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CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
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ECOLOGY OF PEARL OYSTER BEDS

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Introduction

The importance of pearl fisheries in the Gulf of Mannar and the unpredictability of annual fishery due to the disappearance of oysters from beds or failure in oyster spat settlement over the banks have stimulated pearl oyster experts in the past to devote considerable attention to find out the probable causes. Kelaart (1859), Herdman (1903-1906) and Hornell (1905, 1913, 1916 and 1922) have contributed much to our knowledge about internal or external relationships of the pearl oyster with one kind of animal or other in the same habitat, besides some valuable information on the anatomy, reproductive biology and growth of oysters in the beds. Where observations on the associated fauna and flora, their distributional abundance and the topographical features of the banks are concerned Mahadevan and Nayar (1967, 1973, 1974 and 1976) have given useful data and information based on their direct underwater observations by SCUBA diving. Thus the main line of investigations had been to look at the problem from the angle of possible predation of oyster stock by bottom dwelling fishes, and other animals and competition for space and food by cohabiting organisms or seasonal settlers. The effect of sand-drift over the banks, the role played by water movement and current in the dispersal of the planktonic larvae of pearl oysters, the failure of oyster banks to reproduce on account of predominant homogenous populations during certain years were also advanced by earlier workers (Malpas 1929, Devanesan and Chidambaram 1956). Thus these studies on oyster tended only to touch the fringe of the problems of synecology.

It is now clear that studies on integrated ecology are necessary since the ecological set up of the pearl oyster habitat is intricately connected with a variety of factors or combination factors. Although some investigations had been done in previous years in selected segments of the Gulf of Mannar relating to the productivity, plankton and hydrography these have not been decisive enough to arrive at any conclusion about the extent of their exact influence on the pearl oyster biology and reproduction. Some of our knowledge on these factors relates to the Japanese and Australian species through the works of Kawamato and Motoki (1954), Kobayashi and Yaki (1952), Kobayashi (1940), Mori (1948a, b), Ogawa (1952) and Tranter (1958a, b, c, 1959). In recent years precise information on reproduction, larval development and spat settlement of the Indian pearl oyster *Pinctada fucata* has been provided as evidenced from the experimental studies of Alagarswami *et al.* (1983 a, b, c).

The present paper summarises and evaluates information of interest available to date on the response of pearl oyster to intensity variations of major abiotic and biotic ecological factors.

Sea-Land Features of the Shallow Region of the Gulf of Mannar

Substratum

Wadia (1975) refers to the peculiarity of the peninsular east coast of India which has a wide bed of alluvial margin in addition to the deltaic deposits of the mouths of all major east coast rivers. Along the Gulf of Mannar the sea-land boundary is almost uniform and regular but for a few indentations in places where it is intercepted by rivers forming 'Concave crescents' or tidal inlets. The coast is gently sloping. There are no major estuaries in the Gulf of Mannar except for Tambaraparni, Vembar and Vaipaar which are of seasonal nature and categorised as minor ones. A deep

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muddy gully off Tambaraparni river mouth (depth upto 40 m) meanders a few miles in the sea and is considered as a repository of silt and organic sediments brought down by the river while in spate, during October-December. The deposition of sediments by these rivers is only next in importance to those from other rivers of the Coramandel coast since a general spreading of alluvial deposits upto 20 m depth zone in the Gulf region by major rivers is reported by geologists. The rocky bottom within this zone is therefore subjected to an overwash of sand and mud. The intensity and nature of sediments depend on direction and velocity of prevailing current apart from the effects of wave action and swell. The result of the interaction of the natural forces at work determines the extent and contour of the rocky exterior, season after season.

The 8-10 m depth zone nearer the coast all along the Gulf of Mannar from Tiruchendur to Tuticorin, a distance of nearly 25 nautical miles is characterised by a narrow belt of submerged dead coral block formation gradually emerging as a fairly broad fringing live coral reef towards the windward side of 20 islands or ' Sand Cays ' located between Tuticorin to Pamban, a near distance of 150 nautical miles north of Tuticorin. The coral reefs are mostly hermatypic and serve as a barrier against wave action, getting the brunt of pounding waves. Majority of the broken branches in this process, forming the spit and wash are pushed to the leeward shallow areas and intertidal flats. The outer reef edge areas also get strewn with fragments and these get pushed away by bottom swells and current forces to the deeper seaward region accumulating and getting consolidated under coarse sand and coral grains forming pits and hollows on the sea floor.

Patches of hard ground of very low profile known as ' Paar ' are characteristic of the depth zone from 16 m-23 m. These lie roughly in line parallel with and at a distance of 10-16 nautical miles from land. Majority of them are located between 8°-20' N Lat. and 9°-00' N Lat. within 78° 15' E long and 78°25' E Long. There are formations north of 9°-00' N. Lat. but are considered not very important from the point of view of pearl oyster settlement. From 8°-35' N. Lat. an inner series is recognisable at 15-17 m depth whereas the outer series is located at 20-23 m depth, the intervening stretches being coarse and fine sandy sea floor.

There is no strict line of demarcation between the paar and sandy region. The surface of paar consists of rock which appears in many areas of recent origin formed of corals and shells to certain extent and to a great extent by ' Calcrete '-compound of sand and neighbouring organic remains cemented to a continuous mass by calcium carbonate. The character of rock varies considerably partaking usually the character of the circumjacent sand. The latter is made up principally of calcium grains formed from the comminuted remains of shells and corals thus giving the true character of limestone. Where it is not calcrete it is of coarse sand, wholly inorganic containing quartz grains derived from ' granulitic rock ' brought by rivers. Elsewhere shells of foraminifers (*Heterostigina, Orbitolites* and *Amphistigina*) mixed with calcareous remains of many animals form rocky mass. The Indian pearl oyster, *Pinctada fucata*, settles down in large numbers on the rocky substratum of this type and attains harvestable size at the end of the third year of its growth when pearl formation also reaches exploitable proportions. The rocky bed supports a variety of marine plant and animal assemblages, which are characteristic of the region constituting well recognisable and defined pearl bank biota. Mahadevan and Nayar (1974) have described in detail the characteristic fauna and flora of the pearl banks in the Gulf of Mannar.

Variety and abundance of bottom fauna greatly depend on the physical and chemical structure of the substratum. The type of substratum is said to play a pivotal role in modifying the pattern and rate of reproduction of animals living on it in addition to settling and metamorphosis of pelagic larvae of benthic forms (Bacescu, 1972). A widely discussed problem is that of the factors which determine the settling of the pearl oyster larvae, their distribution and completion of life cycle. Recent observations at the Tuticorin Shellfish Hatchery Laboratory on the fertilised pearl oyster eggs indicate that these eggs initially settle down on the bottom and only when the cleavage advances do they rise up and become pelagic (Dharmaraj-personal communication). If the substratum is sticky or loose or soft there is every possibility of the fertilised eggs being locked up or covered by soft sand without allowing them to float up for completing the pelagic larval phase. The macrophytic algae which grow in the pearl banks and whose thallus is often covered with calcareous algae also serve as substrate for very small molluscan spat which may later on migrate to a more agreeable hard substratum. The size of granules, kind and amount of organic matter associated with the substrate, degree and mobility of substrate, degree of hardness of solid substrates and the total area of a given type play a key role in the prosperity of pearl oysters in the natural beds. The reasons for the record of irregular oyster settlement in these areas may be due to possible effects of the change in the nature of sediment and silt covering the substratum and thus modifying it.

Primary Production

Galathea expedition reports give out a value of 0.01 to 2.16 gC/m²/day (Seeman Nielsen and Jenson, 1957, quoted by Qasim, 1979) for the shelf region of the Bay of Bengal. Nair *et al.* (1973) state that the primary production of Tamilnadu coastal areas lying in less than 50 m depth zone averaged 1.33 gC/m²/day. But the Gulf of Mannar area, particularly the zone where pearl oyster beds are situated is rich in coral reefs. The productivity in this zone has been observed to reach 7.3 gC/m²/day (Nair and Pillai, 1972) which appears to be fairly high compared to the values obtained in other areas of east coast nearshore waters. Nair (1970) estimated that the near inshore regions where the euphotic zone is 6 m deep, the column production amounted to 1.2-1.5 gC/m²/day due to turbidity and annual gross production was 450 gC/m²/. But just outside the zone where turbidity is not high enough to affect light penetration the euphotic zone extends from 15-40 m depending on depth and distance from shore. A daily production of 3.5 gC/m² is met with thus indicating the highly productive nature of this region.

Wind, Water movement and current

Wind velocity shows a trimodal oscillation with maximum in June, August-September and December and minimum in March-April. The velocity is greater in southwest monsoon period.

The importance of water movement as an ecological factor is frequently underestimated. Gessner (1955) states that this is a potent factor as it is in the case of temperature and light. Very little is known with reference to the various parameters of water movement over Paar area excepting extrapolation from local current and tide conditions. There is a general drift of water over pearl banks from south to north between April to September and from north to south during height of northeast monsoon with intermittent periods of calm and variable movement from February-April. Many days in late April to early June there is a bottom swell, of water in east-west direction over the Paar area. These are critical months for oyster reproduction. Population replenishment might depend upon conditions of water movement. Devanesan and Chidambaram (1956) state that the water drift and current over the pearl banks of Ceylon and India may carry the larvae of pearl oyster from one coast to the other, thus holding the view of interdependence of the pearl banks of Ceylon and India for getting replenishment of oyster population. There is another possibility also. Depending on the direction and rapidity of water movement the pearl oyster larvae, at the plantigrade stage, might reach such areas in the sea with unsuitable sea bottom where they perish after settlement. All these factors thus play a vital role.

Light

It is a recognised fact that throughout euphotic and littoral regions the various modalities of light modified by the time of the day and year and latitude, the presence or absence of water movement and the depth and clarity of water exert effects upon functions and structure of marine invertebrates. The periodicity and the width of shell opening is said to be influenced in natural beds by alternating light and darkness. The width is narrower in light but broader in darkness, due to the effect of light on adductor muscle. Hence the rate of filtration of water is likely to be affected during day time in areas where light penetration is greater. This is more frequent in depths beyond 20 m and less so in shoreward banks during the months from December to April.

Turbidity

Not much has been done to study the turbidity in various seasons of the year except the observations by Malupillai (1962 a) who recorded that visibility over pearl banks varies from 6.0 m in July to 19.0 m in November to February. The pearl oyster larvae are photopositive in the veliger stage and metamorphosis proceeds normally under favourable light. There is a view that turbidity during metamorphosis is desirable, shielding the larvae against ultraviolet radiation in shaded areas. Conditions in nature, over the pearl banks in May-July satisfy this requirement.

Flood water discharged from east coast rivers during the northeast monsoon rains in October-November, carry with it considerable silt which creates great turbidity over the pearl beds, particularly over the shoreward lying banks. This introduces a new dimension to the problem of growth and survival of oyster population met within 12 m-15 m depth range.

Temperature

There are a few general records of long-term studies on temperature variations. Sewell (1927) and Herdman (1903-1906) gave a general picture. Chacko *et al*, (1954), Prasad (1957), Malupillai (1962 b) Freda Chandrasekaran *et al.* (1967) and Freda Chandrasekaran and Sudhakar (1967) are the major studies relating to Gulf of Mannar. Herdman (1903-06) stated that the general temperature of the sea-water in the paar varies from 27°C (January) to 32.5° C (May). Freda Chandrasekaran *et al.* (1967 a) found a general uniformity in the temperature pattern ranging from 25.6°C30.-6°C. Chacko and Sambandamurthy (1969) observed an annual range of 2.7°C for 1962-63. Alagarswami *et al.* (1983 b) were able to induce mature *P. fucata* to spawn by increasing the temperature from 26.5°C-28°C to 32°C-35°C. In the case of Japanese pearl oyster, Kobayashi (1948) found that the optimum temperature for fertilisation was 28°C-30°C. In the Indian pearl oyster fertilisation in laboratory tanks was noticed to take place in the 27°C-28°C range.

There appears to be some correlation between temperature and the breeding behaviour of the pearl oyster. The breeding season is more restricted in higher latitudes and occurs during warmer months. In lower latitudes there is a less restricted breeding sason, and major spawning occurs outside warmer months (*Pinctada fucata* : 7-10 N ; *P. margaritifera* : 17 S). Orton (1920) states that in those parts of the sea where temperature conditions are constant or nearly so and where biological conditions do not vary much, animals breed continuously. Tranter (1958 d) states that there is a particular threshold temperature which, when exceeded all the year round, permits continuous breeding and, when exceeded only in summer, restricts breeding intensity to summer months.

Uuder laboratory conditions temperature variations appear to affect the larvae of pearl oyster at the time of settlement. Alagarswaml *et al.* (1983a) state that the 'larval set' was achieved after 24 days in temperature range of 28.2°C-29. 8°C whereas it took 32 days to settle when the temperature range was 24.3°C-27.2°C. The lower the temperature the greater the time taken for completing metamorphosis and settlement.

Salinity

Sewell (1927) stated that the salinity in the Bay of Bengal is high in the southwest monsoon period and low during the northeast monsoon months. In the Gulf of Mannar, according to Malupillai (1962 b), the salinity reaches 35.19‰ in September. Freda Chandrasekaran *et al.* (1967) found low salinity in January increasing upto June, dropping in July (30.2‰) and increasing again in August (33.5‰). This was maintained till November when there was a lowering in December. The highest average salinity was 35.9‰ in November and the lowest was 27.40‰ in December. The annual range in the value was 7.9‰. Jayaraman (1954) noted a salinity range of 28.35‰ in January to 36.4‰ in May. The mean annual range was 7.4‰. Alagarswami and Victor (1976) found the average values of salinity in the oyster farm at Veppalodai (near Tuticorin) ranging between 32.15‰-33.50‰ during 1974-1976. The lowest value recorded was 31.26‰ in January, 1974.

The above data would indicate the pattern of salinity variations that can be normally encountered in the pearl oyster beds. Although the pearl oyster lives within this range, seasonal fluctuations in conjunction with other environmental factors are known to exert influence on the physiological functions and reproductive activity of the oyster. By and large the pearl oyster being truly marine form in its entire life cycle is not known to tolerate great variations in salinity. However, some pearl oyster farms in Japan are known to be located in areas which are subject to the influence of freshwater discharge from rivers.

Lower salinities have a depressing effect on filtration rate of bivalves (Cole and Hepper, 1954). Alagarswami and Victor (1976) found that in the laboratory experiments the rate of filtration was generally higher in high concentrations than in the dilution. In salinities of 13.90‰ and 56.96‰ mortality was total after 48 hrs, whereas 3 out of 5 oysters died in the salinity of 19.90‰ in the same period. Katada (1958) stated that low saline waters of 14.35‰ did not cause mortality in the spat and 2-3 year old oysters in Japan during experimental duration of 72 hrs. In one case of extreme lowering of salinity to 15.69‰ observed in the Veppalodai farm during November, 1977 on account of the admixture of flash flood freshwater, the oysters did not suffer mortality for 24 hrs as the very next day the salinity was restored to 26.53‰ (Alagarswami and Victor, 1976). Malpas (1929) stated that changes in temperature and salinity induce the pearl oyster to spawn. He contended that low salinity in December-January and high salinity in July-August acts as breeding stimulus. This can be considered only as one of the probable factors influencing the spawning. Hornell (1910), Moses (1928) and Rao (1951) correlated spawning maxima with changes (dilution) in salinity for *Crassostrea madrasensis.* Detailed assessment of salinity effects and tolerances is difficult in natural conditions because the effects may be increased, decreased or masked by other simultaneously effective environmental factors like light, temperature, water movement and interactions between co-existing organisms.

Dissolved oxygen

Values ranging from 6.84 ml/l in October to 3.4 ml/l in September appear to be common in pearl oyster beds. A trimodal curve has been noticed with distinct peaks in June, October and January with a decline in April, September and November. It looks as though the oxygen saturation is greater in northeast monsoon months and less in southwest monsoon months. The oyster is not stressed much due to limited range of high and low concentrations. It is a known fact that the metabolism of many molluscs is independent of ambient oxygen tension until some low oxygen tension is reached. Dharmaraj (1983) observed that the oxygen consumption was 1,339 μl/h for oysters of 40-50 mm size; 1,650 μl/h for 50-60 mm and 1,810 μl/h for 60-70 mm. After conducting exposure experiments it was found that *Pinctada fucata* withstood exposure upto 21 h, and mortality started from 19th hour in anaerobic medium, when the 'oxygen debt' crossed the safe level.

Silicate and Phosphate

Jayaraman (1954) recorded phosphate content of 0.16 μg at p/l (October) to 0.27 μg at P/l (February). The silicate content showed wide fluctuations from 9.0 μg/l in March to trace in October and January. June-July, November-December, February-March seem to be silicate rich months. Jayaraman (1954) reported values of 3.7 μg at Si/l in September to 7.0/μg at Si/l in February in Mandapam area of the Gulf of Mannar.

Associated Fauna and Flora

The very fact that the fauna and flora of the pearl banks comprise the whole assemblage of more than 2,700 species of animals and 200 species of plants (Herdman, 1906), small and large, makes the study of interrelationship among them very complicated although it is well recognised that the nature and density of such animate surroundings have a profound effect on the well being of the stock of oysters in the beds. Mahadevan and Nayar (1967) have added more information about the density and distribution patterns of the pearl oyster bed biota in different depth zones. Sponges, starfish, molluscs (gastropods particularly), crustaceans, annelids, coelenterates and fishes among the fauna and the luxuriant growth of different species of algae belonging to Rhodophycea, Phaeophycea and Chlorophycea dominate the pearl oyster beds.

Characteristic of the area is the dense growth of sponges, especially in the northern Vaipar area. *Aulospongus tubulatus* (Bowerbank). *Phakellia donnani, Siponochalina communis* (Carter), Iotrochota spp., *Clathria procera* (Ridley), *C. indica* Dendy, *Mycale grandis* Gray, *Zygomycale parishii* (Bowerbank), *Phyllospongia* spp., *Spongionella* spp. and *Suberites* spp. are abundant. Dense forest-like growth of the gorgonid *Juncella juncea* Pallas and *J. gemmacea* (Valenciennes) is noticed in the northern area.

The growth of the coral *Heteropsammia* sp. is characteristic of the inner series. *Montipora* sp. and *Echinopora* sp. are the other corals in addition to *Porites* sp.

The molluscan fauna is mostly represented by myriad numbers of *Modiolus* spp. spreading like mattress on the bottom. Large *Pinna* spp. are found in good numbers rooted in this layer of sand covering the rock in many places. *Cypraea tigrinus* are seen in rocky pits. *Oliva* spp., *Conus* spp., *Nassa* sp. and *Bulla ampulla* are the other common shells.

Among the echinoderms *Lamprometra palmata palmata* (J. Muller) and *Comanthus (Comanthussis timorens)* (J. Muller) are the most common under rocky crevices and over the gorgonids and sponges. *Holothuria edulis* Lesson, *Protoreaster lincki* (Blainville) and tests of *Clyspeaster humilis* (Leske) are the other common species.

The fish fauna is fairly rich and consists of *Scolopsis bimaculatus* Rüppell, *S. vosmeri* (Bloch), *Abalistes stellaris* (Bloch), *Upeneoides* spp., *Chaetodon* spp., *Pomacanthodes annularis* (Bloch) and *Lutjanus lineolatus* (Rüppell). Large fishes like *Gaterin* spp., *Ennaeacentrus miniatus* (Forsk.), *Epinephelus* spp., *Lethrinus* spp. and *Siganus* spp. are abundantly seen.

The flora is poor in the southern area but in the Vaipar area *Gracilaria* spp., *Hypnea* spp. and *Sargassum* spp. are common.

Compared to the inner series, the outer series is richer in fauna and flora qualitatively and quantitatively. The formation of the outer series runs in a southeast to northwest direction, generally between 15-25 m depth range. The formations are fairly extensive stretches of rock whose outcrops differ greatly from tubular fragments, rock of a metre or two across, to great areas of a km in extent. Fine grained sand covers the rock filling up the hollows and crevices occasionally cutting off the continuity of paars to give the impression of sandy bottom. Actually the hard core of the bottom can be easily detected by removing the engulfing sand of 5-10 cm thickness. Live corals are seen as a low fringe running along the 18-19 m depth on the eastern side of the paar. Broken and worn out fragments of pearl oyster shells, cockles, *Pecten* spp., *Conus* spp. etc. are scattered about in great profusion. Balls of *Porolithon* sp. from the size of a nut to that of a lime are seen on the edges of the rocky expanse. All through the length and breadth of the paar are a number of pits ranging from 0.5-1 m diameter and of equal depth. Such pits are inhabited by a number of small and large fishes, eels and lobsters. The general set-up of the area appears ideal for the settlement of oysters as the horizontal clarity at the bottom exceeds 15 m on most days and because of the variety of fauna and flora inhabiting the area.

The concentration of sponges is very high especially in the upper (northern) regions of the paar. The predominant species are *Petrosia testudinaria* (Lamarck), *P. similis* Ridley, *Aulospongus tubulatus* (Bowerbank), *Axinella donnani* (Bowerbank), *A. symmetrica* Dendy, *Spirastrella inconstans* (Dendy), *Suberites* spp., *Cliona vastifica* Nancock, *Clathria indica* Dendy, *C. procera* (Ridley), *Mycale grandis* Dendy, *Raspailia hornelli* Dendy, *Myxilla arenaria* Dendy, *Iotrochota purpurea* (Bowerbank), *Pachychalina subcylindrica* Dendy and *Phakellia donnani* (Bowerbank). There are other species of *Auletta, Spongionella, Hippospongia, Phyllospongia* and *Hircinia* met with in the 25 metre depth line also.

The area is rich in coelenterates with a conspicuous growth of anemones, alcyonarians and gorgonids. Some of the fleshy alcyonarians that are common are *Sarcophytus* spp., *Lobophytum* spp. and *Sclerophytum* spp. *Spongodes rosea* Kukenthal, *Nepthya* sp., *Solenocaulon tortuosum* Gray, *Suberogorgia* sp., *Acanthogorgia* sp., *Lopohogorgia* sp. and the gorgonids· *Juncella juncea* Pallas and *J. gemmacea* (Valenciennes) harbouring many commensals are noticed commonly.

Octopus (*Polypus* spp.) are common in pits and holes. Great numbers of dead, empty broken shells are found in crevices and faults in the rocks haunted by the octopus. Pearl oysters are particularly preyed upon by them thus posing the question as to whether they are the chief enemies of the pearl oysters. On many occasions the octopus has been noticed to open the shell valves of the oysters and eat the flesh.

The echinoderm fauna is found to be lacking in abundance as a whole. By far the crinoids are the most abundant, found attached to the gorgonids, under coral blocks or on sponges. *Lamprometra palmata palmata* (Muller) and *Comanthus annularis* (Bell) are the most common. Among holothurians, *Holothuria edulis* Lesson is the most common. The synaptid *Chondrocloea striata* (Sluiter) is common in deeper waters. Of the sea stars, *Protoreaster lincki* (Blainville) is the most abundant although *P. affinis*. (Muller and Troschel) and *P. australis* (Lutken) are also seen rarely. The southern areas are more thickly populated whereas in the north and shoreward areas there are only 2 per 100 sq. metre. The other sea stars are *Pentaceraster multispiralis* V. Martens, *Linckia laevigaeta* (Linnaeus) and occasional specimens of *Culcita schmideliana* (Retz), *Protoreaster nodosus* (Linn.), *Astropecten indicus* Doderlein and *A. monocanthus* Salden are also seen.

Of the cake urchins *Clypeaster humilis* (Leske), *Echinodiscus auritus* (Leske) and *Laganum depressum* Lesson are common. Of the heart urchins *Echinolampus ovata* (Leske) and *E. alexandri* de Lorial appeared here and there. Among sea urchins *Salmacis bicolor* Agass, and *Salmaciella dussumieri* (L. Agassiz) occur wherever dead coral blocks are covered by coarse sand. In the crevices of the coral stones and under the boulders live many numbers of ophiuroids of which *Astrob clavata* (Lyman), *Ophiocnida echinata* (Lungman), *Ophiocnemis marmorata* (Lamarck), *O. cataphracta* (Brock) and *Ophiocnermis dubia* (Muller & Troschel) are more common. All over the rocky bottom, fishes are found abundantly. Numerically *Abalistes stellaris* (Bloch), *Sufflamen capistratus* (Shaw), *Odonus niger* (Rüppell), *Scolopsis bimaculatus* Riippell and *S. vosmeri* (Bloch) are the most abundant. But wherever the area is rugged with boulders and pits fishes like *Gaterin* spp., *Lethrinus* spp., *Enneacentrus* sp., *Epinephelus* spp., *Pomacanthodes annularis, Lutjanus sebae* (Cuvier), *Pterois miles* (Bennet), *Chaetodon* spp., *Zanclus cornatus* (Linn.) and *Heniochus acuminatus* (Linn.) live in large numbers.

Throughout the rocky expanse studied the density of algal vegetation seems to be moderate especially on the eastern edge between 17-25 m line. The flora on the southern areas seem to be luxuriant with *Sargassum* spp., dominating in most of the areas. Among the red algae *Gracillaria edulis* and *Hypnea valentiae* are common. The other common species in the pearl banks of the outer series are *Caulerpa* (3 species), *Codium* sp., *Halimeda* spp., (2 spp.), *Dictyota* (3 spp.), *Padina* spp., *Porolithon* sp., and *Spathoglossum* sp. It has been remarked by Varma (1960) that the algal flora of the pearl beds is mostly of the types found in coral beds or rocky regions of Indian coast, irrespective of depths. In other words there appears to be no selectivity for algae with regard to depth.

Many of the below mentioned animals have been identified by pearl fishery workers as important enemies of pearl oyster either by direct aggressive action or indirectly in the struggle for existence. In order of importance in causing pearl oyster destruction they are :

Modiolus spp. (Weaving mussel)—by completion and smothering oyster spat settlement.

Octopi—Predation ; by killing and preying on flesh.

Fishes—Predation by *Balistes*, serranids, rays and skates—by crunching the shells and eating the meat.

Boring polychaetes—by drilling the shell valves after setting on them (*Polydora* sp).

Boring sponge—by riddling the shell valves with minute holes for gaining substratum for living.

Seastars—by tearing the shell valves apart and feeding on oyster meat.

Boring gastropods—by gyrating holes on shell valves and feeding on the meat (*Nassa* spp., *Sistrum* spp., *Murex* spp. and *Cymatium* spp.).

Crabs and lobsters—by destroying byssal threads and killing the oysters.

In a vast environment like the sea-bed, control would be impossible. Large-scale colonisation of oyster spat in the rocky area might help to offset the effects since it is likely that considerable percentage of stock might survive after what would be destroyed by enemies. The oysters are often found in clusters piled together in such profusion so as to interfere with one another's growth and stunting many. Except for parasitic infestations by cestodes and trematodes which do not necessarily kill the oysters, very little knowledge exists as regards microbial diseases. Understanding these may provide one of the vital clues for the disappearance of oyster stock from densely populated beds.

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