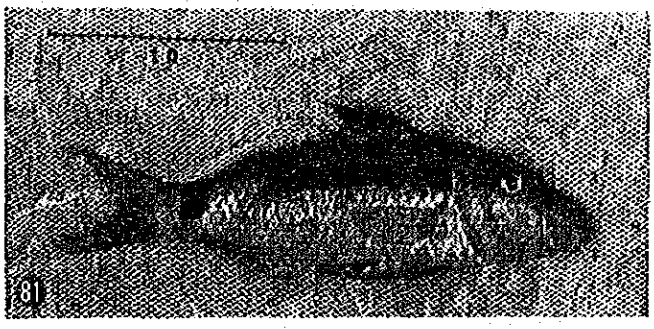
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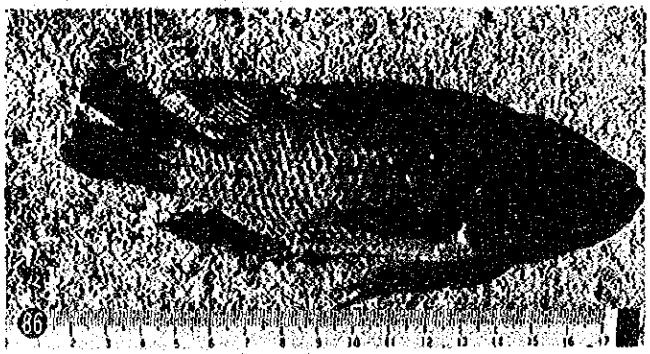
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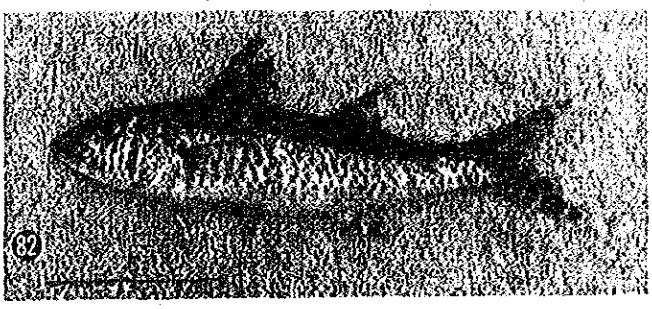
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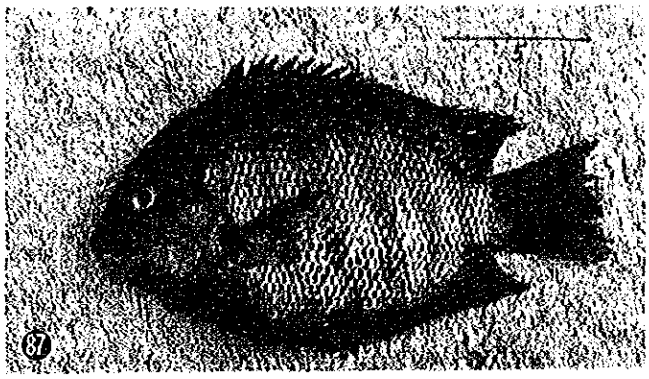
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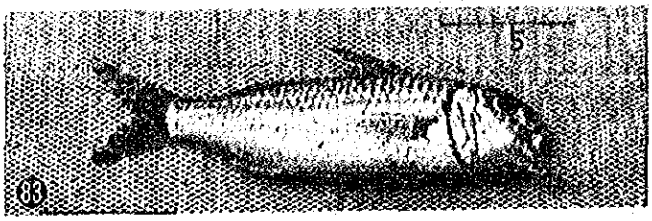
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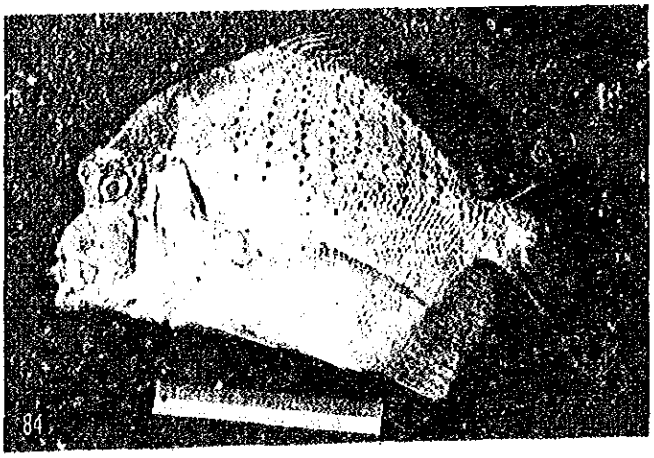
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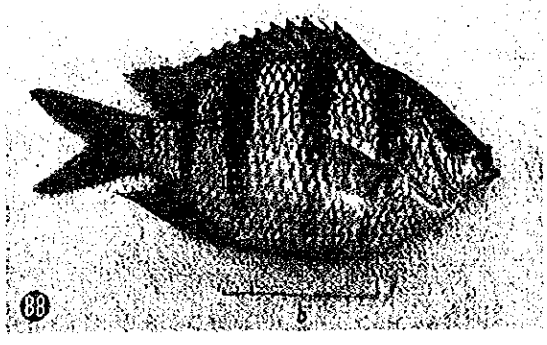
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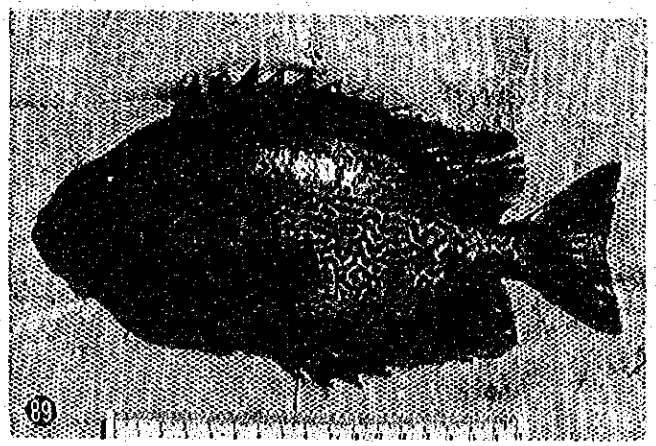

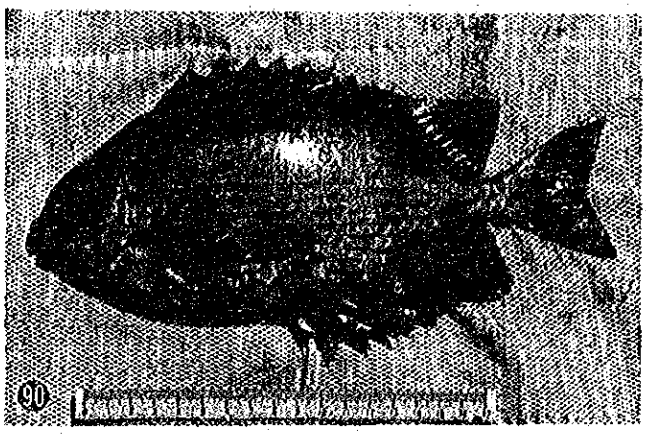

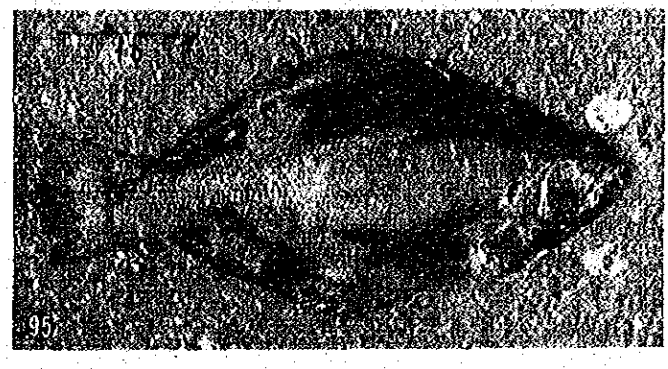

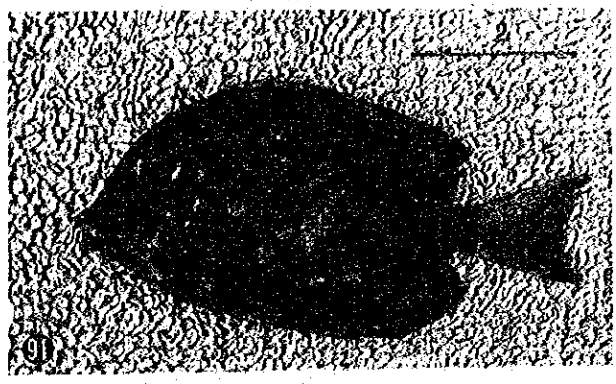

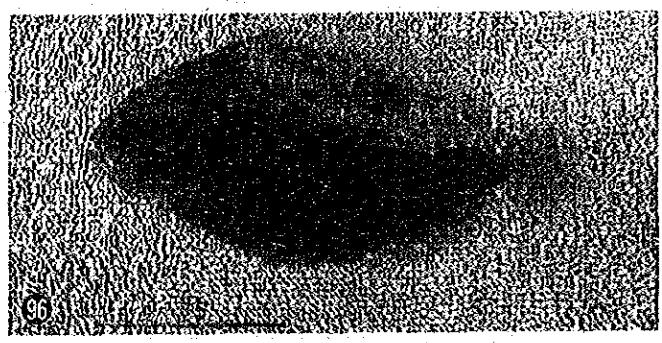

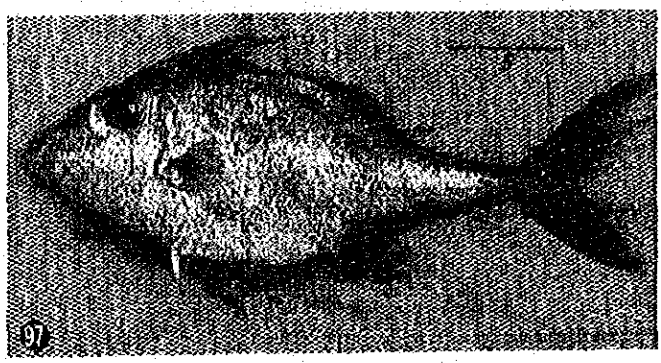

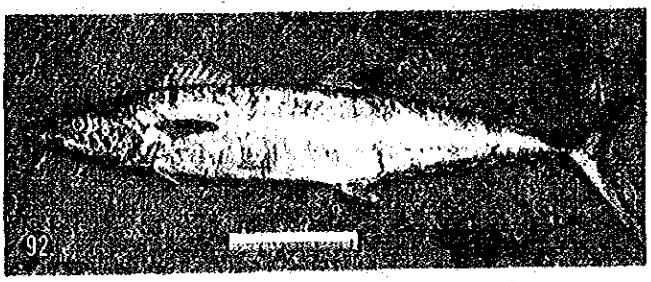

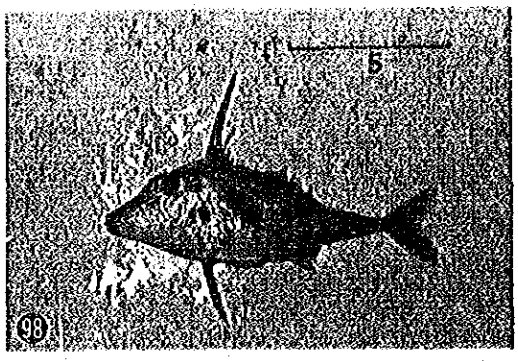

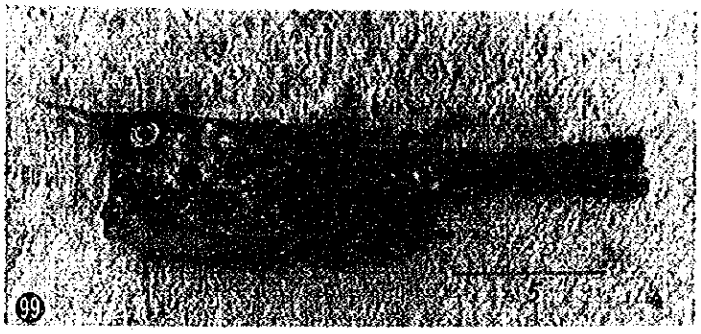
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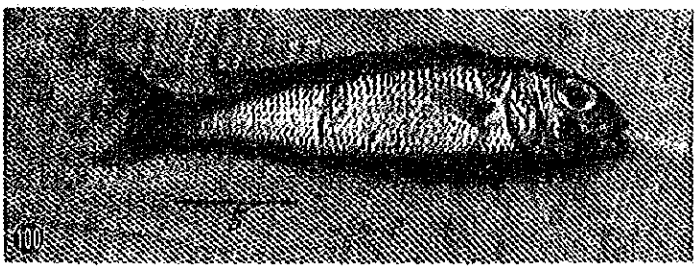
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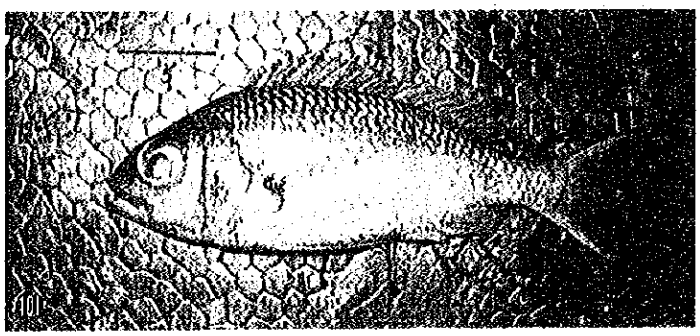
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