LARVAL TRANSPORT AND SETTLEMENT OF PEARL OYSTERS (GENUS *PINCTADA*) IN THE GULF OF MANNAR*

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The pearl oyster resources of India show wide fluctuations in their annual yields. In the Gulf of Mannar, after 27 years of 'barrenness', the pearl oyster beds revived most profusely in 1955, but soon became depleted after sustaining a seven-year fishery series. Such fluctuations are common on both the Indian and Sri Lanka coasts of the gulf, where the same species (*Pinctada fucata*) has contributed to the pearl fisheries since time immemorial.

Larval drift across the Gulf of Mannar has been held as one of the probable causes of repopulating the oyster beds on either side of the gulf. Recently, during the course of experiments on pearl oyster culture at Tuticorin, good settlement of pearl oyster spat was observed even in new areas when suitable substrata for settlement were provided. Good spatfall took place on the collectors suspended from rafts in the Tuticorin harbour basin. Similarly, spatfall was observed in the open sea off Veppalodai. On the southwest coast of India, where pearl banks have not so far been known to exist, there has been a very good spatfall in the fishing harbour at Vizhinjam. These populations are characteristically mixed with different proportions of species such as *P. fucata, P. chemnitzii* and *P. sugillata.*

The settlement of pearl oyster spat in new areas has been examined in relation to the pearl oyster populations in the neighbouring beds. In the recent years incursions of species other than *P. fucata* have been noticed in some of the natural beds. The species composition is similar to that of the populations settling in the artificial coastal basins. Larval transport by currents brings about spatfalls in the natural beds and the basins. Factors which seem to enhance the chances of survival of the veligers in the terminal stage of pelagic phase and their settling as spat are discussed.

INTRODUCTION

The success of shellfish culture depends to a great extent on the ability to collect and raise the spat of the cultivated species. Although hatchery techniques have been developed and put to commercial exploitation, the endeavour is at present limited to a few species and to a few places (Bardach *et al.*, 1972). By far, the aquaculture industry still depends on the natural spat produced either by the wild populations or cultivated stocks.

In India, positive development in pearl culture has only been recent (Alagarswami and Qasim, 1973; Alagarswami, 1974). After the 1955-61 series of pearl fishery in the Gulf of Mannar, there has been a sharp decline in the pearl oyster populations on the natural beds. However, since 1972, good spatfalls were observed in the newly constructed harbours at Tuticorin although the wild populations

*Scheme on Pearl culture.

continued to be sparse. Besides, the composition of species obtained in some of the natural beds and in the harbour basins appeared different from the single species - *Pinctada fucata* - dominance which was characteristic of the beds.

PEARL OYSTER BEDS IN THE GULF OF MANNAR

The distribution of the pearl oyster beds in the Gulf of Mannar adjoining the southeast coast of India is shown in Fig. 1. The term 'paar' in the local language means a pearl oyster bed. The beds extend discontinuously along the Indian coast and lie at a mean depth of about 15 m and at a distance of about 12-20 km from the shore. Hornell (1922), Baschieri-Salvadori (1960) and Mahadevan and Nayar (1968) gave descriptions of the pearl banks. The Gulf of Mannar also has pearl oyster beds on its far eastern side close to the west coast of Sri Lanka. Here the pearl bank plateau is bounded for the most part by the 10-12 fm (18.3-22.0 m) line, although some lie at a depth of 2-3 fm (3.7-5.5 m) close to the shore (Herdman, 1903).

The pearl oyster populations (*Pinctada fucata*) of the Gulf of Mannar have shown considerable fluctuations over the last few centuries. Periods of abundance have alternated with periods of decline. The intervening periods between fisheries have at times extended to as many as forty years. Along the Indian coast, after 1928, there was a pearl fishery series from 1955 to 1961. Subsequently the beds have been closed for fishing due to the depletion of oyster stocks. The number of oysters harvested during the last series, as given below, would indicate the magnitude of the populations in productive years (numbers in thousands): 1955- 3,509; 1956- 2,129; 1957- 11,175; 1958- 21,477; 1959- 16,428; 1960- 16,176 and 1961- 15,361. Such high-yielding beds showed depletion in the immediately following years and the observation "the pearl oysters are very few, almost absent, most of them having been fished; remaining perished or eaten away by predators" made by Mahadevan and Nayar (1968, p. 160) summarised the post-fishery conditions.

On the Sri Lanka side, after a lapse of 33 years, a pearl fishery was conducted in 1958 which yielded 4.5 million oysters (Sivalingam, 1961). Subsequently there were two minor fisheries in 1960 and 1961 and inspections carried out on the pearl banks since then have not shown any large populations (Fernando, personal communication).

SPAT SETTLEMENT

After commencing experimental work on production of cultured pearls at Veppalodai near Tuticorin (Fig. 1) towards the end of 1972 (Alagarswami and Qasim, 1973), observations were made on the settlement of pearl oysters in the farm area. Spat settlement was noticed for the first time in May 1973 on the oysters and also on the ropes forming meshes of baskets holding them. In 1974, it was observed that pearl oysters have colonised the newly constructed artificial harbour at Tuticorin. After making a preliminary survey of the area, a farm was established in the harbour basin for pearl culture work and for monitoring spatfall. In April 1975, collection of pearl oysters could be made in the newly constructed fishing harbour at Tuticorin. Mention may also be made here of the dense spatfalls observed in the fishing harbour under construction at Vizhinjam near Trivandrum along the southwest coast of India, bordering the Arabian Sea. Although the term "spat" should be used to denote the young oysters just past the veliger stage which have settled down and become attached to some hard object, it is used here in a broader sense to include the seed oysters of up to 30 mm size (dorso-ventral measurement) which are suitable for transplantation or caging.

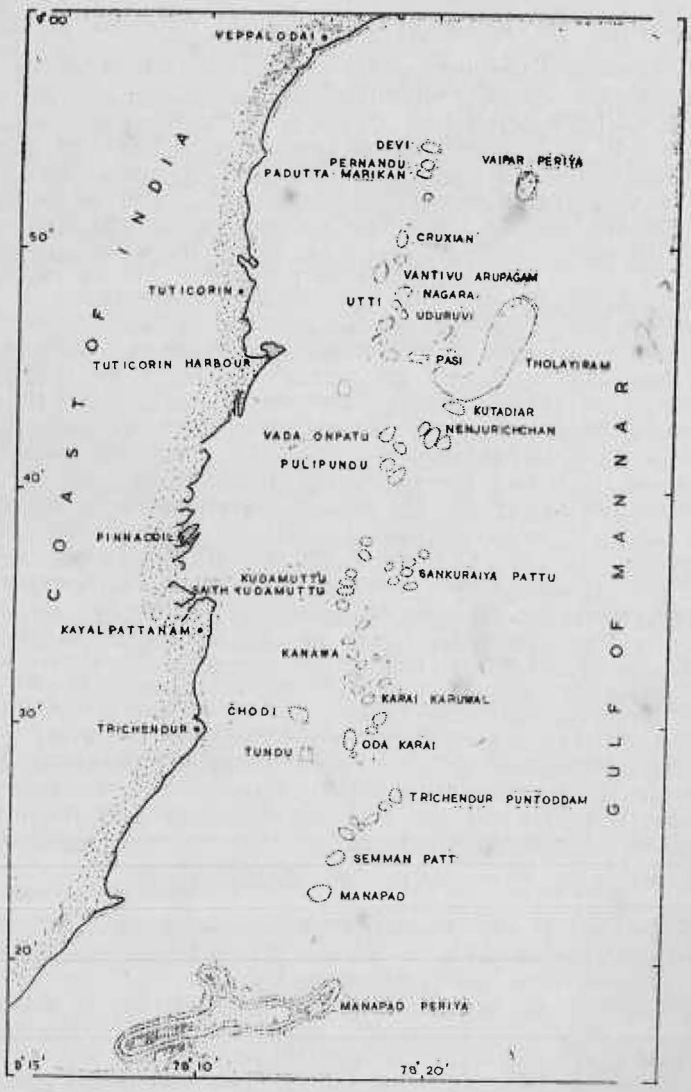

Fig. 1. Map showing the pearl oyster beds in the Gulf of Mannar, along the Indian coast. The dotted lines show the approximate contour of the beds. The names of beds or "paars" are in local language

Spat collection at Veppalodai: The rafts are moored in the open coastal waters, about 2 km from the shore, where the depth is 5 m. The area is subjected to the influence of both the NE and SW monsoons. Turbidity is high almost throughout the year. Spatfall has been observed in the farm since 1973. Seed oysters are more abundant in May, June and July accounting, respectively, for 11.3%, 58.9% and 12.3% of the total collections during 1973-76. February contributed 10.9% of the spat. In the rest of the months spatfall has been insignificant. The minimum size of spat obtained was 2.3 mm in February, 3.0 mm in May, 2.3 mm in June and 4.3 mm in July. The dominant size groups were 5-10 mm in February, May and June and 10-15 mm in July. The species of pearl oysters obtained are mainly *Pinctada sugillata* and *P. anomioides* and a very small percentage of *P. fucata*.

Spat collection in harbour basin: The harbour basin at Tuticorin is an embayment caused by the construction of two parallel breakwaters on the northern and southern sides with an eastern arm extending from the south breakwater. The width of the basin is 1275 m and the water area enclosed is about 390 ha. The depth gradually increases from the shore line and is 11.35 m at the approach channel which is 183 m wide. The basin has a tidal amplitude of 1.07 m. The rafts are moored at about the middle of the length of the harbour where the depth is 8 m. Clarity by Secchi disc extends usually up to 5 m. The basin is calm throughout the year but strong winds during the monsoons create swells on either side (north or south) and the rafts are shifted to the calmer side. Granite stones of different sizes, ranging from rubble to boulders of 6-8 tons weight, have been used in the construction of the breakwaters and these formed a good substratum for the settlement of pearl oysters.

The oysters are found in abundance on the inner sides of the south breakwater which has a greater slope and is filled with quarry rubbish leaving numerous crevices. This part of the harbour was laid during 1972-73 and colonisation seems to have proceeded immediately thereafter judging from the large size of the oysters collected in 1974. The density of population increases seawards. Boulders are present in all other parts of the breakwaters and oyster settlement is thinly scattered on them. On the outer sides of breakwaters there is very poor settlement as they are directly exposed to the breakers.

Spatfall was observed on the collectors suspended from rafts. The oysters and baskets themselves formed good collectors. The peak periods of spatfall in the harbour basin were June and December which, respectively, accounted for 62.2% and 24.6% of the total spat collected during September 1975-August 1976. May yielded 5.0% and January 3.0% of the spat. The minimum sizes recorded were 5.0 mm in June and 4.0 mm in December. The dominant size groups during these months were 10-15 mm and 5-10 mm.

A significant point on the settlement of pearl oyster spat in the harbour basin is that the population consists of several species of the genus *Pinctada*. *P. sugillata, P. anomioides* and other species with relatively flat shells are dominant and *P. fucata*, the important species in pearl culture, forms about 15% of the population. This is reflected both among the spat collected in the farm and among the oysters which have colonised the breakwaters. *P. margaritifera* occurs only in stray numbers.

Settlement in fishing harbour: The breakwaters of the fishing harbour at Tuticorin were found to have a population of oysters closely resembling *P. chemnitzii* in shell characters. Oysters have also settled on the hulls of fishing vessels which were laid up in the harbour for a period of more than a year.

TABLE. 1. DISTRIBUTION OF PEARL OYSTERS IN SOME OF THE

Season	Beds surveyed	No. of oysters collected
1972-73	Tholayiram, Pulipundu, Kudamuttu	2,740
1975-76	Tholayiram, Vada Onpatu, Pulipundu, Kudamuttu, Saith Kudamuttu	1,034
1975-76	Devi, Pernandu, Padutta Marikan, Cruxian, Vantivu, Arubagam, Nagara, Utti, Uduruvi	298
1976 Nov-Dec	Devi, Pernandu	11,919

During April 1975, collections from this basin amounted to over a thousand. The minimum, maximum and average sizes of oysters were 21.4 mm, 80.6 mm and 38.0 mm respectively.

Spat collection from natural beds: It is likely that the spatfall in the basins and inshore areas resulted from the drift of pearl oyster larvae from the nearby pearl banks. To study the populations in the natural beds, surveys were conducted during 1972-73 and 1975-76 seasons and in November-December 1976. The survey was restricted to seasons when sufficient clarity prevailed over the pearl banks enabling visual examination of beds. The season normally extended from November to May, starting from the north and advancing southwards. The pearl banks which have been exploited traditionally lie between 8°15'N and 8°55'N (Fig. 1). Collections were made only in the northern half of this stretch, extending from 8°35'N to 8°55'N. A summary of the distribution of pearl oysters as observed during the surveys is presented in Table 1. Data are not available for the seasons of 1973-74 and 1974-75.

It is seen from the table that while *P. fucata* formed 100% of the collections during 1972-73, in the subsequent seasons the flat-shelled oysters comprising the species *Pinctada sugillata, P. anomioides* and others have made incursions in the pearl banks (Enquiries with the divers who have experience of the pearl banks revealed that pearl oysters other than *P. fucata* used to be very rare in former fishery seasons). In 1975-76 season, a qualitative difference in composition was seen between the oysters collected from the group of paars. While the flat oysters constituted only 12.6% in the former group, their composition was 44.7% in the latter. During November-December 1976, the flat oysters constituted 72.0% of the collections from Devi and Pernandu paars. The data show that the incursion of flat-shelled pearl oysters was more in the northern beds, particularly from Devi paar in the north to Uduruvi paar in the south (8°55'N to 8°47'N) than in the beds situated immediately south. It is also to be noted that the former group of paars lies in the depth range of 11.0-12.8 m while the latter group lies in slightly deeper waters between 14.6 m and 18.3 m.

The table further shows that larger oysters with a mode at the size-group 50.0-55.0 mm dominated the collections during 1972-73. In 1975-76 and November-December 1976, the modes were 20.0-25.0 mm and 30.0-35.0 mm respectively for *P. fucata;* similarly the modes of flat oysters were formed by the younger groups. Spat below 30.0 mm dominated the populations constituting 60.1% to 86.6% in

NATURAL BEDS IN THE GULF OF MANNAR

Species composition (%)		Modal size-group (mm)		Percentage of spat	
P. fucata	flat oysters	*P. fucata*	flat oysters	*P. fucata*	flat oysters
100	nil	50.0-55.0	—	11.7	—
87.4	12.6	20.0-25.0	10.0-15.0 & 25.0-30.1	86.6	80.0
55.3	44.7	20.0-25.0	25.0-30.0	83.0	60.1
28.0	72.0	30.0-35.0	30.0-35.0	30.0	32.4

1975-76. During November-December 1976, spat below 30.0 mm formed 30.0% among *P. fucata* and 32.4% among the flat oysters. However, young oysters of size range 25.0 - 40.0 mm were predominant in this season comprising 79.3% and 87.3% of *P. fucata* and flat oyster collections respectively.

OCCURRENCE OF BIVALVE LARVAE IN PLANKTON

Observations were made on the occurrence of bivalve larvae in the plankton. The monthly average plankton volume in the inshore waters off Veppalodai showed great variations in 10-min hauls made with a nylobolt net of ring diameter 0.5 m, from 1.1 ml in February to 15.3 ml in August. The maximum number of bivalve larvae in the samples was 4192 on July 14, 1976 and other high values were 3252 numbers on September 25, 1975 and 2216 numbers on August 29, 1975. All the larvae were shelled ones belonging to different species of lamellibranchs. Larvae resembling the stages described for the Japanese pearl oyster by Ota (1957) occurred in the plankton in large numbers. Sudhakar and Chandrasekharan (1967) assumed that the planktonic veligers collected from Tholayiram paar may be those of *Pinctada fucata* based on Herdman's (1906) illustrations. Investigations are being continued on identification, isolation and rearing of planktonic larvae.

DISCUSSION

Korringa (1952) noted that in the case of the Limfjord oyster (*Ostrea edulis*) populations, the periods of increase alternated with periods of decline. His observation that rehabilitation of oyster beds is a slow process and a series of favourable years is necessary to produce a marked increase in the stocks of oysters holds good for the pearl oyster beds in the Gulf of Mannar. The pearl fishery series of 1955-61, when over 86 million oysters were harvested, appears to have been a case of overfishing. Chacko and Sambandamurthy (1969) reported the population to be nil in 15 banks and rare in 5 others during the season 1962-63. As Korringa (1952) remarked cumulative effect of overfishing of oyster beds makes a revival very difficult. A revival will be more difficult in the case of the pearl banks which are unsheltered and spread widely over a vast area.

Hornell propounded a theory in 1905 that the beds on the opposite sides of the Gulf of Mannar, namely the Indian and Sri Lanka coasts, confer reciprocal benefits on each other (Hornell, 1916). Based on results of drift bottle experiments

he presumed that the transport of larvae from the Sri Lanka beds to Tuticorin beds would take place during the NE monsoon and the larval drift in the reverse direction would occur during a normally strong SW monsoon. Hornell himself reconsidered his theory subsequently in the same report and stated "my belief in its vital importance was weakened considerably of late years" (Hornell, 1916, p. 19). Devanesen and Chidambaram (1956) considered the above theory fascinating but discredited it. It may be noted that, based on sample surveys carried out in 1955, Sivalingam (1958) estimated stocks of 48.7, 5.6 and 158.4 million oysters on three pearl banks on the Sri Lanka side and predicted a harvest for February 1958. A pearl fishery did take place there in February-March 1958 (Sivalingam, 1961) and again in 1960 and 1961. Around the same period there was the most successful series of pearl fishery on the Indian side from 1955 to 1961. Hornell (1916) established alternative succession of pearl fisheries between the two coasts in over 75% of the instances from the year 1669 to 1904 which appeared to him more than a mere coincidence. The Indian and Sri Lanka pearl banks remained almost simultaneously unproductive since 1928 and 1925 respectively and on both sides fishing was resumed in 1955 and 1958 respectively.

However, the validity of the theory of Hornell on larval transport cannot be established unless we have more information on the hydrographical conditions of the entire Gulf area and on the pelagic phase of the pearl oyster larva. Prasad (1954) observed that, generally speaking, the drift of water at the head of Gulf of Mannar is from south to north during April to August which coincides with the period of SW monsoon and of turbulence and from September onwards, with the onset of the NE monsoon, the direction of drift is reversed. Within this general pattern, Pillai (1962) observed currents in reverse direction over the pearl banks off Tuticorin on certain days during March-May period. Korringa (1952) found that the distribution of *O. edulis* larvae in the Oosterschelde paralleled the hydrographic data so closely that the oyster larvae could almost be used as an indicator of the origin of the water. Reed (FAO, 1962) attributed unusual weather conditions in Dongonab Bay in Sudan as a probable cause for the failure of the 1961 spat collection season for *Pinctada margaritifera.* These observations show that a sound knowledge of the hydrographical conditions of the gulf is necessary to understand the drift of pearl oyster larvae and their setting.

The pelagic phase of the larvae of pearl oysters in this region has not been fully studied. Herdman (1903) and Hornell (1922) held that setting of veligers in the Gulf of Mannar may take place on the 5th day after fertilisation. Larval rearing has been carried out successfully in the Japanese pearl oyster. Kobayashi (*vide* Cahn, 1949) reported 25 days of pelagic phase for *P. martensii* from fertilisation to setting. Ota (1957) determined the total planktonic duration to be 15 to 25 days. Wada (1942), as reported by Cahn (1949), found that the larvae of *P. maxima* were ready for setting from 2 to 3 weeks after fertilisation. It could be reasonably presumed that the pelagic phase of *P. fucata* in the tropical waters may be shorter than that of other species in the temperate waters.

Hornell (1916) laid more faith on the theory of rehabilitation of deep water pearl banks "from scattered oysters in the shallow water around the reefs and islands at the head of the Gulf". Presence of limited pearl oyster stocks in the natural beds is evident from the data in Table 1. The unimodal population of oysters collected during November-December 1976 indicate a successful spatfall on some of the beds by about June 1976. Inspection of Sri Lanka pearl banks carried out from 1962 to 1974 have shown that the oysters were scattered in small numbers on the beds (Fernando, personal communication). These would

show that the wide expanse of the Gulf of Mannar always have a few pockets of pearl oyster populations in uneven concentrations. These pockets may be of a shifting character in the sense that production and destruction may be at random. A series of favourable seasons may be necessary for the revival of these natural beds.

Against the above background of pearl oyster settlement in the natural beds, the good setting of spat in the harbour basin and moderate setting in the inshore farm at Veppalodai highlights a few facts relating to larval drift and spatfall. It is evident that pearl oyster larvae reach these areas from their place of origin carried by currents. When conditions suitable for setting are available, spatfall occurs. Spatfall appears to be more successful in sheltered deep bays than in open shallow waters. The factors promoting the spatfall in the harbour basin seem to be the following: the embayment with only a narrow channel restricting the dispersal of larvae once they have been carried into the basin, low amplitude of tides enabling greater retention of the larvae, absence of strong currents to drift the larvae away, low turbidity of water, presence of suitable substratum in the form of granite rubble bordering the breakwater and finally, the harbour being a recent construction, the absence of water pollution. The appearance of spat in the fishing harbour at Vizhinjam runs parallel to the spat settlement at the Tuticorin harbour, with the difference that the existence of natural beds along the west coast is not known except in the Gulf of Kutch in the north. Both these basins are free from pollution as they have not been or hardly been put to use at this point of time. But spatfall in the fishing harbour at Tuticorin has not been so successful since 1975 as it has been polluted by the oil discharge from the large number of fishing vessels berthing there.

The pearl oysters in the harbour basin comprise a dominant flat-shelled group with a small percentage of *P. fucata*. During 1974 and 1975, the latter species contributed to about 15% and the rest belonged to *P. sugillata, P. anomioides* and others. Since 1975, a qualitative change has been observed in the populations of the natural beds themselves, particularly in the northern beds, where flat oysters formed as high a percentage as 72.0 and *P. fucata* 28.0%. Pearl oyster populations in the inshore beds (depth 6.4 m) off Rameswaram in the Palk Bay have been found to be predominantly *P. sugillata* and *P. anomioides* (unpublished data). It appears, then, that the shoreward beds in the northern zone of the Gulf of Mannar and in the Palk Bay have a dominant flat oyster population and that the spatfall in the inshore areas and basins has a similar species composition. The spatfall in the fishing harbour at Vizhinjam has been found to be composed of *P. chemnitzii, P. sugillata* and others, besides *P. fucata*. This observation further proves that larval drift causes successful settlement of pearl oysters in the sheltered coastal areas and that in such areas the spatfall consists of mixed species of the genus *Pinctada*.

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