

UNDERWATER ECOLOGICAL OBSERVATIONS IN THE GULF OF MANNAR OFF TUTICORIN

VII. GENERAL TOPOGRAPHY AND ECOLOGY OF THE ROCKY BOTTOM

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INTRODUCTION

It is evident from the valuable reports on the fauna and flora of the Gulf of Mannar, brought out in 1903-1906 by Herdman and others as also from the contributions of Thomas (1884), Thurston (1894), Hornell (1922), Gravely (1927) and Pearson *et al.* (1929), to mention only a few, that this area is remarkable for its richness and variety of fauna and that the inshore sea-bottom in the Gulf forms an ideal habitat for the growth of the shell fishes which sustain a good fishery. The records of observations made along Ceylon coast during the latter part of 1904 by Hornell (vide Herdman, 1905) revealed that considerable changes took place periodically in regard to the biological and physical conditions of the sea-bottom there. As for the Indian side many years have lapsed since Hornell (1922) gave his first evaluation of the faunistic conditions and idea of the habitat of the economically important molluscs of the Gulf of Mannar. It was not known since then whether any notable changes had taken place, in the length of time that had elapsed, here also like its counterpart off the Ceylon coast and if so to what extent. An opportunity arose in 1961 when the F.A.O. sponsored a collaborative scheme for conducting direct underwater observations using SCUBA (Photographs 1 & 3) to study the area between 10-27 metres depth off Tuticorin. In addition to carrying out the above collaborative work assigned, we were able to conduct some biological observations of our own on the fauna of the rocky bottom, managing to get some extra time on many days after the main work was over. Many of the interesting observations made by us have been serialized and published already and in this last paper in the series some more observations are recorded and the impressions gained by us are presented so that it would serve as a guide-line for future workers. Detailed report of the main work of underwater survey done in collaboration does not fall within the purview of this paper and should be expected elsewhere at a later date.

METHODOLOGY

For purposes of convenience the area under observation was divided into (1) *Northern zone*, between Lat. 8°45' N-8°55' N and Long. 78°10' E-78°25' E. (2) *Central zone*, between Lat. 8°35' N-8°45' N and Long. 78°10' E-78°25' E and (3) *Southern zone* between Lat. 8°25' N-8°35' N and Long. 78°10' E-78°25' E. The commencement of the 10 metre depth zone beginning due east of Devil point beacon

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off Tuticorin was taken as 'O' point for reference and the imaginary straight line projected further due east of this point up to the 27 metre depth zone was considered as the 'O' point first line; incidentally this coincided with Lat. 8°45' N. With reference to this line the area was divided into the three zones already mentioned. Each zone was again split into 30 parallel lines (E-W), equidistant at 600 metres intervals. The observations in the above zones were planned in such a way as to cover one zone after the other. The work was done in two stages in each zone. During the initial stage the area to be studied was buoyed daily or once in two or three days. For this purpose, bamboo spar-buoys suitably weighted were kept in a motor launch to which was fitted a patent log operating from the stern, to denote the distance travelled by the launch. At intervals of 600 metres a colour flagged buoy was laid out (Photograph 2). This pilot launch was followed by another from which dives were made. This scheme of work involved as many as 3-4 sea trips for the completion of each line. A cursory look of the sea-floor between 10-27 metres was done in all the 30 lines of each zone diving at intervals of 600 metres so as to get an idea of depth at various points, nature of bottom and other useful particulars. Dives were made in the shallow water during this stage by means of skin-diving using masks and fins (Apnea). Beyond 18 metres quick aqua-lung dives were necessary. Based on the data gathered thus, detailed study of only the rocky places encountered in each zone was made during the second stage with particular reference to the fauna. Flagging of chosen areas was done at 300 metres intervals because of the close observations to be made. All dives during this period were made with aqua-lung only. The duration of each dive varied from 5 to 50 minutes depending on many factors like the density of fauna and flora to be observed and studied, water clarity, time spent in photographing the habits and habitats of animals etc.

The diving work off Tuticorin was possible only during November-May (i.e.) N.E. monsoon period when as a rule the water remained clear and fairly calm in the Gulf. Detailed study of the rocky areas in depth less than 12 metres had to be left out altogether because of the permanent turbidity which prevailed there even during the days when good clarity of water existed elsewhere in deeper areas. Contrary to expectations the southern zone had to be dropped out of the schedule. Perhaps it may be possible to study this zone at a later date.

CENTRAL ZONE

15 localities of rocky bottom—*paar—became evident from the survey observations, occupying an area of 30 sq. km. in a total of 363 sq. km. sea floor investigated. The largest 'paar' was located running north to south in the offshore region between lines I to X (Fig. 1). It was seen as a southward extension of a continuous rocky bed lying in the northern zone. The second area of importance lay between lines XXIV-XXX on the shoreward side, running north to south. This again was noticed to extend still further south which would be further investigated at the time of detailed study of southern zone. Two other 'paar' smaller in size than this were seen close to this. It was clear that except for the area between lines XV-XXII, all other lines in one place or other, were traversed by rocky outcrops either in the shoreward region or in the offshore region. The shoreward region between lines XV-XXI was unusually deep in many stations and perhaps indicated the muddy gully off Pinnakayal village at the mouth of the river Tambarparni.

* 'Paar' is the local terminology used to denote the rocky sea floor. Hence this expression is used throughout, hereafter for the sake of convenience.

The general physical features and faunistic characteristics on the 'paar' appeared to be the same throughout. However, here and there interesting differences did exist. It was felt desirable to describe the general pattern of fauna and flora for the region as a whole instead of station-wise account. For this purpose the 15 rocky localities were brought into 5 groups (Fig. 1, Nos. 1-5) so as to get a representative account of the conditions in the shoreward and offshore side in the upper, middle and lower regions of the central zone.

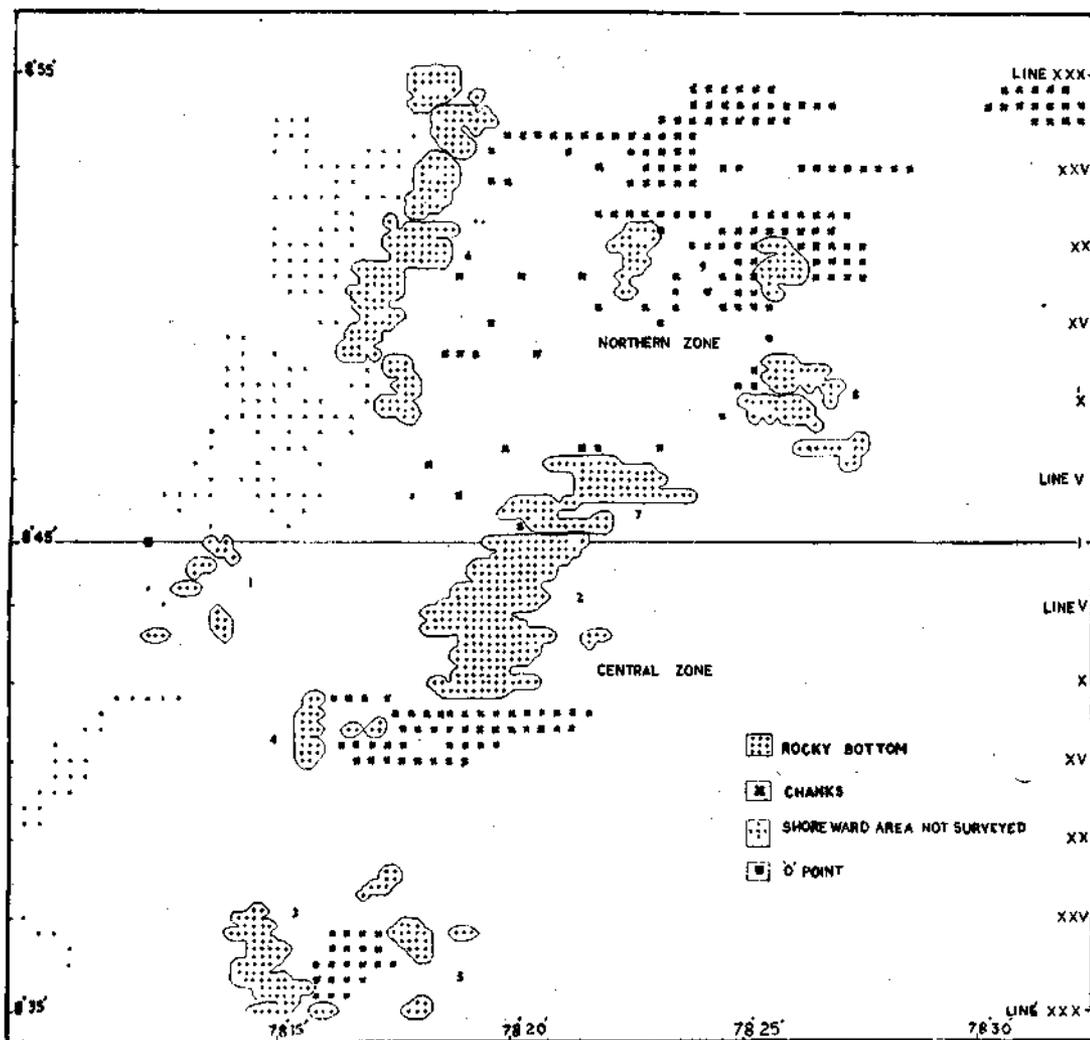


FIG. 1

Chart showing the 'rocky bottom' and the contour of the rocky sea floor in the North and Central zones of the sea off Tuticorin in the Gulf of Mannar.

Group 1: Several dives were made in the area but only in 21 stations the substratum was found to be of 'paar' and sand. The floor was essentially of sand grains of coarse nature but appeared to have been broken up by a multitude of rocky

outcrops of loose blocks of calcrete of various sizes ; elsewhere fragments of corals. Faunistically this area did not seem to be rich, the intimate intermingling of rock and sand upon the paar might have produced effects, when the sea was disturbed, which but comparatively few species of animals can tolerate. Characteristic of the organisms was the growth of the coral *Heteropsammia* sp. The sponges were sparsely found. But predominant amongst them were *Siphonochalina communis* (Carter), *Spongionella nigra* (Dendy) and *Suberites inconstans* Dendy. Zoophytes were abundant with many colonial masses of *Filigrana* tubes and everywhere the curious branched tubes of *Eunice tubifex*. The growth of the gorgonid *Juncella juncea* Pallas was also seen here and there. *Pinna* sp. was seen in fair numbers lying buried almost with only the sharp edges projecting above the sand. *Rhabdocynthia pallida* (Heller) was occasionally met with as also colonial ascidians *Pyrosoma* sp. grown over rocks and sponges. Among the echinoderms a few *Clypeater humilis* (Leske) tests were noticed at random. Except for an occasional block of *Montipora foliosa* and *Turbinaria* sp., live corals were scarce.

Modiolus barbatus Linn. and *M. metcalfei* Wood were seen here and there as also the chanks (mostly small ones less than 55 mm. diameter whorl) in the adjacent sandy stretches.

The algal flora was thin except for the growth of *Hypnea* sp., *Gracillaria* sp. and *Halophila ovalis* (R. Br.) J. D. Hooker in patches. The calcareous sea-weed *Halimeda opuntia* (L.) Lamx. was seen in some places.

Among the fishes inhabiting the area, *Scolopsis vosmeri* (Bloch), *S. bimaculatus* Rüppell and *Abalistes stellaris* (Bloch) were present in fairly good numbers. *Saurida tumbil* (Bloch) and *Upeneoides* spp. were seen in the area where sand proportion was greater. Large sized fishes were rare, perhaps due to the absence of deep pits or massive coral blocks.

For a greater portion of this area the clarity was poor at the bottom and the oscillation of water at the bottom was also fairly much. Although the hard surface of the bottom might afford facilities for pearl oyster settlement, the other two factors mentioned above would seem to be detrimental for the healthy survival of oysters as well as for the good formation of pearls.

Group 2 : This was by far the largest area studied and was in the northern side of the Central zone, the others lying down south or westwards towards the shore. The formation was in a south-east to north-east direction and extended 6 km. in length and about 4.2 km. in breadth in its broadest region, covering an approximate area of 19 sq. km. The depth in which the ' paar ' was located varied from 17-21 m. Occasionally an extension towards the east of the rocky face was met with in depths ranging from 23-25 m. as noticed in the case of lines II, VII and X. The ' Paar ' was surprisingly continuous without any large sandy track intervening. The sizes of the outcrops differed greatly from tubular fragments, rocks of a metre or two across to great areas of a kilometre in extent. The sand covering it was nowhere more than 20 cm. in depth, filling up the hollows and many crevices in the rocky framework of the bank. Although thus silted the hard nature of the bottom was indicated by the growth at a number of places of gorgonids, *Juncella juncea* Pallas and the giant sponge *Petrosia testudinaria* (Lamarck). The rock was fine-grained limestone, compact and resonant with brownish black colour. The sand was also fine grained and mostly calcareous, a similar material to that from which the underlying rock had originated. The live coral area was demarcated by means of a low

fringe running along the 18-19 metre depth on the eastern face of the 'paar'. Perhaps the silting noticed in the shoreward face (west) of the area had a hand in the live corals confining to the eastern side. Cultch was fairly abundant in places, scattered over the area. Broken and worn-out fragments of pearl oyster shells, cockles, *Pecten* sp., *Cardium* sp., *Conus* sp. etc. were scattered about in great profusion. Balls of nullipore (*Porolithon* sp.) from the size of a nut to that of a lime were lying on the edges of rocky expanse. All through the length and breadth of the 'paar' were a number of pits ranging from 0.5-1 m. diameter to equal depth. Such pits were inhabited by a number of small and large fishes, eels, lobsters and octopi. The general set-up of the area was considered ideal for the settlement of pearl oyster. The area surveyed presented a variety of animal life and plant life and the clarity in the region exceeded 15 metres on most days. This enabled easy observations on the general faunistic conditions of the area; an account of which may be found below :—

**Sponges* : Concentration of sponges was very high in most of the stations studied, especially in the upper regions of the area. The predominant species were *Iotrochota* sp., *Siphochalina communis* (Carter), *Spongionella nigra* (Dendy), *Aulospongos tubulatus* (Bowerbank), *Axinella donnani*, *Petrosia testudinaria* (Lamarck), (Photograph 8), *Clathria indica* Dendy, *Pachychalina subcylindrica* Dendy and *Axinella carteri* Dendy.

There were other species of *Auletta*, *Hircinia*, *Spirastrella*, *Suberites*, *Raspailia*, *Placospongia* and *Cliona* which were met with often.

Coelenterates : The area was rich in coelenterates with a conspicuous growth of anemones, alcyonarians and gorgonids. Live corals were found in the outer fringe and it was surprising to find that nowhere in the area were the species of *Acropora* represented. Commonly, *Favia* sp. (Photograph 6), *Montipora* sp., *Turbinaria* sp., *Goniastrea* sp., *Pocillopora* sp. were seen. Wherever live corals were seen (Photograph 7) the area was much animated with fishes of attractive colours like labrids, pomacentrids, chromides, balistids, scarids, pomacanthids, chaetodonts, and serranids. Amongst sea-anemones the most common was *Stoichactis giganteum* (Forsk.). Next in importance were the solitary corals of *Fungia* spp. which were found distributed all over. *Dendrophyllia* sp. and *Fungia dentigera* Leuckart were recognised. The latter always on hard rock while the former two were found on sand spread over 'paar'. In some places *Heterocyathus* spp., *Lobopsammia* sp. and *Trochocyathus* sp. were also found growing on rock and chank shells.

Some of the fleshy alcyonians were very common on the rock covered with calcareous sand. *Sarcophytum*, *Sclerophytum*, and *Lobophytum* spp. were commonly seen. *Spongodes* sp. and *Solenocaulon* sp. thrived well in the area playing host to a variety of commonsals like alpheids, porcellanids, ophiuroids, shrimps and small gobids. The gorgonid *Juncella juncea* Pallas were noticed occasionally. The growth of hydroid colonies were limited mostly to *Lytocarpus* spp.

Molluscs : The area was rich in molluscan fauna. Noteworthy among the bivalves were the *Pinna* spp., *Malleus* sp. and many species of *Pecten*. Pearl oysters, *Pinctada fucata* Gould [= *Pinctada vulgaris* (Schumacher)] were few and far between all lying loose near and under crevices and fissures (Photographs 11 & 12). Many had lost their byssus which might mean that the oysters had reached advanced stage of growth. Oyster spat were few and never in cluster.

* We are grateful to Shri P. A. Thomas, Research Scholar C.M.F.R.I. for confirming the identification of most of the sponges.

Modiolus spp. (local name 'Suram' or 'Suran') had settled down over the entire area enveloping the floor, wherever such settlement was noticed, like a mattress. This feature was not noticed during the I stage of the work thus obviating that the settlement had taken place subsequently (December-January 1962). This prolific growth seemed to have had the effect of smothering many of the pearl oysters seen earlier as evidenced by the shiny fresh nacreous layer of the pearl oyster shells recovered which lay buried in the mattress of *Modiolus* spp. By the end of May 1962 the *Modiolus* spp. themselves had perished and were being washed away by the current over the adjoining sandy areas. It was feared, therefore, that the settlement of *Modiolus* spp. albeit a short period might have had deleterious effects on the existence of the general fauna itself, not to mention oysters alone. The observations of workers like French (1860), Jeffreys (1867), Wicks (1884), Herdman (1906) and Hornell (1922) are of great interest in this regard (vide Discussion).

Live shells of *Cypraea* spp. *Conus* spp. were found in good numbers. Large-sized *Cypraea tigrinus* was rare while *Xenophora* sp. was commonly seen. *Turbo* and *Trochus* spp. were totally absent. Shells of *Pteria* spp. wherever collected were all found on the sea fan or attached to the gorgonid and great numbers were seen in the 20-22 metres depth limit and beyond. *Pteria penguin* (Roding) which had been recorded off Tuticorin by one of the authors (Mahadevan, 1962) was not seen within 25 metres depth limit. Amongst the Scaphopod mollusc, the occurrence in good numbers of *Dentalium formosum* was noteworthy. Occasionally *Murex ramosus*, Linn. the so-called 'elephant chank', was found in some places. Captain Steuart (quoted by Hornell, 1922) considered this animal as an enemy of oysters. But as expressed by Huxley (1864) we also feel that their numbers are too few to exercise any bad effect on the well-being of oysters.

A variety of ophisthobranchiate molluscs were seen in different habitats, on seaweeds, dead shell valves, on crinoids or on sand with admixture of sand or underneath coral blocks. Species of *Eolis*, *Hervia*, *Pleurophyllidea*, *Discodoris*, *Thordisa*, *Halgerda*, *Phyllidea*, *Platydoris*, *Chromodoris* among nudibranchs, *Philene aperta* and *Notarchus* sp. among tectibranchs were all common. It was of interest to note that *Dolabella* sp., *Aplysia* sp. or *Onchidium* sp. were not noticed so far in this area.

The commercially important gastropod, *Xancus pyrum* (Linn.) was found in fair numbers in the sand track adjacent the rocky area. During the three months from January-March chank egg capsules occurred in and around this area. Special observations made on the chanks on their movements, breeding habits etc., had been separately published by the authors. Baby chanks were not noticed anywhere on the sea floor. Either they were present but not noticed because of their very small size or they lay superficially buried under the sand which might afford them protection from enemies.

Hornell (1922) had shown two chank beds of moderate expanse on the shoreward side of 'Tholayiram Paar' (incidentally the area under review happened to coincide with the southern and middle portion of the Tholayiram paar of Hornell). The observations brought to light chank beds of an average breadth 5.25 km. and length of 2 km. thus occurring over an area of 10 sq. km., bound within depths of 17-25 metres. Apart from this regular bed, chanks were found at random towards the fringe of this group at depths of 14-15 metres. Most of the chanks encountered between 17-20 metres depth seemed to be undersized (below 55 mm. diameter for purposes of commercial exploitation). The wormed chanks did not appear to be

much. The chanks that lay between 23-25 metres were large ones and the area was well populated.

Octopus (*Polypus* sp.) were common in pits and crevices. Great number of empty and broken oyster shells found in crevices and faults in the rock haunted by the octopus posed the question as to whether they were one of the enemies of oysters. On many occasions octopi were noticed opening the shell valves of the oysters with the help of the suckers in the arms. Many shells found near the holes were still bright and shining thus evidencing as to the death of the oysters only a few days before.

***Echinoderms :** The fauna was found to be lacking in abundance as a whole. By far the crinoids were the most abundant found attached to the gorgonids, under coral blocks or on sponges. Prominent amongst them were *Lamprometra palmata palmata* (Muller) and *Comanthus annulata* (Bell) (Photograph 9). Common among the holothurians were *H. edulis* (Lesson), the pink coloured sea-cucumber very characteristic of the pearl banks and the synaptid *Chondrocloea striata* Sluiter. It was rather remarkable to note *H. scabra* Jager was not met with in the entire area surveyed and *H. atra* Jager was found living on the sandy edge of the 'paar'. Of the sea-stars *Protoreaster lincki* (Blainville) was the most common (Photograph 11) although *Pentaceraster affinis* (Muller and Traschel) *P. hedimanni* (Lutken) or *P. indicus* were also rarely met with (Photograph 10). In the northern region of this group of 'paar' they were thinly populated whereas further south, along the shoreward edge of the patch they were more. But at no place the number exceeded one or two per hundred sq. m. Other sea-stars of interest were *Pentaceraster multi-spiralis*, *V. Martens*, *Linckia laevigaeta* (Gmel.) and an occasional specimen of *Culcita schmideliana* (Retz), *Echinaster purpureus* (Grey), *Pentaceros nodosus* (Grey) and *Astropecton indicus* Doderlein.

Of the cake-urchins, the most common was *Clypeaster humilis* (Leske). *Echinodiscus auritus* Leske and *Laganum depressum* Less. were seen on sand covering the rock. Amongst heart urchins *Echinolampus ovata* (Leske) was seen at random. Of the sea-urchins *Salmacis bicolor* Agass. and *S. sulcata* Agass. were the common forms. Of the ophiuroids found amongst the sponges or under the rocks *Ophioneries dubia* (Muller & Traschel) was the common form.

Fishes : All over the rocky bottom fishes were found abundantly. Since observations were mainly directed towards the most conspicuous amongst them no effort was made to prepare and present an exhaustive list of all fishes. *Abalistes stellaris* (Bloch), *Sufflamen capistratus* (Shaw), *Odinus niger* (Rüppell), *Scolopsis bimaculatus* and *S. vosmeri* were the most common. Large fishes like *Gaterin schotaf* (Forsk.) (Photograph 17), *Enneacentrus miniatus* (Forsk.) (Photograph 14), *Epinephelus malabaricus* (Schneider) were seen in places where pits were present *Chaetodon* spp., *Heniochus acuminatus* (Linnaeus) (Photograph 18), *Zanclus cornutus* (Linnaeus), (Photograph 19), *Pterois miles* (Bennet) (Photograph 15), *P. volitans* (Linnaeus), *Lutjanus sebae* (Cuvier), *Lethrinus nebulosus* (Forsk.), and *Pomacanthodes annularis* (Bloch) were mostly seen in areas where live corals thrived (Photograph 16). These fishes either were found hovering over the corals or perching underneath or on the sides of the coral reef columns. It may be of interest to note that species of Scaridae, Lutjanidae and Lethrinidae did not seem to be abundant in the area.

* We are thankful to Shri D. B. James, of the C.M.F.R. Institute for the identification of most of the echinoderms.

Among the eels inhabiting the large pits were *Gymnothorax undulatus* (Lacépède) and *G. punctatus* (Bloch and Schneider).

Except for *Galeocerdo cuvieri* (Le sueur) and *Eulamia melanopectera* (Q & G) (both very rarely seen) no shark was noticed. Equally scarce was the incidence of skates and rays. *Rhinoptera javanica* Muller & Henley was occasionally seen at the surface only. Never during the day time did we see large number of any of the elasmobranchs as to support the contention that they were abundant over pearl banks constituting a threat to the rocky fauna in general and the pearl oysters in particular.

Sea-weeds: Throughout the rocky area surveyed the density of algal vegetation seemed to be moderate especially in the outer (eastern) edge of this patch between 17-25 metres. The brown algae dominated throughout (Photograph 5) although a more balanced growth of green and brown algae were noticed in the western edge.

Gracilaria edulis (Gmel.), *Hypnea valentiae* (Turn), *Padina* sp., *Sargassum wightii* (Grev. & Mscr.) Ag., *Spathoglossum asperum*, J. Ag., *Gelidium* spp. and *Polysiphonia* sp. were mainly noticed. Amongst the calcareous sea-weeds *Porolithon* sp. and *Halimeda* spp. were found in greater profusion in deeper water than in the shoreward rocky area.

Group 3: Compared to the group 2 this was a very small rocky area lying shoreward, met with at about a distance of 11-12 km. off the Pinnakayal village. It was a compact area of 2.4 km. length and 1.2 km. width. Another small patch was seen separated from this roughly of an area of 0.36 sq. km. (1.2 km. long and 0.3 km. broad). This was for all practical purposes, considered as a continuation of the larger one. The patches lay in depth between 17-18 metres.

The 'paar' here was covered with much sand, concealing in many places the flat surfaced rock. Everywhere was found lot of cultch with considerable amount of water-worn coral branches called locally 'Challi' and *Porolithon* sp. ('Uruttu'). The sandy region astward of this 'paar' was rich in chanks and plenty of ascidians, *Rhabdocynthia paleida*. The sandy area adjacent to this 'paar' was a good ground for collecting *Amphioxus* sp.

The usual massive sponges *Iotrochota* sp., *Siphonochalina communis*, (= *Callyspongia*) *Suberites inconstans* and *Spongionella nigra*, and a few *Petrosia testudinaria* were met with on the outer fringe. Good number of *Pinna* spp. (*Pinna atropurpurea*, *Pinna bicolor*, *P. vexillum*) were found growing all along the length and breadth of 'paar'. Attached to the *Pinna* shells were found quite a number of pearl oyster spat.

Many dead oyster spat were also found all over, under the matrix of the *Modiolus* spp. which proliferated in this area also. This feature augured bad for the remaining live spat. Also majority of the dead oyster shells were found enveloped in the encrusting mass of the sponge *Clathria indica*.

The coelenterate life was not much in evidence except for a few live corals, *Fungia* sp. and occasional *Solenocaulon* and the gorgonid *Juncella gemmacea*.

Salmacis bicolor, *S. virgulata*, *Clypeaster humilis*, *Protoreaster lincki* and *Linckia laevigaeta* were found over the area, although the first two were common,

Dentalium formosum, *Bulla ampulla* and *Oliva* sp. shells were seen in few numbers. Algal growth seemed less dense and mostly represented by *Sargassum* sp., *Gracillaria* sp., *Hypnea* sp. and *Cystophyllum* sp.

The sandy tract which existed east of this group was found to be a rich chank ground and of an extensive nature.

Groups 4 & 5: A series, stretching north and south, of six small banks lying within 8-9 km. off the coast of Pinnakayal and Kayalpatnam. The banks showed some diversity in appearance made of compact and solid coral stones. The bottom was cut up by intervening sandy stretches. Dead corals were common. The sand was fine grained and passed gradually into a chank bed consisting of silky sand. On the surface of the rock, foraminiferan shells (*Orbitolites* sp.) were found very commonly; elsewhere the sand grains became frequently coarse and occasionally graded into a distinct gravel. Much of the bottom was well culched with *Porolithon* nodules. The proportion of mud present in the sand was much greater than in the case of the other patches. Perhaps this was due to the vicinity of the river Tambarparni. In several places, north and south, were seen eddies, caused by the deflection of the current forming mud deposits.

The faunistic characters were similar to those of group 3. A special feature of the area was the paucity of the sea-weed flora.

NORTHERN ZONE

Out of the 403 sq. km. of area investigated about 30 sq. km. was of rocky bottom. This approximated to 13.5% of the total area of the northern zone. From the map drawn based on the data collected (Fig. 1) two series of rocky substratum came to evidence in this zone. The shoreward formation, on an average 1.5 km. broad, lay between 9-15 metres depth range from line VIII extending in a general N-E direction to a distance of about 6.5 km. It was observed that in 7 or 8 places narrow strips of sand intersected the 'paar' giving the impression of the formation of 7 separate rocky patches. Notwithstanding this, for all practical purposes the entire stretch was considered as a single entity and called group 6. Equally extensive rocky bottom existed shoreward of this group in very shallow waters upto 4 metres. In many places this formation was contiguous with group 6. In view of the fact that the area lying at depth less than 9 metres was always very turbid and unproductive it was decided to skip surveying this area and therefore not taken into account in calculating the percentage of rocky bottom in the entire zone.

The offshore rocky formation, was located within 18-22.5 metres depth range. This series was rather discontinuous, each expanse being separated from the other by means of fine sandy stretches of considerable extent. Of these the 'paar' in the southernmost locality was the largest and was called group 7. This group was the northern extension of the rocky area group 2 described in the Central zone and was located at depth range 17-21.5 metres, from line I-V of northern zone (i.e.) to a distance of 2.5 km. It was as much as 4.0 km. broad, east to west, most of its breadth thus showing the very extensive nature of the 'paar'. Located outer to this in a general north-east direction were three more patches between depth range 20-23 metres from line V-XII. Each of this was, as already stated separated from the other by means of fine sand and nullipores. These three small patches occupying an area of 3.25 sq. km. were grouped into one and called group 8. Group

9 consisted of 2 paars, each of 3.5 sq. km. area separated from each other by intervening chank beds of extensive nature. One 'paar' was situated at 18-19 m. depth range, a little shoreward and the other was located at 21-22 m. depth, about 4.5 km. east of the previous one, just north of group 8.

The main purpose of the grouping of rocky floor was only to bring to notice the broad physiographical feature of the area. So far as the biological aspects were concerned, there was not much significant difference among groups 7, 8 and 9, all of them lying within 17-23 metres. Wherever noteworthy peculiarities were noticed in one or the other group, special mention had been made of them.

Group 6 : Out of 381 stations dived in this area rocky floor was encountered in 190 stations. The 'paar' was of calcrete containing in some places considerable quantity of quartz grains embedded in a calcareous matrix. In most of the places balls of *Porolithon* sp. were found commonly.

The lowermost of the 5 main rocky patches in this group lying within lines VII-XII showed a mediocre fauna consisting of mainly sponges here and there. The flora was very poor. Fishes were conspicuously absent, on the shoreward side. Amongst the sponges *Suberites* sp. and *Iotrochota* sp. were the most abundant. *Spongodes* sp., *Lobophytum* sp. and *Solenocaulon* sp. were the other common fauna of importance.

The next patch which was the largest of the group lay within lines XII-XX and was very significant in that there was a lush of faunistic richness, the most striking of them all being the occurrence in good numbers of *Holothuria atra* in line XII, averaging 3 per square metre. The solitary corals, *Heteropsammia* sp. and *Lobopsammia* sp. were found all over firmly growing on the rocky core beneath, especially along the shoreward fringe of this entire patch.

The eastern fringe of this patch was distinct and was well demarcated in many places because of the elevated rocky edge dropping vertically down to the adjacent sandy ground. The deep undercuts of the shelves at this rock sand interface housed lobsters and varieties of large sized fishes. From line XVI onwards up to the end of this patch dense forest like growth of gorgonids, *Juncella juncea* and *J. gemmacea* was noticed. Many of them harboured crinoids met with on the gorgonids (Photograph 9). This profusion in growth was very marked in line XVI-XVII. Further north also the gorgonids were abundant but lesser in numbers than before. Detailed notes on this have been published elsewhere.

The sponge fauna was very dense and mostly of *Suberites* sp., *Iotrochota* sp., *Phakellia* sp. and *Hippospongia* sp. The algal flora was almost absent. Only decaying *Hypnea* sp. were noticed being washed down by underwater current.

The last three patches lay between lines XXI-XXV, XXV-XXVII and XXVIII-XXX and presented luxuriant flora and fauna. The bottom area consisted of local stretches of continuous rock, black and brownish coloured calcrete. Dead shells, with rounded off edges mixed with bits of *Porolithon* sp. and dead *Halimeda* sp., characterised the bottom.

By far abundance of a variety of sponges was at once remarkable in this area. In addition to the sea-weeds and hydroid colonies the entire sea-floor was covered with the dense growth of sponges (Photograph 4). *Aulospongos tubulatus*, *Phakellia*

donnani and *Siphonochalina communis* with its numerous commensals was amongst the most common. Next in abundance occurred *Iotrochota* sp., *Clathria* sp., *Phyllospongia* sp., *Spongionella* sp. and *Suberites* sp.

Fixed corals were scarce. Zoophytes were profuse with many colonial masses of *Filigrana* sp. tubes everywhere and the curious, branched tubes of *Eunice tubifex*. The sandy region adjacent to the offshore fringe of these three patches were very remarkable for the occurrence of *Solenocaulon tortuosum* and of *Pennatula* sp. and *Virgularia* sp. Many ophiuroids lying completely buried in sand with one of its arms protruding out like an erect needle were seen. The slightest touch of the tip made the ophiuroid's arms retract into the sand.

Large *Pinna* sp. were found in abundance rooted in thin layer of sand covering the rock in many places. The molluscan fauna was generally poor but in one or two instances *Cypraea tigrinus* shells were picked up from rocky pits. *Cypraea moneta* and species of *Oliva*, *Conus* and *Nassa* were less abundant. The echinoderm fauna was restricted to a few *Lamprometra* sp. growing in rocky crevices and occasional *Protoreaster lincki*. Pearl oysters were totally absent in the area. Fishes found were mostly *Scolopsis bimaculatus*, *S. vosmeri*, *Abalistes stellaris*, *Upeneoides* sp. and *Saurida tumbil*. Large fishes were found, wherever crevices and pits were sufficiently large. *Chetodon* spp., *Pomacanthodes annularis*, *Serranus* spp. and *Gaterin schotaf* were the most common.

In general it was observed that the water over the area north of lines X-XXX was always turbid even during good weather. The proportion of mud present in the sand was greater than in the case of other 'paars'. As a consequence, this was a handicap in the way of detailed observations. This feature, it was felt, might have been due to the vicinity of the embouchure of Vaipaar and Vembar rivers. Survival of the oysters, should they settle down in the northernmost portion of this zone especially in the shoreward rocky areas, would be greatly reduced because of this factor combined with the heavy underwater oscillation experienced in this area. Groups 7, 8 and 9; The rocky bottom was at depths varying from 17-23 metres, with a thin layer of sand covering the flat surface of the calcrete. The rock was usually encrusted with Polyzoa, nullipores and worm tubes, affording attachment to adherent shells. In all the cases the limestone was bored by molluscs and *Clione*, but only for a short distance from the margin. The ground mass was mostly composed of shell fragments, foraminifera and small broken pieces of nullipore. Dead pearl oyster shells were most frequent. It appeared to us that the loose material at the bottom was being cemented together into calcareous sand stones on calcretes at the 'paars' chiefly through the agency of polyzoans and nullipores.

The faunistic and floral characteristics of the groups 7, 8 and 9 appeared to be identical. The live coral area was seen as a low fringe running along 19-21 m. depth on the eastern side of the group 7 and in small localized formation in the groups 8 and 9 indicating thereby the near end of live coral fringe off Tuticorin. Cultch was abundant in places. Balls of nullipores were more abundant in northern groups 8 and 9. The 'paar' abounded in pits and fissures (Photograph 13) which were inhabited by fishes, large and small, eels, octopi and lobsters. The water over the bottom was fairly clear and the current weak. The area was considered ideal for the settlement of pearl oyster.

Sponges: Growth of sponge was very high in most of the stations studied, especially in group 9. The predominant species were *Siphonochalina communis*, *Spon-*

gionella nigra, *Pachychalina multiformis*, *Suberites* sp., *Petrosia testudinaria*, *P. similis*, *Hircinia* sp., *Clathria* sp. and *Phakellia* sp. This abundance of sponges noticed in this sector was in marked contrast with the central zone where the density was not so much.

Coelenterates: The area was rich in coelenterates with a conspicuous growth noticed in group 7, of hydroids, anemones, aloyonarians, gorgonids and live corals. *Companularia* sp., *Plumularia* and *Idia* sp. were found growing abundantly attached to sponges and bits of rocks. *Stoichactis giganteum* was the most conspicuous of the sea anemones although species of *Adamsia* on shells, and *Zoantharia* were also seen. Of the aloyonarians, *Chironophthya* sp., *Spongodes* sp., *Suberogorgonia*, *Lophogorgia* sp., *Juncella* spp. and *Telesto* sp., were seen growing commonly. *Lobophytum* and *Sclerophytum* spp. were also noticed at random.

The solitary corals were more predominant in groups 8 and 9 and included *Stephanoseris* sp., *Fungia dentigera* and *Dendrophyllia* sp. In addition *Heteropsammia* sp., *Lobopsammia* sp. and *Heterocyathus* sp. were seen abundantly over the rocky bottom in the northern extremity. Among the live corals *Goniastraea* sp., *Turbinaria* sp., *Montipora* sp., *Pocillopora* sp., *Favia* sp. and *Leptastraea* sp. were found here and there, especially in groups 7 and 9.

Molluscs: The group as a whole was richer in molluscs than the others. Noteworthy among the bivalves was the settlement of *Modiolus* spp. The presence of innumerable quantity of *Nassa* sp. ('uri') was characteristic of groups 8 and 9.

Pinna bicolor, *Cardium* sp., *Vulsella rugosa*, *Avicula vexillum*, *Arca* sp., *Chama* sp., *Malleus* sp., *Fasciolaria* sp., *Murex haustellum*, *M. tenuispina*, *Xenophora* sp., *Strombus* spp., *Doliolum maculatum* *Conus* spp. (about 7), *Cypraea arabica*, *C. lynx*, *C. moneta*, *C. tigrinus* (rarely), *C. erroneus caput serpentis*, *Terebra* sp., *Bulla ampulla* and *Natica* sp. were the other common shells noticed.

The sandy areas adjacent to the groups 7, 8 and 9 from line XII on till the XXX line to a distance of nearly 11 km. (south to north) was found to be an extensive chank ground. Chanks were found living in enormous numbers at depths varying from 16-23 m. The extent of the chank ground in each was mapped and it was noticed that the major concentration was in and around group 9. The percentage of undersized chanks (below 55 m. diameter) was great throughout. The chanks found in the northernmost region of this chank bed showed a greater percentage of worming than elsewhere. Compared to the central zone the chank grounds were more extensive and well spread out. The spawning of chanks observed during December-March was considerable as evidenced by many numbers of upright capsules found planted on the sea bottom.

The chank beds shown by Hornell (1922) in the corresponding area was of little or no significance. Further north he had shown the great expanse of chank bed. Perhaps with the passage of time the chanks had spread further south to areas now explored and thus well established.

Echinoderms: The crinoids and holothurians were the most abundant. Prominent amongst the crinoids were *Lamprometra* sp. (4 sp.), *Comanthus* (2 sp.) and *Actinometra* (3 sp.). Of the holothurians *Holothuria edulis* was the most common. In addition to this form, which was found at random, *Synapta* sp. were found under rocks and crevices. *Chondrocloea striata* found specifically on the sponge *Petrosia testudinaria*, *Holothuria vagabunda*, *H. atra* (rarely), *H. pardalis*, *Cucumaria* sp. were

the other forms met with characteristically. Of the sea stars *Protoreaster lincki* was the most common. *Linckia laevigaeta* and *Echinaster purpureus* were also seen in groups 7 and 8.

Clypeaster humilis and *Echinodiscus auritus* were found in greater number all along the shoreward sandy margin of the groups 7, 8 and 9.

The fish fauna was the same as in group 2 in central zone.

DISCUSSION

The outline of the various rocky area of the zones studied (vide Fig. 1) as compared with the figures of Hornell (1922) in the same area shows a changed pattern although detailed comparison beyond this is not possible, due to lack of data from his records. The methods followed by him to delineate the outline of the different 'paar' areas are also not available. In order to enable future workers to make comparative studies of the conditions in the later years and improve the techniques adopted we have taken pains to give detailed account of the methods followed in the survey work. It is evident from the results obtained that silting had taken place in many areas as evidenced by the sand covering the pits and crevices of the rock and even portions of the live coral blocks. This poses the possibility of natural silting up of the rugged surface due to passage of time. As a remedy to counteract the effects of silting, Salvadori (1960) suggested that rocky boulders 50 cm. diameter be stacked over the silted area for an approximate area of 200 sq. m. and observe the effect of animal settlement. But, this experiment could not be done due to practical difficulties. Cultching as a method to avoid silting was tried by us in these zones. It was opined by Hornell (*op. cit.*) that cultching would serve two purposes of vital importance, it would give additional and much needed holding ground to oysters and other fauna and would tend largely to diminish the damage liable to result from the inroads of rays, especially. Throwing cultch in enormous quantities over the area did not give satisfactory results as most of the dead pearl oyster shells thus thrown lay loose over the bottom and were at the mercy of the bottom current and oscillation, ultimately getting thrown over the adjacent sandy area, only to be engulfed by the sand.

Regarding the physical character of the water over the two zones it was seen that the sediment suspension is greater over the 'paars' in the northern zone between lines IX-XXX and in the central zone between lines XX-XXX. This was more pronounced over groups, 1, 4, 5 and 6 which were disposed shoreward. However the rest of the groups enjoyed very good clarity, especially groups 2, 7, 8 and 9. These were the offshore formations. It is not considered therefore, that the sediment laden water will exercise much deleterious effect upon the oysters on the outer 'paar' areas of these zones. On the 'inner' side where the profusion of muddy sediment is more one cannot expect spat fall to reach maturity although the nature of bottom and the other factors are found ideal for oyster settlement. From the mouths of Vaipaar and Tambarparni rivers along the coast mud is brought annually and this river sediment might have been responsible for the live coral reefs also being restricted mostly to the outer banks as mentioned in text.

As compared to the central zone, the northern zone seems to be more rich in sponge fauna, both in variety as well as in density. Whereas the shoreward 'paar' in central zone are found to be thinly populated with sponge, as one proceeds north

the sponge fauna becomes dense. On the whole the general sponge fauna in the area studied was fairly encouraging. But with the present state of our understanding of sponge industry in India, it is difficult to assess the usefulness of these species for commercial purposes.

Chanks seem to flourish most vigorously wherever there is a plentiful admixture of mud with the sand, especially if there be organic matter present, as happens off the mouth of rivers. Chank beds of extensive nature occur adjacent to group 2 in the central zone and shoreward of groups 7, 8, 9 in the northern zones at depths varying from 16-22 m. These chanks are either of medium size (55-66 mm.) diameter whorl or below. There appears to be much scope for exploitation from deeper unfished areas as the chanks found there were large in size. Perhaps this is only to be expected since the local fishermen exploit the chank beds up to 20 metres commonly and remove large-sized chanks periodically. Beyond 22 metres they rarely tap the resources. It is recommended therefore that diving with Aqua lung in sandy area beyond 22 metres can be profitably done. This may help in reducing the pressure of fishing in the present area of fishing also. It may not be out of place here to mention that the abundance of chanks adjacent to the 'paar' made Captain Phipps (1866) to suggest that 'the chank would attack and devour every pearl oyster and leave empty shells only.' So far no evidence, direct observation or otherwise, has been found by us to test this statement. If it is to be taken seriously it would be worth while to study the food and feeding habits of chanks when pearl oyster settlement is noticed in profusion in future. The result will take us a long way in planning for oyster fishery management.

As a result of the studies it is noticed that the pearl oysters are very few, almost absent, most of them having been fished; remaining perished or eaten away by predators. The paucity of oyster life over the vast expanse of the 'paar' shows that there is no possibility of conducting a pearl fishery in the area, during the next three years at least. The area which in 1955-'60 teemed with oyster life is bereft of oysters now and what little remained after fishing possibly served as food for fishes like serranids, balistids and octopi. Lots of oyster byssus were found in the stomach of these fishes which had been harpooned from this area at the beginning of the work.

Much has been written about the destructive nature of sea-stars with reference to the oyster beds. Judging from the sparse population and distribution of sea-stars over the rocky area examined at present it appears quite unlikely that they would constitute a serious threat to the existence of pearl oysters. In the opinion of Herdman (1906) 'star-fishes are probably the most serious of all invertebrate enemies. They are present in such large numbers on some parts of the pearl banks.' The star-fishes are classified as 'notorious predators' of edible oysters in temperate waters (Korringa, 1952). Widespread observations have been made on the predatory nature of sea-stars on oysters and their control elsewhere in the world (Loosanoff & Engel 1942, Needler 1941). It is said that the star-fish can migrate from one feeding ground to another (Korringa, 1946). Perhaps in Tuticorin area also they might have moved away from the erstwhile oyster ground to nearby areas lying still north or south of the present area of observation and might be once again attracted to the rocky areas once oyster settlement is noticed. In view of this it appears feasible to periodically observe the condition of the rocky beds for the sea-star population and carry out further observations, before arriving at a definite conclusion.

The profuse settlement of *Modiolus* spp. over the rocky bottom seems to have been adversely commented upon by many earlier workers. ' *Modiolus barbatus* ', states Herdman (1906), ' from its habit of weaving entanglements is considered to be another enemy of the oysters and other sessile fauna. ' French (1860) stated in his report that ' in the opinion of Franklin, the " Suran " (*Modiolus* spp.) dying after six months putrefies and forms a mud which covering the oyster destroys it. ' Hornell (1921) had also the same view. He says that ' the bearded weaving mussel (*Modiola barbata*) is so abundant that I have seen several square miles of sea bottom covered continuously with a carpet of these shells, felted together in a tangle of byssal threads. The presence of Suran in such myriads is one of the adverse influence militating against the prosperity of pearl banks. ' However, Jeffreys (1867) has stated that he does not consider ' Suram ' (= *Modiolus* spp.) or *Mytilus* or mussel or *Avicula* very injurious to oyster. Judging from the observations made presently there seems to be little doubt regarding the adverse effect of *Modiolus* spp. on the well being of oysters, particularly, and other fauna, in general. Wicks (1884) after his return from Ceylon reported that ' Suran ' was quite unknown on the Ceylon coast. This was partly corroborated by Herdman (1906) who stated that ' it is very rarely sufficiently abundant in Ceylon waters to cause serious injury. ' It would be of great interest to know whether the same condition exists even this day on the Ceylon rocky beds. However, working on the collections of shells placed at their disposal by Herdman, Standen and Leicester (1906) have listed *M. barbatus*, *M. japonicus* (Dunker), *M. tulipa* Lamarck and *M. metcalfei* Wood from Ceylon coast. There seems to be no dearth for these along Indian coast of Gulf of Mannar.

The probable damage done by the octopi to the pearl oyster population should also be reckoned with while planning for an effective management of the pearl fisheries. Herdman (*op. cit.*) did not seem to attach a great deal of importance to the damage done by cephalopods to the oysters. He said incidentally that octopi are abundant in some areas of the banks and are well-known to live at the expense of oysters and mussels. The Japanese, on the other hand have taken account of octopus damage in their fisheries and ' get rid of these inconvenient guests and hunt them regularly ' (Boutan, 1925).

It was suggested by Hornell (1916) that the ' depredatory fishes on pearl banks are upon such enormous numbers as frequently to wipe out in their entirety densely packed beds of young pearl oysters. The bare level bottom free from clefts and crannies and boulders gives the rock-perch and trigger-fish every facility to devour enormous quantities of oysters during the first year of their existence. ' Although we are in agreement with the predatory nature of the balistids and serranids, the bottom on which they live is certainly not like the one described by Hornell. We have found a lot of broken oyster shells and byssus from the stomach of these fishes. Hornell (*op. cit.*) stated that these fishes disperse gradually with the disappearance of the oysters. On the contrary we find that these fishes are the more frequent than any others on the rocky bottom and seem to show a preference to return and inhabit the same crevice or rocky hide-out even if they are frightened away by us.

Equally interesting is the destructive role attributed to the sharks, rays and skates. Time and again several authors have said that *Rhinoptera javanica* is the arch enemy of the pearl oysters. Hornell (1922) graphically describes ' I once walked over an oyster bed ravaged at the most but a few days previously. The sight was one never to be forgotten . . . wide lanes had been ploughed through, every oyster gone within the breadth of the lane. At frequent intervals lay piles of broken shells, crushed flat as if passed through a mill. ' But for stray cases, *R. javanica* is

not so frequently noticed while diving. It is quite possible that they might visit the beds during their nocturnal hunts. Nevertheless, there were signs at the bottom (once or twice) of decapitation of large numbers of *Petrosia* (the massive sponge), innumerable cut pieces of the gorgonids and uprooting of weeds suggesting thereby that something abnormal had happened earlier. It might be that something like a school of rays or skates passed over the bottom playing havoc on the rocky fauna in general. Large-scale damage to the pearl oysters was not noticed which might perhaps be due to the paucity of these in the area investigated. It may be that if the oysters happened to be in the way of such an indiscriminate destruction, they may also share the same fate. It would be worth while to look in to this aspect again in future when the rocky bottom contains profuse oyster population.

SUMMARY

Results of underwater observations made to study the physical and biological conditions of the sea-floor in the Gulf of Mannar between Lat. $8^{\circ}35' N$ - $8^{\circ}55' N$. and Long. $78^{\circ} 10' E$ - $78^{\circ}25' E$. are given. Two series of rocky substrata are evident at depth range 9-14 m. and 17-25 m. respectively. The bottom of flat rock type with plenty of fissures and crevices, is suitable for oyster settlement.

The general fauna and flora found over the rocky bottom are listed. Faunistic features of the rocky bottom appear to be same throughout except for peculiarities like the abundance of one or the other fauna, here or there. Chank fishing grounds have been delineated.

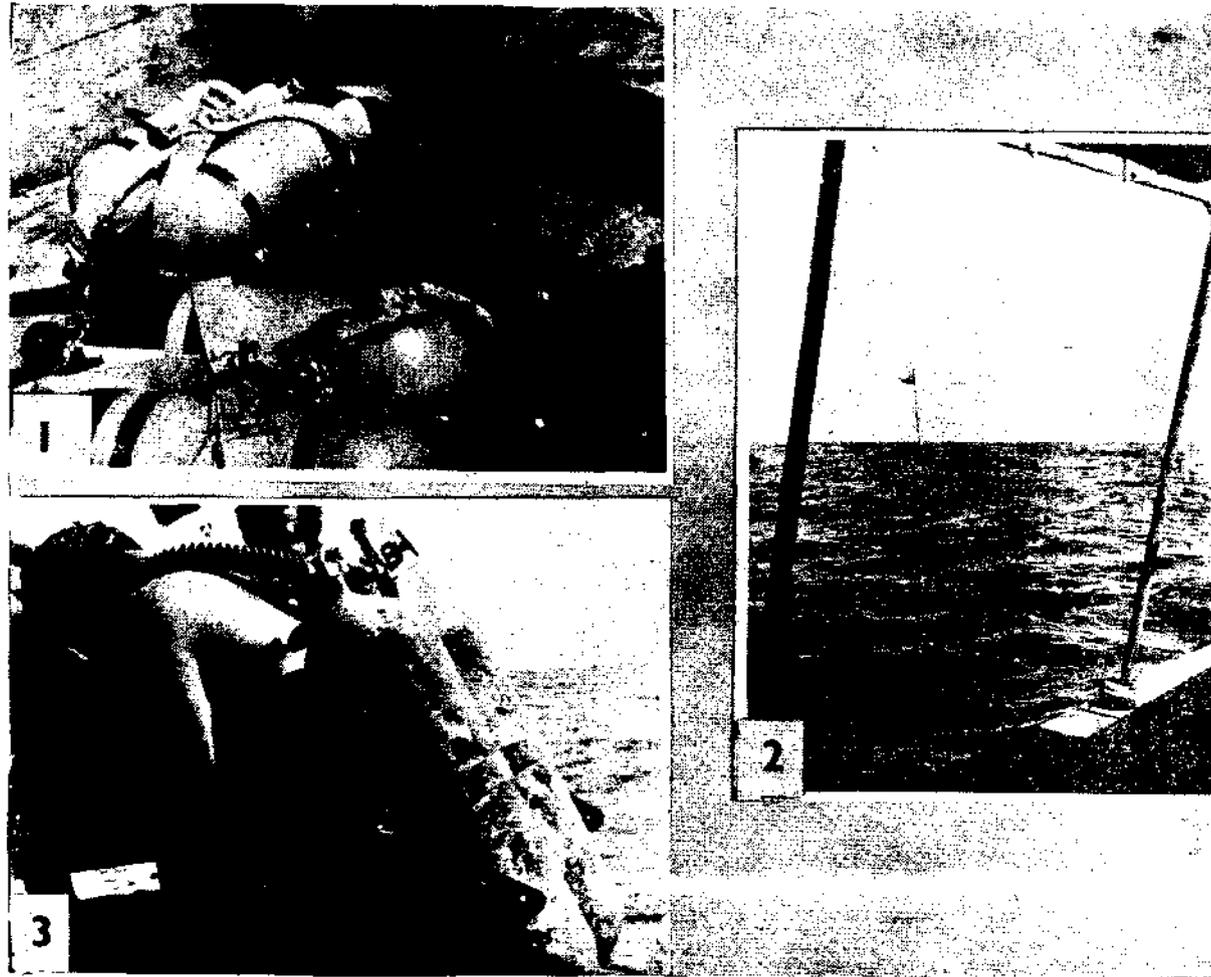
Pearl oyster population has not been noticed. The possible role of star-fish, *Modiolus* spp., octopi and fishes in the destruction of pearl oysters is discussed.

ACKNOWLEDGEMENTS

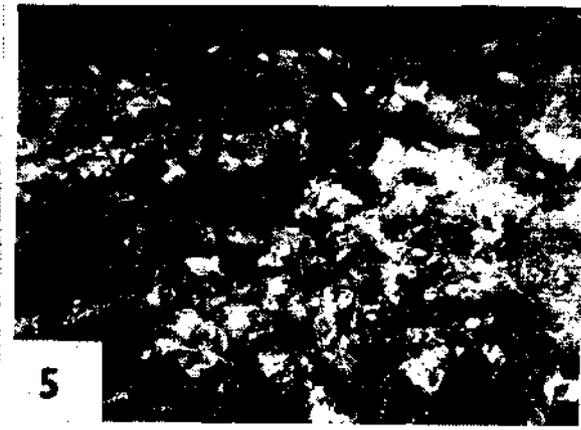
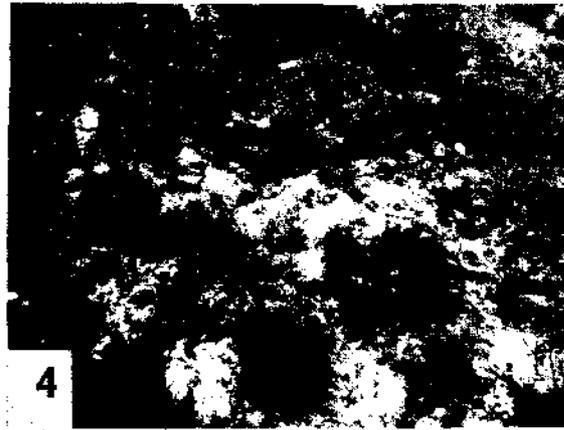
The idea of making special observations on the habit and habitat of the bottom fauna off Tuticorin was suggested by Dr. S. Jones, Director, C.M.F.R. Institute. We are very grateful to him for his guidance, criticism and encouragement of the work. To him and to Dr. R. Raghuprasad, Deputy Director, C.M.F.R. Institute we owe our debt of gratitude for critically going through the manuscript and offering suggestions for improvement. To the many members of staff who accompanied us on the sea trips and helped us in diving work we offer our special thanks.

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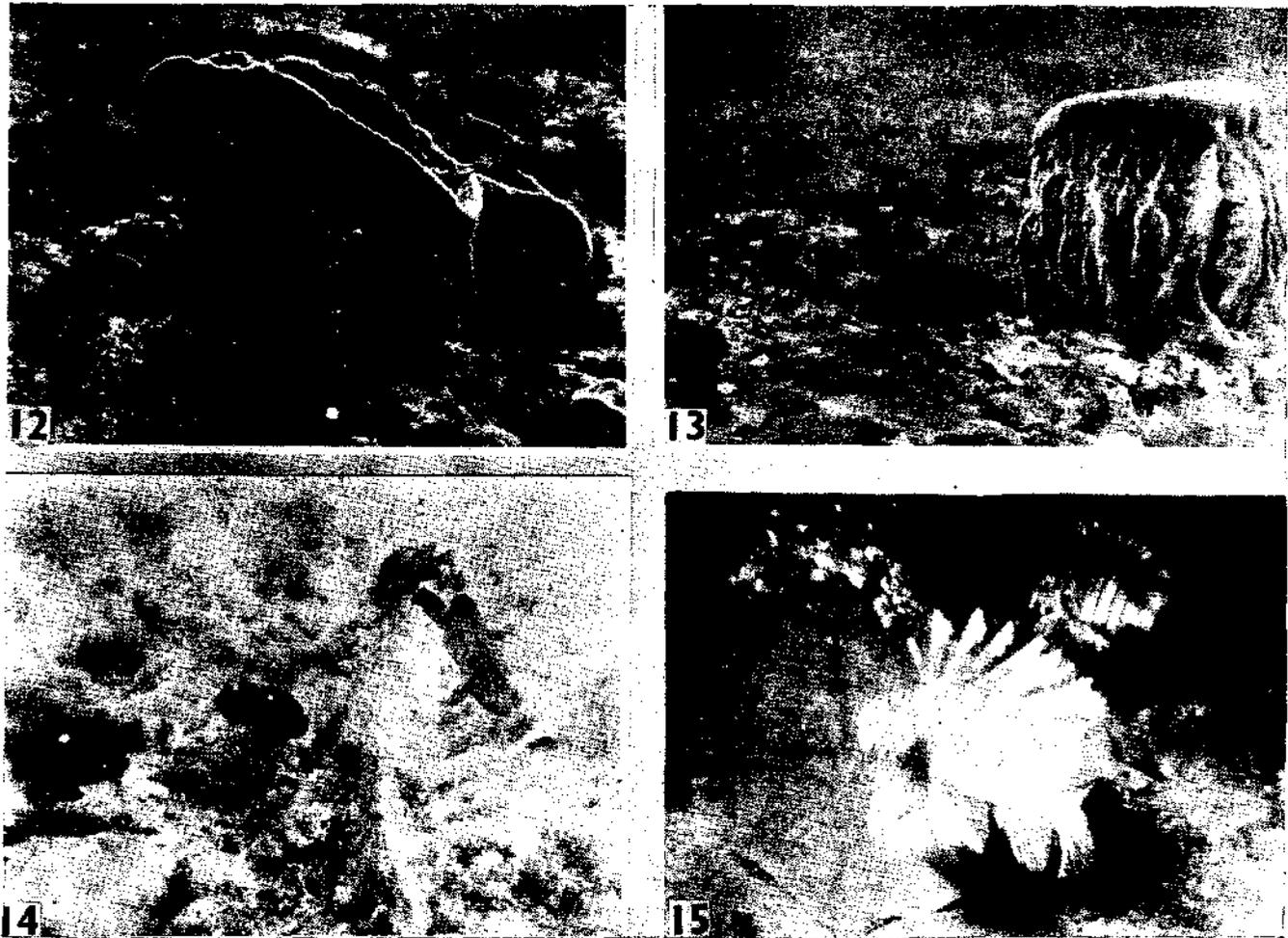
1. Aqualungs used for diving.
2. Diving Station 'flagged' with a Spar-buoy.
3. Getting ready for the dive.



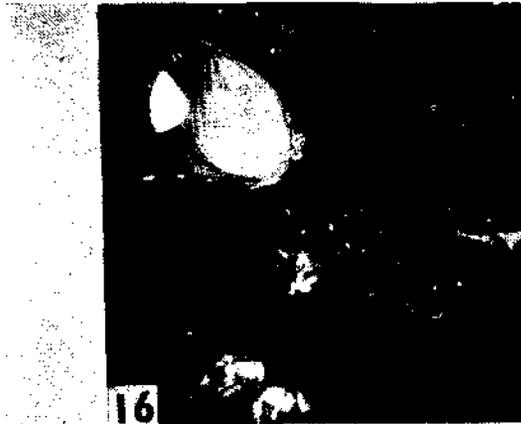
4. A typical sea bottom (northern zone, Group 6) with the sponges hydroid colonies and weeds.
5. 'Paar' with Sea-weed, *Padina* sp. densely growing (Central zone, Group 2).
6. Live coral *Favia* sp. with the scorpion fish close by.
7. Another live coral block ; small fishes may be seen swimming all around the anemone nearby.



8. *Petrosia testudinaria* (Lamarck), the massive sponge.
9. *Juncella juncea pallas* with *Lamprometra palmata palmata* (Muller) clinging on to the stem.
10. *Pentaceraster hedimanni* (Lutken) on the paar.
11. *Protoreaster lincki* lying on an anemone (not identified). Live pearl oyster may be seen near the anemone.



12. A rugged 'paar' *Chaetodon* sp. swimming around, the massive sponge, *Petrosia testudinaria*.
13. Flat rocky bottom with crevices and holes.
14. *Enneacentrus miniatus* (Forsk.), *Dascyllus trimaculatus* (Rüppell) and *Scolopsis vosmeri* (Bloch) over the crevices and crannies.
15. The scorpion fish *Pterois miles* (Bennett) near a dead coral block of *Montipora* sp.



16. *Pomacanthodes annularis* (Bloch) over a block of *Porites* sp.
17. *Gaterin schotaf* (Forsk.) from a rocky crevice.
18. *Zanclus cornutus* (Linn.) Live pearl oysters are lying loose on the sea-floor.
19. *Heniochus acuminatus* (Linn.) and a 'grouper' behind.

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