CMFRI
bulletin 39

JANUARY 1987

# PEARL CULTURE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
P.B. No. 2704, Cochin 682 031, India

CMFRI
bulletin 39

JANUARY 1987

# PEARL CULTURE

Edited by: K. ALAGARSWAMI

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
P.B. No. 2704, Cochin 682 031, India.

# 8

# PEARL OYSTER CULTURE IN VIZHINJAM BAY

K. K. APPUKUTTAN[1]

## INTRODUCTION

In India, Gulf of Kutch in Gujarat and Gulf of Mannar in Tamil Nadu are well known areas for pearl oyster resources. Hornell (1922) gave the history of pearl fishery of Gulf of Mannar in detail. Alagarswami (1970, 1975) and Alagarswami and Qasim (1973) have dealt with the distribution of pearl oysters in India, exploitation, farming methods and technology of culture of pearls. Mahadevan and Nayar (1973) reviewed Indian pearl fishery resources and identified *Pinctada fucata* as the common Indian pearl oyster from Gulf of Mannar and Gulf of Kutch. Rao and Rao (1974) have identified six important species of pearl oysters from Indian Coasts. Preliminary idea of pearl oyster resources from Gulf of Kutch is from Hornell's work (1909). Later Easwaran *et al.* (1968) described the present status of pearl fishery in Gulf of Kutch and Pandya (1974) gave pearl oyster fishery and culture experiments in Gujarat.

Recently occurrence of pearl oysters has also been reported from Kerala coast from Vizhinjam Bay. Periodical settlement of oyster spat takes place in the fishing harbour at Vizhinjam, which has been brought to light by Central Marine Fisheries Research Institute (Anon., 1977, 1978). Through a research project of Central Marine Fisheries Research Institute at Vizhinjam the spatfall of pearl oyster in the fishing harbour under construction has been taken advantage of in raising pearl oyster stock. The Fisheries Department of Government of Kerala had undertaken a Pilot Project on Pearl Culture at Vizhinjam in the year 1976. The species composition of pearl oysters from Vizhinjam was *P. fucata*, *P. sugillata*, *P. anomioides*, *P. chemnitzii* and *P. margaritifera* in the order of abundance. In the present account the details of pearl oyster culture work at Vizhinjam with special reference to environmental features of farm, spatfall in different years, spat collection methods, observations on the biology of *P. fucata* and details on fouling and predation in the farm from 1977 to 1980 are given.

## ENVIRONMENTAL FEATURES OF VIZHINJAM BAY

Vizhinjam Bay situated in the southwest coast of India, about 16 km south of Trivandrum (Long. 76°59' E, Lat. 8°22'30" N) in a narrow bay enclosed by a breakwater jutting into the sea on the western side (Fig. 1). The depth of the bay varies from 10 to 15 metres and the bottom of bay is muddy. This area is protected from heavy wave action and violent wind and current during monsoon period.

Temperature, salinity and dissolved oxygen content of surface sea water of this bay was studied from 1977 to 1980 and the results are shown in Figs. 2 and 3. The surface water temperature varied from 20.75°C to 30.50°C, the lowest recorded in July 1978 (20.75°C) and the highest in January-February 1977 (30.50°C). Salinity ranged from a minimum of 31.44‰ in July, 1979 to maximum of 36.31‰ in October 1979. Dissolved oxygen varied from 4.05 ml/l to 5.85 ml/l during 1979-80. The minimum dissolved oxygen was found in March 1979 (0.05 ml/l) and the maximum in November 1979 (5.85 ml/L). Turbidity of water was high during monsoon, especially from May to October. Dharmaraj *et al.* (1980) have studied the seasonal variation in rainfall, salinity, temperature, light penetration, pH, dissolved oxygen content and availability of nutrients from Vizhinjam Bay for a period of one

*Present address :* [1]CMFRI, Research Centre, Vizhinjam 695 521.

year during 1977-78. Their results agree with the present observations and they have found the nutrient value, high during northeast monsoon period.

Temperature and salinity showed increasing trend from October to March and were low during June to September when monsoon was active. During monsoon dissolved oxygen was high compared with rest of the months. There was no marked change in these features from year to year at Vizhinjam.

baskets and then to big box-type iron pearl oyster cage covered with plastic twine meshes.

In 1977, 60 spat collectors of various types were released and settlement in March-April period was found to be good. In the frilled nylon rope-spat collectors, 1-15 numbers of pearl oysters were found. A few numbers were collected from mussel ropes suspended from rafts and also from the nylon meshes of pearl oyster cages. During November-December period spat settlement was

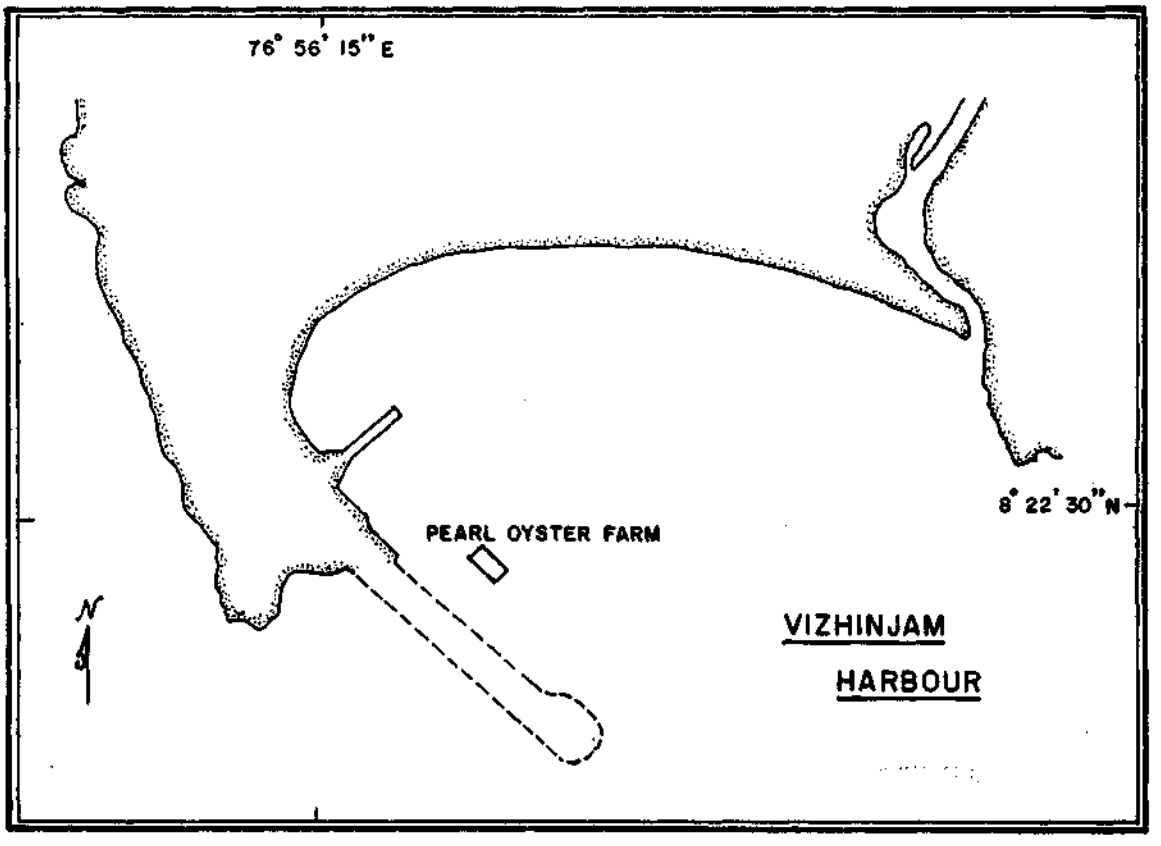


FIG. 1. Vizhinjam Harbour showing the site of rafts for pearl oyster farming.

## OBSERVATIONS ON SPAT SETTLEMENT

Experiments were conducted from 1977 onwards to monitor the spatfall of pearl oysters in Vizhinjam Bay. Various types of spat collectors were used to identify a suitable spat collector for large scale collection of pearl oyster spat. The spat collectors used were roof tile, string of coconut shells, split bamboo poles, frilled nylon rope (Pl. I A), iron hapa covered with nylon netting and nylon net bags. These were released from rafts near the mother oyster stock. Spatfall pattern was noticed every year and the young ones were taken out from the spat collectors and stocked in plastic fruit

poor. A total of 550 spat were collected, mainly from frilled nylon rope. 80% of the spat collected were *Pinctada fucata* and rest flat oysters.

In 1978 February-March period 100 numbers of frilled nylon rope, 55 roof tiles, 15 *hapas* covered with nylon screen and 15 nylon netting bags were released. Inside the *hapas* and bags mother oysters were stocked to note the settlement of spat on the oysters. Frilled nylon ropes were taken to open sea mussel rafts, where also mother oysters were stocked in a few cages. It was found that good settlement of spat was observed in the spat collectors in the open sea

rafts. Only 15 numbers of spat collectors could be retrieved from the open sea, when there was cyclonic weather and ultimate damage of rafts. From these, 500 spat in size 15-34 mm, were collected. Inside the bay a total of 750 spat were collected, mainly from frilled nylon rope (Pl. I B) iron *hapa*, mussel rope and pearl oyster cages in the order of abundance. The percentage of *P. fucata* was 60 to 70% and the rest flat oysters comprising *P. sugillata*, *P. anomioides* and *P. chemnitzii*. During November-December 225 spat were collected of which only 40% formed *P. fucata*.

During 1979 a total of 343 frilled nylon ropes were released. 125 numbers were released in the open sea, of which 45 only could be retrieved during May when sea was rough. From these spat collectors, 1350 spat were collected with an average of 30 spat per collectors. The size of spat ranged from 15 to 34 mm. 985 spat were collected from the spat settlers, pearl oyster cages and mussel ropes from March-June period from the bay. The percentage of *P. fucata* has come down to 30-40% with the rest flat oysters.

In 1980 February spat ranging from 24 to 35 mm were collected which is presumed to be of November-December spawning of the previous year. 3,895 numbers with 20-25% of *P. fucata* were collected from the spat settlers inside the bay. During March-June the spat settlement was very poor. 96 spat collectors released during July have also not shown good settlement, whereas it was interesting to note that profuse settlement of spat was noticed in the nylon netting covering the round fish cages suspended from rafts for fish culture, where the area of attachment is more, and the cage is a cylindrical one with 2-3 metre diameter and 3-4 metre depth. 5 such cages were there inside the bay. From all these cages a total of 6,000

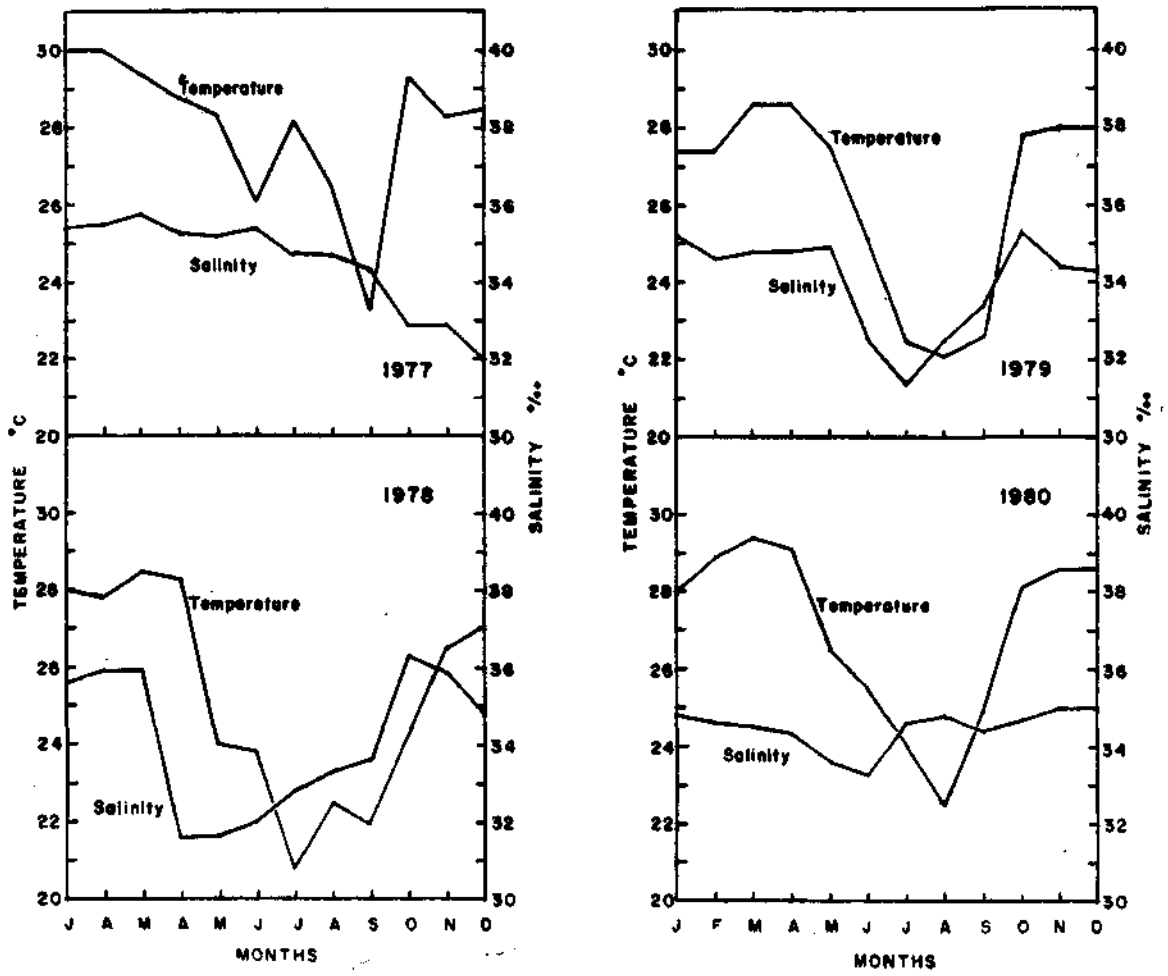


FIG. 2. Monthly average temperature and salinity in 1977, 1978, 1979 and 1980 in the farm site.

spat were collected from July to August. Another 250 numbers were collected from frilled nylon ropes and oyster cages. A total of 10,145 spat were collected of which only 20-30% were *P. fucata*. Mortality of young oysters was caused by crabs and 20-40% damage of the oysters was observed.

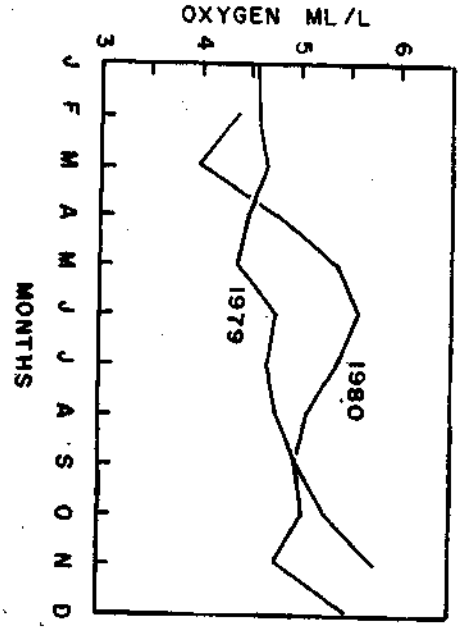


FIG. 3. Monthly averages of dissolved Oxygen in 1979 and 1980 in the farm site.

The observations showed that spat settlement from March to June was fairly good in first two years but in 1980 November-December settlement was good. Peak period of spat settlement coincided with the peak spawning period. It is also interesting to note that the percentage of occurrence of *P. fucata* gradually decreased in the bay. Though several types of spat collectors were tried, frilled nylon rope, nylon screen over *hapa* or fish cage seemed to be effective spat collectors for pearl oysters. It is felt that pearl oyster spat prefer smooth surface for attachment as evidenced by its preference towards the frilled nylon rope, nylon netting and nylon rope. The depth at which maximum number of spat occurred was upper 0.25 m. Very rarely young oysters were collected from depth beyond 2 m from the bay. The reason can be due to the clarity of water in the upper water column and the pearl oyster larvae are known to be phototrophic preferring surface water area for settlement. Another factor which interferes with the profuse settlement of oyster spat is the presence of *Modiolus* sp. and *Avicula vexillum* which appear simultaneously with pearl oyster spat settlement and reduce the space for attachment of pearl oysters.

## BIOLOGY

### *Growth*

Growth increment of farm grown pearl oysters *Pinctada fucata* was estimated by examining samples in the bay from 1978 onwards. During 1978-79 period peak modes of samples were traced for a period of 10 months. In October 1978 peak mode observed was 50-54 mm and through 10 months the peak mode has shifted to 65-69 mm. Thus an average growth of 15 mm for ten months with growth rate of 1.5 mm/month was estimated. Again observations from August 1979 to May 1980 were made by keeping 100 numbers of oysters ranging from 21-61 mm. In the first month the peak mode observed was 45-49 mm and in the tenth month the mode has shifted to 60-64 mm, thus showing 15 mm growth at an average of 1.5 mm/month. During these observations, average length of pearl oysters was calculated for every month and the results are plotted in Fig. 4. It could be seen that growth increments were 5.3 mm, 4.5 mm, 2.1 mm, 1.5 mm, 1.1 mm, 0.8 mm, 0.6 mm, 0.6 mm and 0.7 mm during the first

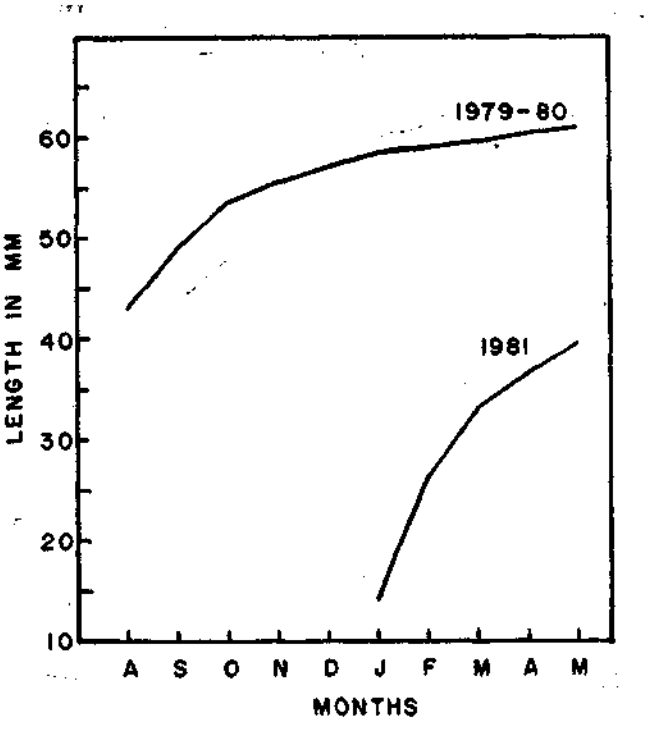


FIG. 4. Growth of pearl oyster based on monthly average size during 1989-80 and 1981.

nine months, respectively. This shows that pearl oysters in their young stage grow faster whereas growth rate is not fast in adults. Observations on spat collected from a single brood of same length range and kept in cages for 3 months have confirmed this information in

1981 beginning. In January pearl oyster spat showed a peak mode of 10-14 mm, in February it was 25-29 mm and in March 30-34 mm, thus a growth increment of 15 mm in the first month and 5 mm in the second month. It is thus quite evident that young oysters exhibit faster growth rate which slows down as the oysters grow.

*Spawning condition*

Regular samples of *P. fucata* were examined to note the gonadal condition of farm grown oysters in different months. The gonadal condition was grouped into 5 major stages *viz.*, stage I—inderterminate-sexes could not be identified; stage II—ova have not attained regular shape, sperm non-motile; stage III—granulation in the ovary appeared, sperm non-motile; stage IV—mature ova, motile sperm, reproductive body creamy coloured-spawning stage; and stage V—spent. The percentage of occurrence of each stage in different months from October 1978 to December 1980 is given in Table 1 which shows that from December 1978 to January 1979 mature stage was high. Again during March to June 1979 another peak of spawning condition was observed with cent percent spawners in April-May period. Thus two peak modes of spawning periods were observed in all the years, which was found agreeable with the spatfall periods observed. Incidentally the peak spawning periods coincide with the southwest and northeast monsoon also. Though these were the peak spawning periods, spawners were found in almost all the months of the year. There was slight variation in the peak spawning months from year to year.

TABLE 1. *Percentage of maturity stages of* Pinctada fucata from *October 1978 to December 1980*

| Month | | Maturity Stage | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| 1978 Oct | .. | 50.00 | 50.00 | .. | .. | .. |
| Nov | .. | .. | 6.67 | 93.33 | .. | .. |
| Dec | .. | .. | .. | 43.33 | 46.67 | 10.00 |
| 1979 Jan | .. | .. | 46.67 | 13.33 | 40.00 | .. |
| Feb | .. | .. | .. | 100.00 | .. | .. |
| Mar | .. | .. | .. | 33.33 | 66.67 | .. |
| Apr | .. | .. | .. | .. | 100.00 | .. |
| May | .. | .. | .. | .. | 100.00 | .. |
| Jun | .. | .. | .. | .. | 46.67 | 53.33 |
| Jul | .. | .. | .. | 6.67 | 30.00 | 63.33 |
| Aug | .. | 100.00 | .. | .. | .. | .. |
| Sept | .. | 86.67 | 13.33 | .. | .. | .. |
| Oct | .. | .. | 90.00 | 10.00 | .. | .. |
| Nov | .. | .. | .. | 43.33 | 56.67 | .. |
| Dec | .. | .. | .. | 40.00 | 60.00 | .. |
| 1980 Jan | .. | .. | 70.00 | .. | .. | 30.00 |
| Feb | .. | .. | .. | 100.00 | .. | .. |
| Mar | .. | .. | .. | .. | 100.00 | .. |
| Apr | .. | .. | .. | .. | 70.00 | 30.00 |
| May | .. | .. | .. | 100.00 | .. | .. |
| Jun | .. | .. | .. | .. | 100.00 | .. |
| Jul | .. | .. | .. | .. | .. | 100.00 |
| Aug | .. | 100.00 | .. | .. | .. | .. |
| Sept | .. | .. | 100.00 | .. | .. | .. |
| Oct | .. | .. | .. | 100.00 | .. | .. |
| Nov | .. | .. | .. | 100.00 | .. | .. |
| Dec | .. | .. | .. | .. | 100.00 | .. |

*Feeding habits*

Examination of the stomach contents of pearl oysters was made from October 1978 to September 1979. In October 1978, 93% of the oysters examined had bivalve eggs and larvae in the stomach. Specific identification of the eggs and larvae could not be done. In November 1978, 27% of oysters and in January 1979, 6% of oysters had eggs and larvae. In the rest of the period under observation the food item observed were only digested algae and detritus.

## FOULING AND PREDATION

The important fouling organisms found in Vizhinjam Bay along with pearl oysters were rock oysters (Pl. I F), barnacles, tubicolous polychaetes, ascidians, bryozoans, alcyonarians, calcareous algae, hydrozoans and crinoids in the order of abundance. Apart from these animals, amphipods, crabs, flat worms, free living polychaetes and sea weeds were found in the pearl oyster cages and also in spat settlers. Seasonal profuse settlement of *Modiolus* spp. (Pl. I C) and *Avicula vexillum* were also observed. In 1977, 1978 and 1979 *Modiolus* and *Avicula vexillum* settlement over the cages and spat collectors were high during March-April. During November-December 1980 heavy settlement of both these bivalves was observed inside the bay. It could be seen that spat collectors, when released are subject to fouling and periodical cleaning of settlers is required to keep it clean for good pearl oyster settlement. Pearl oyster cages and fruit baskets used for stocking oysters were also subject to heavy fouling (Pl. I D,E) when it is kept for longer period in the bay. The main boring organisms observed in the oysters were the polychaete *Polydora* sp. and sponge *Cliona* sp. The bigger shells ranging 60-80 mm often had borers in the umbonal area. The effect of these borers on settlement and growth of oysters was also observed. The oyster and barnacle settlement over the shells hinder the growth of pearl oysters and become a competitor for food. Sponge encrustation even closes the shells of oysters leading to ultimate destruction of the animal. Heavy

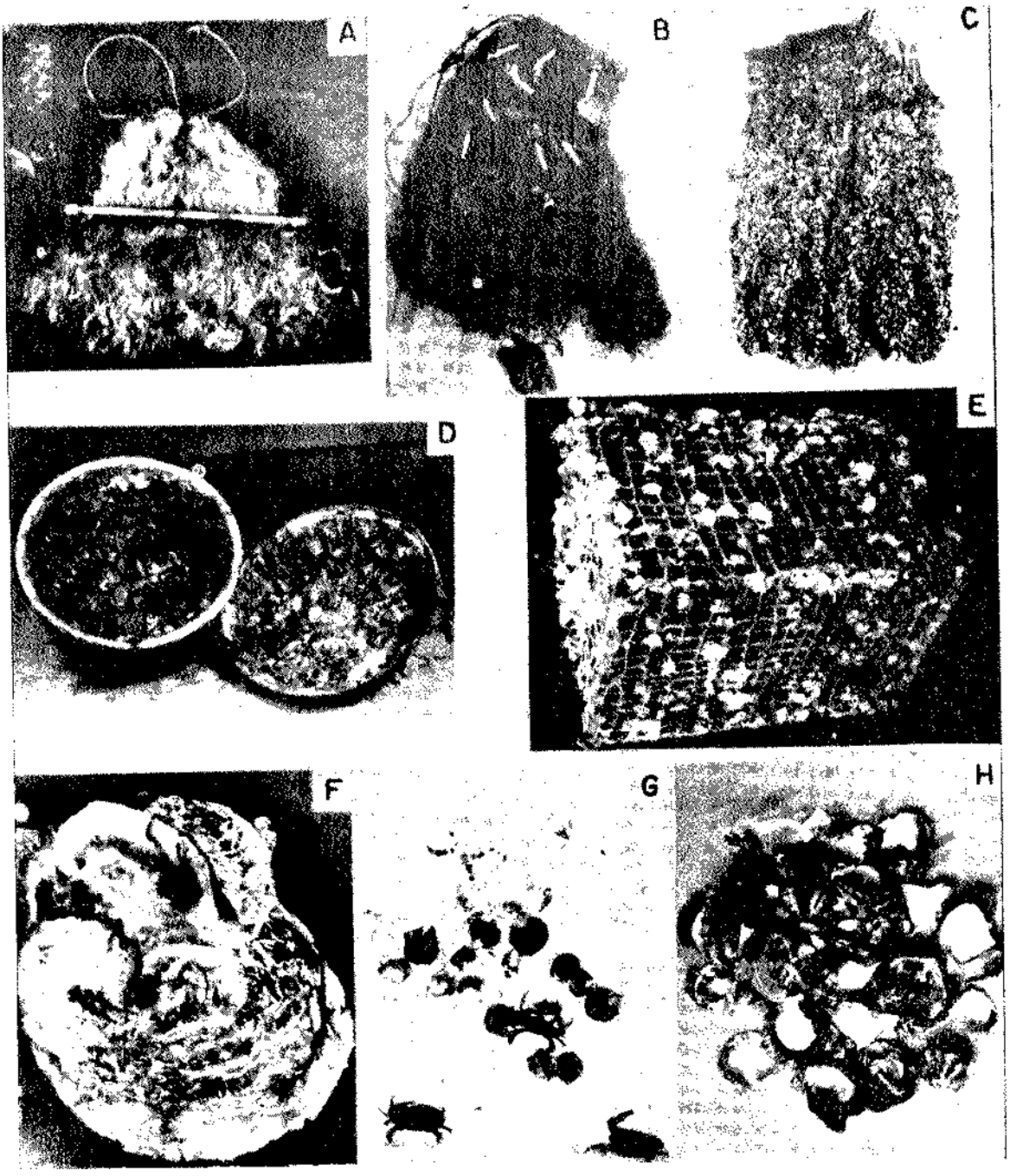


Plate 1. A. Frilled nylon rope-spat collector. B. Spat collector with young pearl oysters - arrow indicating the position of attachment ; C. Spat collectors with *Mytilus* settlement ; D. Fruit basket with fouling organisms ; E. Pearl oyster cage with fouling organisms encrusted over the meshes ; F. Rock oyster settled over *P. fucata* ; G. Predation of *P. fucata* by crabs in the laboratory. H. Broken shells of pearl oysters subject to predation, collected from cages.

ouling by oysters, barnacles, ascidians and sponges block the holes of fruit baskets and meshes of pearl oyster cages obstructing free flow of water through them. Cleaning of cages and spat collectors periodically was found to be effective to check the overcrowding of fouling organisms. The fouling problem was not so serious at Vizhinjam for pearl culture work except the periodical heavy settlement of *Modiolus* pp. and *Avicula vexillum*. Among the borers *Polydora* sp. causes blister formation inside the shell. About 5% of the shells examined had blisters due to polychaete boring. About 3-8% of farm grown oysters were also subject to *Cliona* boring. No serious destruction was caused by this borer to farm grown pearl oysters.

Predation by fishes *viz.*, *Diodon* sp. and *Arothron nigropunctatus* and *Ostraceon* spp. were observed in 1977, 1978 and 1979 in a minor scale. They usually feed on young pearl oysters settled over spat settlers. In 1980 mortality of spat was caused by the predation of crab *Charybdis* sp. which got inside baskets in very early stage and completely destroyed the oyster stock. In certain cases 100% oysters stocked were subject to predation. As a whole 20-40% of oysters stocked were subject to predation in 1980. The process of predation was closely observed in the laboratory keeping the pearl oysters and crabs in fibreglass tanks (Pl. I G). The crab first broke the antero-dorsal margin of the right valve with the chelipede and cut the adductor muscle, thus opening the shell valve. The crab ate away the flesh portion within 4-5 hours. All the oysters which were subject to crab predation had invariably a broken anterodorsal shell margin in the right valve (Pl. I, H). The peak period of predation observed was from October 1980 to January 1981. The size of pearl oysters subjected to predation ranged from 20-40 mm. The oysters of higher length range were not subject to crab predation. Appukuttan (1980) has observed mass-scale predation of mussel by *Rhabdosargus sarba* from Vizhinjam Bay, but it is interesting to note that these fishes were not causing any destruction to oyster stock.

## Discussion

The occurrence of pearl oyster spat in Vizhinjam harbour has led to the initial investigation of this resource and attempts were made to raise a stock of pearl oysters for pearl culture work. Alagarswami (1977) has rightly pointed out that the success of shellfish culture depends to a great extent on the ability to collect and raise the spat of cultivable species. As observed by Alagarswami (1977) a multi-species composition with *Pinctada fucata* forming major species was observed at Vizhinjam. The protected bay is ideally suited for pearl oyster farming. Victor (1980) studied the seasonal changes in atmospheric temperature, surface water temperature, salinity, dissolved oxygen, pH, turbidity and silt deposition around the pearl culture farm at Veppalodai, Gulf of Mannar. He has reported double oscillation of temperature. High salinity during southwest monsoon and low salinity in northeast monsoon and high silt deposition in December are some of the features observed at Veppalodai. At Vizhinjam the spawning and high temperature were interrelated. Both peak spawning periods were observed during October-March coinciding with the period of high temperature and salinity. Compared with Gulf of mannar, the temperature and salinity ranges were low at Vizhinjam Bay.

Spatfall pattern at Vizhinjam was studied by using artificial spat collectors and as noticed at Tuticorin (Alagarswami, 1977). Incursion of species other than *P. fucata* was observed at Vizhinjam also. Experiments at Vizhinjam have shown that frilled nylon rope and *hapas* covered with nylon netting gave good results during peak spawning period. Mahadevan and Nayar (1976) also have suggested spat collection of pearl oysters from spat collectors as more reliable method than the collection from natural bed. Though there are two peak spatfall period at Vizhinjam, spawners and spat are observed in almost all the months of the year. Alagarswami and Chellam (1977) described dimensional relationship in *Pinctada fucata* and observed the heterogenous nature of the population at Tuticorin. At Vizhinjam also the heterogenous nature of *P. fucata* is seen as two peak spawning periods are observed and thus an overlapping of population. In 1977 and 1978 March spawning showed good settlement, whereas in 1979 and 1980 November-December spawning was good. Thus annual variation in spatfall was observed.

Malpas (1933) has used weight curve of pearl oyster from Ceylon as a reliable index of age since it was impossible to separate each generation of oysters from the natural bed, as there is considerable overlapping with successive spawning periods. Observations of Devanesen and Chidambaram (1956) show that the oysters grow to a height of about 36 mm in six months, 35-45 mm at the end of one year, 50-55 mm at the end of second year, 55-60 mm at the end of third year, 60-65 mm at the end of fourth year and 65-70 mm at the end of fifth year. Gokhale *et al.* (1954) and Narayanan and Michael (1968) have observed that pearl oysters from Gulf of Kutch grow fairly fast during the first three or four years and therefater show little growth. Observations at Vizhinjam also show

that young oysters show faster growth and later growth rate is very slow. Compared with other areas the pearl oysters register a fast growth in first year itself at Vizhinjam. In Gulf of Mannar two spawning periods in an year are observed, one in the southwest monsoon period and the other in northeast monsoon period. Herdman (1906) found May-July and November-January as spawning period in Gulf of Mannar while Hornell (1916) gave April-May and September-October as intense spawning periods. Mahadevan and Nayar (1976) also noted biannual spawning in *P. fucata* after observing spatfall in the natural bed. In the present observations at Vizhinjam two peak spawning periods are observed.

Chellam (1980) observed bivalve eggs and larvae in the stomach inclusions of pearl oysters during certain periods of the year at Tuticorin. Phytoplankton and detritus formed the major items of food of pearl oysters at Tuticorin. The occurrence of bivalve eggs and larvae in the stomach of pearl oysters need further study to establish whether it is an isolated event or a regular phenomenon.

Rao and Rao (1974) have listed the major fouling organisms and predators found associated with Indian pearl oysters. Mahadevan and Nayar (1976) observed settlement of *Modiolus* spp. in the natural bed around Tuticorin and stated that increasing *Modiolus* settlement causes severe damage to the oyster bed from year to year. Alagarswami and Chellam (1976) studied the fouling and boring organisms found associated with pearl oysters at Veppalodai, Gulf of Mannar and the seasonal variation in abundance of various organisms and its effects on farming. At Vizhinjam though fouling organisms were not considered as a serious problem for pearl oyster stocking, predation of pearl oyster spat was alarming. Achari (1980) has indicated the impact of introduction of pearl oyster in the new environment and consequent concentration of their biological associates which are new to the locality and the subsequent development of a parallel community. The appearance of predators like crabs in the bay can be attributed to this principle.

## REFERENCES


ACHARI, G. P. K. 1983. Artificial biocoenosis for ecological reconstruction to facilitate aquaculture. *Symposium on Coastal Aquaculture*, Mar. Biol. Ass. India. Abstr. 29 : 18.

ALAGARSWAMI, K. 1970. Pearl culture in Japan and its lessons for India. *Proc. Symp. Mollusca.*, Mar. Biol. Ass. India. Pt. III : 975-993.

ALAGARSWAMI, K. 1975. Preliminary study on the growth of cultured pearls. *Indian J. Fish.*, 22 (1 & 2) : 300-303.

ALAGARSWAMI, K. 1977. Larval transport and settlement of pearl oysters (genus *Pinctada*) in the Gulf of Mannar. *Proc. Symp. Warm Water Zooplamkton. Spl. publication.* National Institute of Oceanography, Goa : 678-686.

ALAGARSWAMI, K. AND A. CHELLAM. 1976. On fouling and boring organisms and mortality of pearl oysters in the farm at Veppolodai, Gulf of Mannar. *Indian J. Fish.*, 23 (1 & 2) : 10-22.

ALAGARSWAMI, K. AND A. CHELLAM. 1977. Change of form and dimensional relationship in the pearl oysters *Pinctada fucata* from Gulf of Mannar. *Indian J. Fish.*, 24 (1 & 2) : 1-14.

ALAGARSWAMI, K. AND S. Z. QASIM. 1973. Pearlc ulture—its potential and implications in India. *Indian J. Fish.*, 20 (2) : 533-550.

ANON. 1977. Pearl culture training. Long term and short term courses. *CMFRI Special Publication*, No. 1 : 39 pp.

ANON. 1978. Mariculture Research and development activities. *CMFRI Special Publication*, No. 2. 48 pp.

APPUKUTTAN, K. K. 1980. Predation of mussels in culture by silver bream *Rhabdosargus sarba*. *CMFRI Bulletin*, 29 : 44-45.

CHELLAM, A. 1983. Study of the stomach contents of pearl oyster *Pinctada fucata* (Gould) with reference to the inclusion of bivalve eggs and larvae. *Proc. Symp. Coastal Aquaculture*, Mar. Biol. Ass. India. Pt. 2 : 604-607.

DEVANESAN, D. W. AND K. CHIDAMBARAM. 1956. Results obtained at the pearl oyster farm, Krusadai Island, Gulf of Mannar and their application to problems relating to pearl fisheries in the Gulf of Mannar. Part 1. *Cont. Mar. Biol. St., Krusadai*, 4 : 1-89.

DHARMARAJ, S. AND A. CHELLAM. 1983. Settlement and growth of barnacle and associated fouling organisms in pearl culture farm in the Gulf of Mannar. *Proc. Symp. Coastal Aquaculture*, Mar. Biol. Ass. India. Pt. 2 : 608-613.

DHARMARAJ, K., N. B. NAIR AND K. G. PADMANABHAN. 1980. Studies on the hydrographical features of Vizhinjam bay *Symposium on Coastal Aquaculture*, Mar. Biol. Ass. India. Abstr. 30 : 19.

EASWARAN, C. R., K. R. NARAYANAN AND M. S. MICHAEL. 1968. Pearl fisheries of the Gulf of Kutch. *J. Bombay Nat. Hist. Soc.*, 66 : 338-344.

GOKHALE, S. V., C. R. EASWARAN AND R. NARASIMHAN. 1954 Growth rate of pearl oyster, *Pinctada fucata* in the Gulf of Kutch with notes on pearl fishery 1953. *J. Bombay nat. Hist. Soc.*, 52 (1) : 124-136.

HERDMAN, W. A. 1906. Reproduction and life history of the pearl oyster. *Rep. Govt. Ceylon Pearl Oyster Fish. Gulf of Mannar*, **5** : 109-186.

HORNELL, J. 1909. Report to the Government of Baroda and the prospects of establishing a pearl fishery and other marine industries on the coast of Okhamandal. *Report to the Government of Baroda on the Marine Zoology of Okhamandal in Kattiawar*, Part I : 1-34.

HORNELL, J. 1916. An explanation of irregularly cyclic character of the pearl fisheries of the Gulf of Mannar. *Madras Fish. Bull.*, **8** : 11-22.

HORNELL, J. 1922. The Indian pearl fishery of the Gulf of Mannar and Palk Bay. *Madras Fish. Bull.*, **16** : 1-188.

MAHADEVAN, S. AND K. NAGAPPAN NAYAR. 1973. Pearl oyster resources of India. *Proc. Symp. Living Resources of the Seas around India. Spl.* Publication, CMFRI, 659-671.

MAHADEVAN, S. AND K. NAGAPPAN NAYAR. 1976. Underwater observations on the settlement of spat of pearl oyster on the paars off Tuticorin. *Indian J. Fish.*, **23** (1 & 2) : 105-110.

MALPAS, A. H. 1933. Further observations on the age and growth rate of the Ceylon pearl oyster, *Margaritifera vulgaris* with special reference to oysters of Donnan's Muttuvarattu Paar. *Ceylon J. Sci.*, (Fish), **5** : 21-48.

NARAYANAN, K. R. AND M. S. MICHAEL. 1968. On the relation between age and linear measurements of the pearl oyster, *Pinctada vulgaris* (Schumacher) of the Gulf of Kutch. *J. Bombay nat. Hist. Soc.*, **65** (2) : 442-452.

PANDYA, J. A. 1974. Pearl oyster resources and culture experiments in Gujarat. *Proceedings of the Group Discussion on Pearl Culture* held at Tuticorin. January 1974, CMFRI.

RAO, K. V. AND K. S. RAO. 1974. Pearl oysters. In : *The Commercial Molluscs of India, Bull. Cent. Mar. Fish. Res. Inst.* **25** : 84-106.

VICTOR, A. C. C. 1980. Ecological conditions of the pearl culture farm off Veppalodai in the Gulf of Mannar. *Proc. Symp. Coastal Aquaculture*, Mar. Biol. Ass. India. Pt. 2 : 619-626.