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SPAT SETTLEMENT OF BROWN MUSSEL *PERNA INDICA* KURIAKOSE AND NAIR IN THE SOUTHWEST COAST OF INDIA*

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ABSTRACT

Brown mussel *Perna indica* contribute 15% of the total mussel production in India. This species spawns from June to August from Quilon to Cape Comorin. The spat settlement in the natural bed was observed from July to September and the peak mode of spat size in the natural bed and the growth rate were estimated. Regular sampling from natural bed was done to observe the density and changes in the spat settlement pattern. The byssogenesis of spat ranging from 5-35 mm were studied in the laboratory condition. The effect of temperature, salinity and dissolved oxygen on spawning and settlement are also presented in this paper.

INTRODUCTION

BROWN MUSSEL *Perna indica* is found abundant along the southwest coast of India contributing an average annual landings of 420-450 tonnes which is 15% of the total all India mussel landings (3100-3400 t). From time immemorial this resource is being exploited from the natural beds along the southwest coast of India and from 1971 onwards experiments for evolving suitable farming techniques were done at Vizhinjam. Further experiments at Calicut, Karwar, Goa, Ratnagiri and Madras have shown the possibilities of large-scale mussel farming in India utilising the seed resources available in the natural beds. However the present status of seed availability from Indian Coasts are not fully known. Jones (1950), Jones and Alagarswami (1973), Nair *et al.* (1975) and Appukuttan and Nair (1983) have described the colonisation of spat along the west coast of India for both the species of mussels. An important problem in mussel farming all over the world is the collection of required quantity of seed. An understanding of the distribution, abundance, seasonal fluctuation and factors affecting settlement are essential for maximum utilisation of the seed resources. The present study deals with spawning and settlement period, growth rate of spat in the natural bed, settlement pattern and the results of byssogenesis experiments. The details of environmental factors *viz.* temperature, salinity, dissolved oxygen and rainfall which influence spawning and settlement of brown mussel are also given in this paper.

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Material and Methods

Maturity stages and spawning of mussels from natural bed were studied by examining samples of reproductive tissues microscopically for 10 years from 1976-1985. The spat settlement period was ascertained by regular examination of natural beds in selected centres in three major zones of southwest coast of India *viz*. Quilon to Valiathura, Vizhinjam to Chowarah and Enayam to Muttom (Fig. 1 and 2). As the mussel settlement was noticed

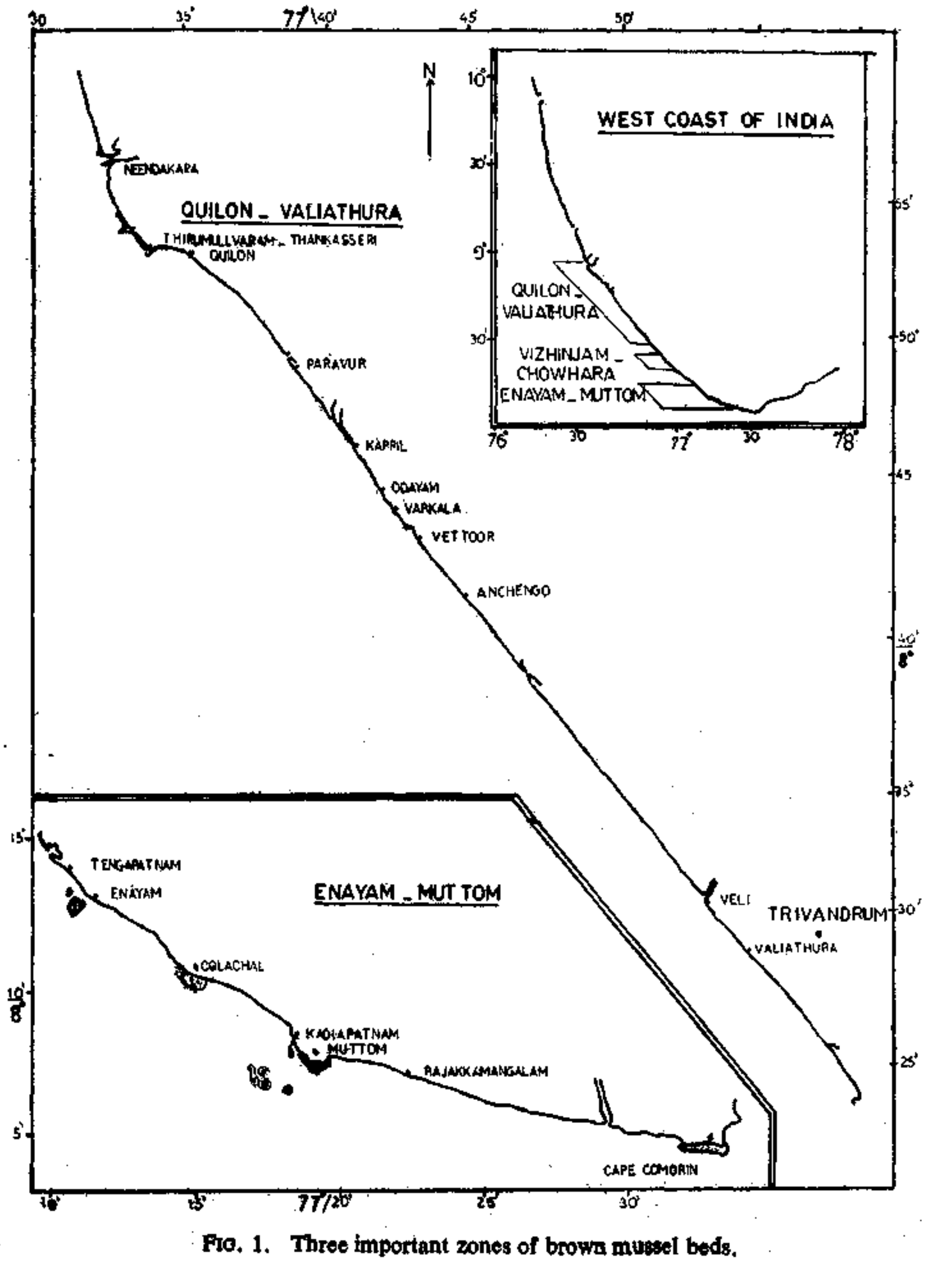

Fig. 1. Three important zones of brown mussel beds.

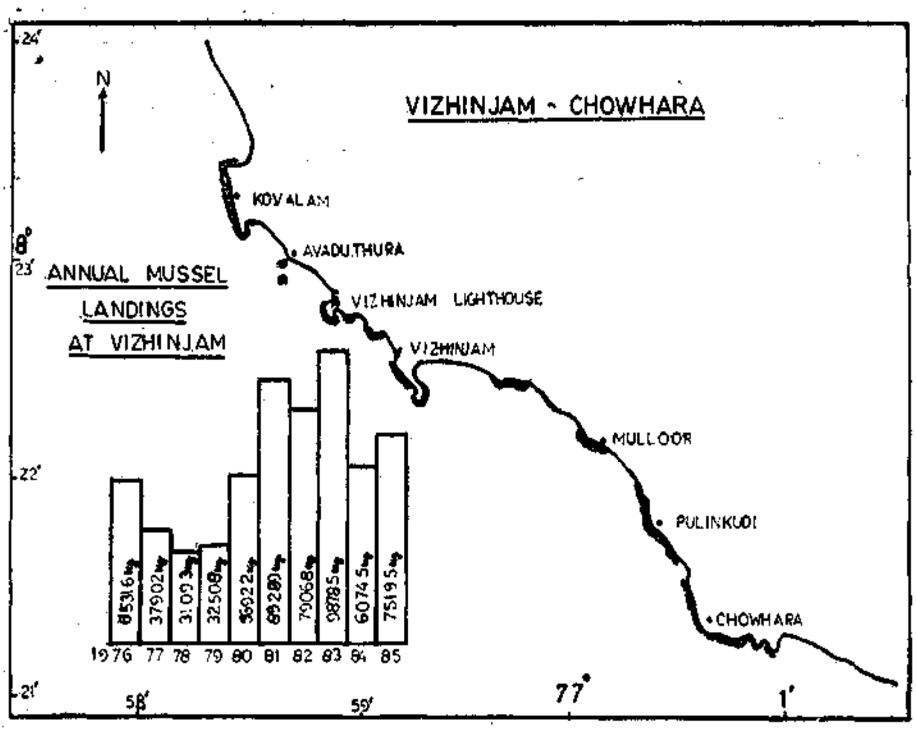

FIG. 2. Mussel landings at Vizhinjam—Chowarah area from 1976-1985.

in the intertidal and inshore rocky areas, the zone between lowest level exposed to air by waves to the highest level washed by wave actions was considered as intertidal area and the zone from intertidal to deeper area as sub-littoral or infralittoral zone. Growth rate of spat for 1976, 1979 and 1984 were observed by tracing the peak mode. The total landings of mussel at Vizhinjam from 1976 to 1985 was taken to observe the trend in mussel fishery during 10 year period. Two size groups of mussel spat *viz.* 6-15 mm and 16-35 mm were used for byssogenesis experiments in the laboratory. A total of 11 experiments using 20 numbers of mussel spats of each group were used for these experiments. The number of byssus threads secreted within 18 hours were counted at the end of each experiment. The mussels secreting 1-20 numbers of byssus threads are expressed in per cent to the total number of mussels used for experiments.

RESULTS

Spawning season

Appukuttan and Nair (1980) have described the spawning periodicity of brown mussel and classified the maturity stages into four stages. Long term observations on spawning help to provide informations on recruitment to the population. In the present study the details on the months of first maturity and spawning period of brown mussel were consolidated for 10 year period (Table 1) (1976-85). In most of the years fully mature adult males having motile sperm and females with fully yolked round eggs appears from April and spawning commences by late May or early June. The environmental details *viz.* temperature, salinity and rainfall for 10 years shown in Fig. 3 indicate that with the onset of southwest monsoon, the salinity and temperature decline and this coincide with the commencement of spawning

TABLE 1. *Months of first maturity, spawning and settlement period of* Perna indica *from Vizhinjam and adjacent areas from* 1976-1985, *peak periods of spawning and settlement shown in paranthesis*

Year	Month of first maturity	Spawning period	Settlement period	Remarks
1976	April	May-July (June)	June-September (July-August)	Moderate settlement of spat in all the major landing centres.
1977	April	May-August (July-August)	May-October (July-September)	Heavy *Modiolus* sp. settlement in the natural bed all along the coast. Poor settlement of mussels.
1978	April	May-September (July-August)	June-November (August-October)	Heavy *Modiolus* settlement and poor mussel settlement in the natural bed.
1979	April	May-September (June)	June-November (July-August)	Heavy *Modiolus* settlement and prolonged settlement period of mussel.
1980	May	May-July (June)	July-August (July)	Moderate mussel settlement in all the major centres and no *Modiolus* settlement observed in natural bed.
1981	April	June-August (June-July)	June-September (July)	Good mussel settlement all along the coast. Green mussel also seen settled in the natural bed. Stray numbers.
1982	May	June-July (June)	June-August (July)	Good settlement of brown mussel spat in all the centres.
1983	April	June-July (July)	July-September (July-August)	Good spat settlement in all major centres.
1984	June	June-August	August-November (July-September)	Prolonged settlement in major centres observed. Good settlement
1985	June	July (July)	July-September (August)	Good, prolonged settlement period.

TABLE 2. *Dissolved oxygen (ml/l) in the mussel beds off Vizhinjam and nearby places from* 1980-85 *period*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1980	..	..	..	4.50	4.44	4.80	4.70	4.88	5.04	5.10	4.80	5.51
1981	5.10	5.07	4.90	5.14	5.25	4.64	5.13	5.15	5.09	4.68	4.80	4.54
1982	4.58	4.66	..	4.37	4.33	4.78	4.61	4.52	4.63	4.63	4.78	4.47
1983	4.32	4.92	5.05	4.84	4.87	4.82	4.84	4.62	4.24	4.02	4.21	5.22
1984	4.62	5.03	4.93	4.35	4.61	4.87	4.86	4.03	4.02	4.51	4.80	4.47
1985	4.48	4.77	4.82	4.41	4.44	4.17	4.36	4.37	4.00	4.74	4.92	4.35

in natural bed. Spawning usually lasts till August and the peak period is June-July. In 1978 and 1979 spawning extended upto

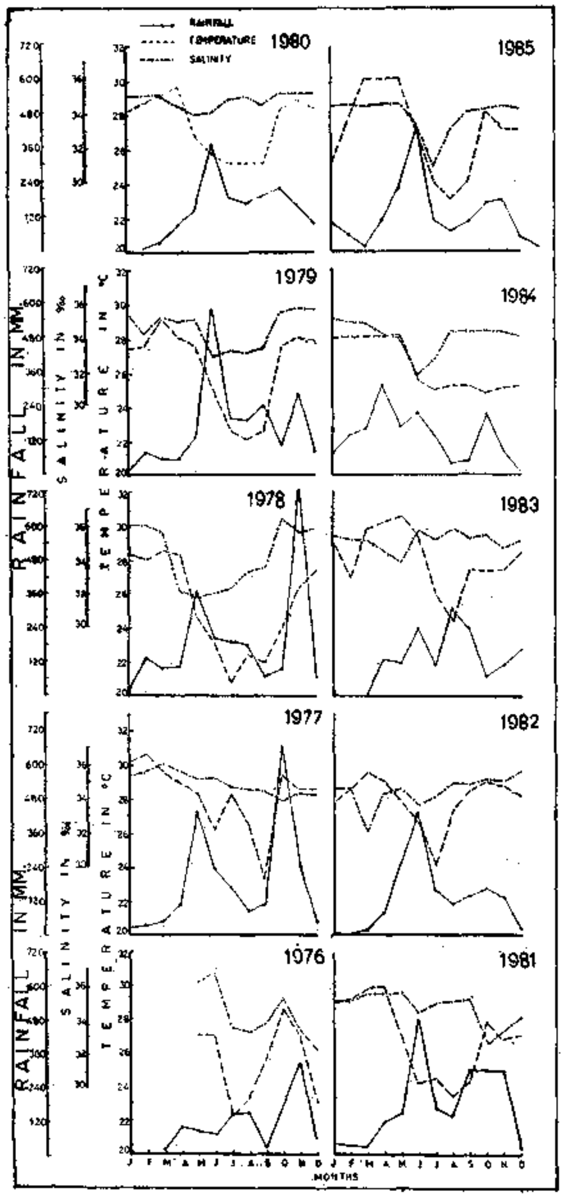

FIG. 3. Salinity, temperature and rainfall in the Vizhinjam and adjacent areas from 1976-85.

September and in 1978, 1979, 1981 and 1984 there was prolonged spawning period. Analysis of environmental data indicate that prolonged spawning period is related to a prolonged low temperature in the natural bed (Fig. 3). Though salinity also shows decrease during spawning period, the changes are not very sharp and the effect of decrease in salinity on spawning is not studied in detail. Observations on dissolved oxygen from 1980-85 indicate that there is no significant change in the natural bed and it ranges from 4.0 to 5.51 ml/l, minimum noticed in September 1985 and maximum in December 1980. It is felt that dissolved oxygen does not play any important roll in inducing spawning.

Spat settlement

Spat settlement in mussels is broadly classified into primary and secondary settlement (Bayne, 1984). Appukuttan *et al.* (1984) have shown that the brown mussel larvae take 15 days for initial settlement in the laboratory. It is quite possible that in the natural bed also the settlement commences by 15th day after fertilization. The settlement fluctuate year to year in relation to commencement of spawning (Table 1). Settlement begin from May-June period and extends even upto November. In most of the years it extends from June to September with July and August months as peak settlement period.

Primary settlement of spat is noted always on the seaweeds attached to the intertidal rocks or other harbour structures. The common seaweeds present in this areas are red algae *Hypnea spinella*, *Asparagopsis taxiformis*, *Gracilaria corticata*, brown algae *Chaetomorpha antennina*, *Sargassum* sp. and green algae *Ulva fasciata* (Pl. I G). Examination of natural beds all along the coast reveals that mussel settlement is good, wherever there is luxuriant growth of these seaweeds. Maximum settlement of early stages from eyed-stage, pediveliger and 0.5 to 3.0 mm spat are noted in red algae especially *H. spinella*, *A. taxiformis* and *G. corticata* in the order of abundance. In brown algae the settlement is poor and in green algae it is rare.

Secondary settlement is observed in rough substratum especially in the intertidal and sublittoral rocks, granite stones of breakwater constructions of harbours, anti-erosion seawalls, tetrapods and in the stones of groyens (Pl. I D). Incidentally all these have good algal growth during June to December period every year. A close observation of the 3 important zones (Fig. 1 and 2) along the southwest coast of India show that in the Quilon to Valiathura the important mussel beds are the harbour breakwater structure in Neendakara Port, the groyens and sea wall or granite stone embankments from Paravur to Anchengo and Valiathura pier. At Neendakara the maximum settlement of brown mussel spat is observed in the submerged granite stones of breakwater construction in the southern side of harbour and it is quite interesting to note that northern side has maximum green mussel settlement (85%) and inside the backwater *P. viridis* settlement alone is noticed upto 1 km interior to the barmouth. Brown mussel in the granite stones of breakwater form thick carpet-like settlement with luxuriant seaweed growth and the density is high towards seaward side. Between Paravur and Anchengo there are number of perpendicular granite stone groyens extending 20 to 50 metres upto the sea, where there is colonisation of mussel spat during spawning period. The granite stone sea walls, which are found submerged in sea water with constant wave lash during monsoon also afford an excellent substratum for spat settlement in this zone. Apart from these structures, there is granite rocks near Kappil and Odayam near Varkala with good settlement. In the Valiathura pier (Pl. I A) 20-30 pillers have good settlement and it is noted upto a depth of 2-3 m in the seaward pillers. In Vizhinjam-Chowarah area the major beds are near Kovalam, Avaduthura, Vizhinjam lighthouse, Pl. I B), Vizhinjam, Vizhinjam harbour reakwater structures, Kottappuram, Mulloor, ulinkudi and Chowarah (Pl. I E, F). In the tertidal and sublittoral granite rocks there is excellent settlement in all these years. There are plenty of submerged rocks near shore at a depth ranging from 1-3 m and these rocks have profuse growth of red and brown algae. In the breakwater constructions of Vizhinjam harbour the tetrapods (Pl. I D) afford an ideal substratum for spat settlement. From Enayam to Muttom the granite rocks in the intertidal and infralittoral area have good mussel beds. The huge rocks found scattered 1-3 km off Muttom, Kadiapatnam, Colachal and Enayam are also good mussel beds. Profuse settlement is noticed in these areas from July to September every year. Poor settlement is noticed beyond Muttom upto Cape Comorin in the submerged rocks.

Nair *et al.* (1975) observed the colonisation of green mussel spat over the granite stones in the Central Kerala Coast and Appukuttan and Nair (1980) noted the brown mussel settlement around Vizhinjam. The laboratory experiments on larval rearing on brown mussel also revealed that from eyed-stage onwards the larvae aggregate and settle over smooth surface of tanks and spat settlers *viz.* bunches of polyethylene monofilament, mussel shells and plastic sheets and when they reach 0.5 mm length, they creep and settle over hard substratum (Appukuttan *et al.*, 1984). The present observations also reveal that in all the major mussel beds primary settlement is over smooth surface of seaweeds and then they move towards the rough substrata (Pl. I C). Appukuttan *et al.* (in press) have observed that from Muttom to Quilon the mussel spat settlement is noticed in an approximate area of 2,61,700 sq. m and the average number per sq. m was 4794 with an average weight of 7 kg. The observations made at selected centres around Vizhinjam during 1976, 1979 and 1984 reveal that the number of spat initially settled in the submerged intertidal rocks vary from 7000-9000 /sq.m (5-10 mm) 5000-6000/sq.m (16-25 mm) and 4000-5000 /sq.m (26-35 mm). The density varies from place to place in the same bed and year to year in the entire coast. Mass mortality of settled spat was noticed only in the shoreward stones of groyens, sea walls, harbour pillers at Valiathura and also in the breakwater structures at Neendakara. The probable reason is the severe monsoon action causing deposition of sand and silt in between the granite stones of breakwater and groynes and sea recedes far away from the shore exposing the mussel settlement for longer period in the granite stones of sea walls and harbour piers in postmonsoon period.

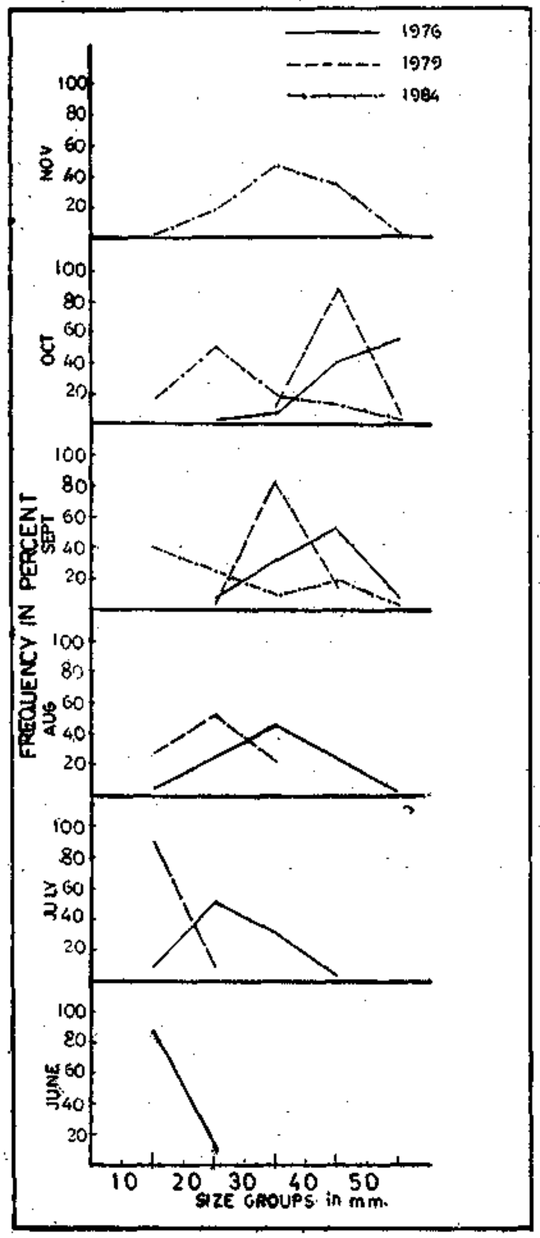

FIG. 4. The peak modes of mussel spat noted in the natural bed in 1976, 1979 and 1984.

By tracing the peak modes (Fig. 4) of spat, it could be seen that 1-9 mm size group was dominent in June 1976, 10-19 mm in July, 20-29 mm in August, 30-39 mm in September and 40-49 mm in October showing 40 mm growth for 4 months and 10 mm growth per month. In 1979, 1-9 mm mode was observed in July and it reached 30-39 mm in October showing 10 mm growth per month. In 1984 also same growth rate was observed when it was traced from August to November. The growth rate of spat in the wild is faster than the growth rate of mussels seeded on ropes (Appukuttan and Nair, 1983).

In 1977, 1978 and 1979 the settlement of spat in the natural bed was poor and this was reflected in the total landings of Vizhinjam (Fig. 2). Temperature and rainfall play an important roll in the success or failure of spatfall. The water temperature has come down to 23-26°C in 1977, 20.7-24.0°C in 1978 and 22.6-27.0°C in 1979 during July-November period (Fig. 3) when there was poor settlement. During 1980-85 period temperature varied from 24.0°C to 28.9°C in the corresponding months showing good settlement in the natural beds all along the coast. In 1976-79 period total rainfall for July-November ranged from 960 mm to 1259 mm and in 1982-85 period it ranged from 471 to 737 mm. In 1980 and 1981 it was 877 mm and 1277 mm respectively. A low temperature and high rainfall rate during July-November period inhibit heavy settlement and high temperature and low rainfall accelerate the settlement. Another interesting featur noted was the heavy settlement of *Modiolu* sp. in the mussel bed from June preventing goo settlement of mussel spat. In 1977, 1978 ar

PLATE I. A. Valiathura pier with mussel settlement in the submerged pillers, B. Intertidal rocks with profuse mussel settlement at Kovalam, C. Submerged and intertidal rocks with mussel settlement at Vizhinjam, D. Breakwater construction of Vizhinjam harbour with tetrapods in the seaward side having good mussel settlement, E. Intertidal rocks with mussel settlement at Mulloor, F. Intertidal rocks with mussel settlement at Chowarah and G. Common seaweeds in the mussel beds showing primary a settlement of mussels. (*a*) *Gracilaria corticata* (*b*) *Hypnea spinella* (*c*) *Asparagopsis taxiformis* (*d*) *Sargassum* sp. (*e*) *Chaetomorpha antennina* (*f*) *Ulva fasciata*.

1979 there was heavy settlement of *Modiolus* sp. in the mussel beds of entire southwest coast of India (Table 1) and this has affected the settlement and total landings.

While examining the nature of spat settlement, it was observed that the laterite rocks and stones in the intertidal and sublittoral zones at Varkala, Paravur, Thangasseri, Thirumullavaram and the inner regions of breakwater structures of Neendakara and Vizhinjam had no spat settlement in all these years. The probable reason could be the absence of seaweed growth in the laterite stones and lack of constant wave action inside the harbour area. In 1979 there was green mussel settlement in the spat collectors suspended from the mussel culture rafts inside Vizhinjam Bay and 2-3% of spat settled in the natural bed was also green mussel. Only in 1979 this phenomenon was observed and the reason could be the presence of green mussel spawners attached to the hulls of fishing boats kept inside Vizhinjam Bay which were being operated earlier in the northern part of Kerala.

As the rich resources of seed settled over the natural bed could also be used for mussel farming, one of the point is to identify the ideal size of the seed which yield good settlement on transplantation to rope or other objects. Byssogenesis experiments were done in the laboratory to observe the number of byssus secreted by two size groups of mussel seeds. When the number of byssus threads secreted is more, the efficiency for attachment also increases. The results of experiments are given in Table 3. 43.1% of larger size group (26-35 mm) secrete more than 10 numbers of byssus threads where as in smaller size groups (6-15 mm) only 8.3% secrete more than 10 byssus threads and 20.9% of the spat do not secrete byssus threads at all. This clearly indicate that 16-35 mm size group is ideal for transplantation.

TABLE 3. *Number of byssus threads secreted by two size groups of mussel spat* (Perna indica) *indicated in per cent in byssogenesis experiments*

6-15 mm size group		16-35 mm size group	
Number of byssus threads secreted	Number of mussel spats in per cent (Total 220 no.)	Number of byssus threads secreted	Number of mussel spats in per cent (Total 220 no)
Nil	20.9	Nil	2.3
1	0.9	1	..
2	2.7	2	1.8
3	6.3	3	4.5
4	8.2	4	5.0
5	9.1 (91.6)	5	9.1 (56.8)
6	9.1	6	6.8
7	11.8	7	7.3
8	9.1	8	9.1
9	6.3	9	6.8
10	7.2	10	4.1
11	..	11	1.4
12	2.7	12	9.5
13	0.9	13	6.8
14	0.9	14	3.2
15	0.5 (8.3)	15	4.5 (43.1)
16	0.5	16	2.7
17	1.4	17	5.0
18	1.4	18	2.7
19	..	19	5.5
20	..	20	1.8

DISCUSSION

Appukuttan and Nair (1980) have noted the spawning of *Perna indica* at Vizhinjam from May to September and Narasimham (1980) indicated that *Perna viridis* has got a prolonged spawning season both in the east and west coast of India. In the present account details of spawning for 10 years in the entire southwest coast is being consolidated indicating May to September as apwaning period for *P. indica* with peak spawning observed in June-July. Appukuttan *et al.* (1984) have indicated induced spawning of brown mussel by giving leap in ambient temperature. Present observation reveal that in the wild the spawning is activated by decrease in temperature due to monsoon rainfall every year. It could be assumed that a leap or decrease in temperature activate spawning in brown mussels. Seed (1976) observed that various exogenous and endogenous factors stimulate the reproduction and temperature plays an important roll in spawning.

The details on mussel spat fall in the southwest coast of India is not fully known except for the works of Jones (1950), Jones and Alagarswami (1973) and Nair *et al.* (1975). The primary settlement of spat in the seaweeds and secondary settlement over the hard substrata observed in the present study agrees with the observations of Bayne (1964) in *Mytilus edulis* from European waters. He demonstrated that mussels pass successfully from plankton to temporary attachments on filamentous algae and these via a secondary phase to sites of more permanent attachement on adult beds and suggests that primary phase of attachment is a natural prelude to final settlement and not a wasteful settlement on suitable substratum. It has been noted that the seeds of *Mytilus* prefer flat stones which receive constant wave splash for good settlement and fewer mussels occur on rapidly draining vertical faces though dense settlement is observed in piers and harbour walls. In the present study also profuse settlement was observed on granite rocks and boulders where there was constant wave splash and this explains the reason for absence of settlement inside the harbour breakwaters. Settlement season of *P. indica* reveals that immediately after spawning mussel spat start settling over hard substratum and the prolonged settlement is correlated to the prolonged low temperature over the natural bed.

The byssogenesis experiments by Mathew and Menon (1983) shows that increase in the heavy metal contents inhibit the byssus secretion. In the present study, *Perna indica* of larger size group (16-35 mm) showed good byssus secretion and indicate that this group is ideal for transplantation. It is felt that regular monitoring of spat fall through studies of abundance of mussel larvae in the known mussel beds along west coast will help to predict the periods of maximum recruitment to the population. Studies on survival of spat in natural bed, movement of larvae and spat and physiological details of primary and secondary settlement and factors activating gregarious settlement in areas where there is heavy wave action are some of the problems yet to be studied in detail from Indian coasts.

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