Settlement Characteristics of *Crassostrea madrasensis* in the Cochin Backwaters*

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Settlement pattern of *Crassostrea madrasensis* (Preston) at five different habitats in and around Cochin Harbour is reported. The settlement pattern is found to be considerably influenced by the distribution of salinity at the various locations. Peak settlement occurred when salinity ranged between 22.4‰ to 33‰.

For the successful cultivation of oysters a knowledge of the factors influencing spawning, larval development and settling is an essential prerequisite. Studies pertaining to the settlement of oysters from the Indian waters are those of Hornell (1910), Awati & Rai (1931), Paul (1942), Kuriyan (1952), Ganapathi *et al.* (1958), Rao (1951), Rao & Nayar (1956), Nair (1967), Balasubramanyan & Nair (1968), Rao & Menon (1978), Menon *et al.* (1977) and Dharmaraja & Nair (1981). Detailed studies on the settlement of oysters from the Cochin backwaters are few and it is thought worthwhile to undertake a detailed study on this aspect.

Stations investigated

Settlement of oysters was studied at 5 different locations in the Cochin backwaters (The test stations 1, 2, 3, 4 and 5 are shown in Fig. 1.)

Station 1: Pier of the School of Marine Sciences, University of Cochin, in the Ernakulam channel on the eastern side of Willingdon Island, about 4 km. away from the barmouth. The depth here is about 2. 5m.

Station 2: Drydock of the Cochin harbour, in the Mattancheri channel, about 2 km away from barmouth. The water here is usually turbid, owing to the churning action of propellers of fishing boats and ships. The depth at this station is around 4 m.

Station 3: Pier of the Exploratory Fisheries Project. This station is situated just

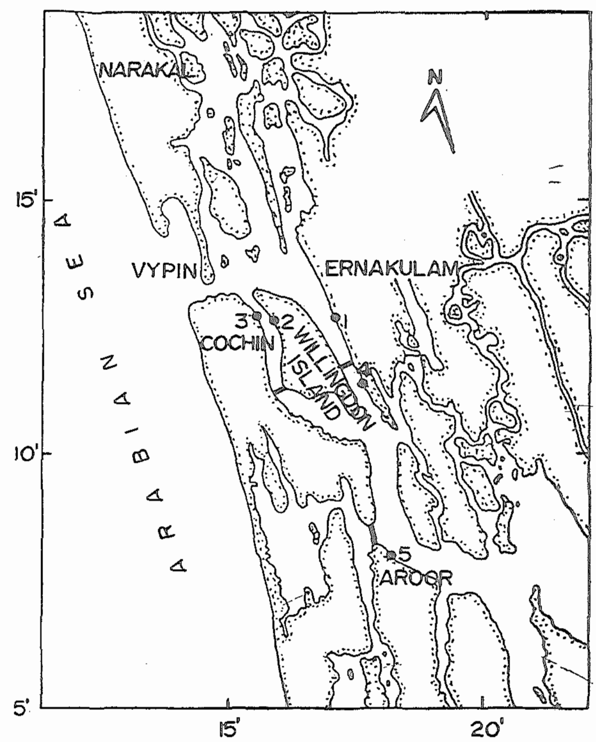

Fig. 1. Cochin harbour and its environment showing the test stations.

*Formed post of the Ph.D thesis of the first author approved by the University of Cochin opposite to station 2 on the western side of the Drydock (Station 2) in the Mattancheri channel about 2 km. from barmouth. As in station 2, here also the water is turbid owing to the frequent plying of fishing boats. The Cochin Fisheries Harbour is situated adjacent to this station on the southern side. The depth at this station is about 2 m.

Station 4. Thevara: This station is also located on the eastern side of Willingdon Island about 1 km. south of station 1. It is separated from the Ernakulam channel by a low belt of sand. The depth is approximately 2.5 m. Here the water is comparatively less polluted and less turbid.

Station 5. Aroor: This station is situated about 20 km. from the barmouth towards the south, silting and turbidity are negligible and the depth here is about 2.5 m.

Materials and Methods

3 glass panels of 10 x 10 cm. size were suspended and kept at the intertidal, the subtidal and the bottom positions at stations 1, 4 and 5 by passing a rope through holes drilled at the centre of the glass panels. The glass panels were kept in position by providing a knot on the rope above and below each panel. At station 2, (Drydock) owing to greater depth, than at other stations, six glass panels were suspended from the intertidal region to the mudline at intervals of 50 cm. To avoid the effects of silting, the bottom panel was kept 50 cm above the mudline. At station 3, glass panels were arranged on a grooved wooden rack and exposed subtidally 30 cm below low water line. With the aid of this system of panels, it was possible to observe the pattern of settlement of oysters at the stations mentioned above and at different depths in station 2 (Drydock).

Short-term (A series)

Short-term series were put out and changed at the end of 15 days at station 1 and 5 (Tables 2 and 6) and at intervals of 30 days at stations 2 and 4 (Tables 3 and 5). At station 3, thirty panels were exposed together for each month. The panels were mounted on a grooved wooden rack, one panel removed for examination every day. The settlement of oysters on the 30 panels was averaged and represented for each month (Table 4).

Long-term (B series)

Eight sets were exposed at the beginning of each period and recovered one by one at intervals of 15 days at stations 1 and 5 (Tables 2 and 6). Four sets were exposed at the beginning of each period and recovered one by one at intervals of 30 days at stations 2 and 4 (Tables 3 and 5).

Pattern of settlement of C. madrasensis

The settlement characteristics of *C. madrasensis* at stations 1, 2, 3, 4 and 5 are presented in Tables 2 to 6. As is evident from the tables, during the major part of the monsoon period and early post-monsoon period there was no settlement of oysters on panels at any locality investigated. The general trend in the settlement of oysters was a well defined one, though the post and pre-monsoon months in general recorded the incidence of oyster spat. During the monsoon period and early post-monsoon period, no settlement was noticed on panels at the various stations except on the subtidal and bottom panels at station 4 (Table 5) in the month of June. The station-wise settlement is outlined below.

Marine Science Pier (Ernakulam channel)

The panels exposed at three depths at this station during the monsoon period did not register the presence of oyster spat at any time (Table 2) during the period beginning from June and ending in September. This trend was continued till the middle of December. The settlement of oysters was confined to the period begining with the end of December to the end of May. Although oyster spat appeared on the panels throughout this period, two peaks in settlement were noticed, the first one being the major one occurring during January and a second minor peak during early March. The average number of oysters settled was 5/200 cm^2 in December and 57/200 cm^2 during January and 15/200 cm^2 during March and 10/200 cm^2 in April and 5/200 cm^2 in May (Table 2) on short-term panels. Another feature of the pattern of settlement was that, fresh attachment was not continuous in short-term

Table 1. *Salinity and temperature data of the stations investigated*

	Station 1		Station 2		Station 3		Station 4		Station 5	
	Water temp.°C	S‰	Water temp.°C	S‰	Water temp.°C	S‰	Water temp.°C	S‰	Water temp°C.	S‰
June, 1981	29.6	2.4	29.5	21.5	29.7	22.0	31.0	18.8	29.0	3.6
July	29.5	3.2	29.0	1.7	28.5	4.5	28.5	2.0	28.3	0.3
August	27.6	1.9	27.5	6.4	28.3	2.1	29.5	3.8	28.0	1.8
September	29.5	10.1	31.0	10.6	29.4	2.8	30.5	1.7	30.0	1.3
October	28.5	16.3	31.0	19.3	28.0	7.2	31.0	4.2	31.2	3.8
November	29.9	18.1	29.0	29.6	29.8	12.5	29.5	7.8	32.0	15.0
December	28.8	20.4	31.5	28.7	28.8	22.4	31.0	19.3	29.0	18.6
January, 1982	30.7	28.3	32.0	30.2	27.9	32.4	32.5	29.1	32.0	26.5
February	30.5	33.0	31.3	31.5	29.4	33.4	30.2	31.7	33.0	28.9
March	30.0	33.4	32.1	33.9	30.5	32.0	34.0	33.6	31.9	31.9
April	32.0	32.0	32.9	31.0	31.0	33.0	32.4	28.6	33.5	31.7
May	30.0	34.0	29.5	34.0	31.0	32.5	29.5	20.6	31.5	31.0

Table 2. *Station* 1. *(Marine Science Pier). Settlement of C. madrasensis on short-term and long-term panels (200 cm² area)*

	Monsoon								Postmonsoon								Pre-monsoon							
	June 1981		July		Aug		Sept		Oct		Nov		Dec		Jan 1982		Feb		Mar		April		May	
Short-term panels	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8
Intertidal	-	-	-	-	-	-	-	-	-	-	-	-	-	1	43	-	-	-	16	-	7	-	-	-
Subtidal	-	-	-	-	-	-	-	-	-	-	-	-	-	1	34	27	-	-	15	-	-	-	-	-
Bottom	-	-	-	-	-	-	-	-	-	-	-	-	-	12	114	68	-	-	13	-	4	18	-	5
Monthly average														5	57				15		10			5
Long-term panels	B1	B2	B3	B4	B5	B6	B7	B8	B1	B2	B3	B4	B5	B6	B7	B8	B1	B2	B3	B4	B5	B6	B7	B8
Intertidal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	19	-	8	2	-	2
Subtidal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	5	-	1	2	1	3
Bottom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	13	-	13	8	-	3
Monthly average																		36	12			6		3

– = absent

Table 3. *Station 2. (Dry Dock) Settlement of C. madrasensis on short and long-term panels (200 cm² area)*

	Monsoon				Post-monsoon				Pre-monsoon			
Period	June 1981	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1982	Feb.	Mar.	Apr.	May
Short-term panels	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
30 cm	—	—	—	—	—	—	—	—	—	—	—	—
60 cm	—	—	—	—	—	—	2	8	13	—	—	—
90 cm	—	—	—	—	—	—	4	—	19	8	16	—
120 cm	—	—	—	—	—	—	7	28	27	6	7	—
130 cm	—	—	—	—	—	4	5	170	28	13	26	—
160 cm	—	—	—	—		5	—	—	27	8	5	—
Average	—	—	—	—	—	5	5	69	23	9	14	—
Long-term panels	B1	B2	B3	B4	B1	B2	B3	B4	B1	B2	B3	B4
30 cm	—	—	—	—	—	—	—	—	—	7	—	—
60 cm	—	—	—	—	—	—	—	—	—	7	9	10
90 cm	—	—	—	—	—	—	4	2	—	8	18	7
120 cm	—	—	—	—	—	—	2	—	—	13	13	4
130 cm	—	—	—	—	—	—	8	5	—	10	10	7
160 cm	—	—	—	—	—	—	4	30	—	10	2	5
Average	—	—	—	—	—	—	5	12	—	9	10	7

— = absent

Table 4. *Station 3. (Exploratory Fisheries Project Pier) Settlement of C. madrasensis on test panels (200 cm² area)*

Monsoon				Post-monsoon				Pre-monsoon			
June 1981	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1982	Feb.	Mar.	Apr.	May
10	7	—	—	—	14	60	5	5	9	8	5

although the long-term panels continued to harbour oysters throughout the post and pre-monsoon periods from January to May.

Drydock (Mattancheri channel)

Fresh settlement as evidenced by the incidence of oysters on short-term panels, occurred in this area during November to May (Table3) which include both the post and pre-monsoon months. In this locality no settlement of oysters was recorded during the monsoon period. The peak settlement was in January when the average number of oyster settled was 19/200 cm² in short-term panels. More number settled, on panels maintained in the midwater and bottom.

Exploratory Fisheries Project Pier

The maximum settlement of oysters at this station was during December being 60/200 cm². Oysters settled from November to July but were totally absent during August, September and October (Table 4).

Thevara (Mid-estuarine region)

The settlement of oysters in this station was very poor. Although fresh settlement was noticed from March to June, the number of oysters settled here was small. A spurt in oyster settlement was noticed during June (37/200 cm²). Apart from this, settlement was insignificant during the other months (Table 5).

Aroor

The settlement of oysters occurred at this station for a short duration of four months commencing from January in the short-term panels. Maximum settlement was noticed during March being 60/200 cm^2 in the short-term panels. In long term panels (Table 6) peak settlement was recorded in February being 42/200 cm^2.

Discussion

Crassostrea madrasensis enjoys a wide distribution in the backwater environment of South India. It is a very common representative of the sedentary community of brackish water benthos. The settlement of oysters on submerged substrata is a direct indication that spawning had taken place. Usually oysters may settle on any hard substrata. Therefore the settlement data obtained from a series of panels exposed at the different localities should give a general picture of the pattern of settlement of these bivalves. Five stations studied here represent five localities with varying salinity conditions (Table 1).

It is clear from the settlement data presented in Tables 2 to 6, that in general, the larvae of *C. madrasensis* settle in the estuary during the period November to May/June. However, there could be regional differences in their settlement and abundance. At station 3, nearer to barmouth with a perennial oyster bed nearby, the locality from which oysters were collected for various studies in the present case, oyster settlement was noticed for nine months from November to July (Table 4). During this period, major settlement was confined to the panels kept at relatively greater depths (< 90 cm) at station 2 (Table 3). The duration of settlement was reduced to six months at station 1 beginning from December and ending in May, nearly seven months at station 2 from November to May, five months at station 3 from November to May, five months at station 4 (Thevara) from February to June and about four months (February to May) at Station 5 (Aroor). At station 4, settlement was confined to February–June period, in intertidal, subtidal and bottom panels. In the short-term series settlement was chiefly on bottom panels from March to June. Very sparce settlement was noticed in the subtidal panels during February and April in the long-term series. The most important hydrographical parameter which inhibited settlement was wide fluctuation in salinity. The settlement of oysters occurred when the salinity of the water was above 20.4, 29.6 and 12.5‰, at stations 1, 2 and 3 respectively. However at Thevara (Station 4) and Aroor (Station 5) settlement of oysters occurred only when the salinity exceeded 29‰. The total absence of settlement of oysters during

Table 5. *Station* 4. *(Thevara) Settlement of C. madrasensis on short-term and long-term panels (*200 *cm^2area)*

Period	Monsoon				Post-monsoon				Pre-monsoon			
	June 1981	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1982	Feb.	Mar.	Apr.	May
Short term	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
Intertidal	—	—	—	—	—	—	—	—	—	—	—	—
Subtidal	23	—	—	—	—	—	—	—	—	—	—	2
Bottom	50	—	—	—	—	—	—	—	—	5	13	2
Average	37	—	—	—	—	—	—	—	—	5	13	2
Long term	B1	B2	B3	B4	B1	B2	B3	B4	B1	B2	B3	B4
Intertidal	—	—	—	—	—	—	—	—	—	—	—	—
Subtidal	—	—	—	—	—	—	—	—	2	—	—	—
Bottom	—	—	—	—	—	—	—	—	2	—	5	—
Average									2		5	

– = absent

Table 6. *Station 5. (Aroor) Settlement of C. madrasensis on short and long-term panels (200 cm² area).*

	Monsoon								Post - monsoon								Pre-monsoon							
	June 1981		July		Aug		Sep		Oct		Nov		Dec		Jan 1982		Feb		Mar		Apr		May	
Short-term panels	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8
Intertidal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	35	-	-	-	-	-	-	-	-
Subtidal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	30	-	2	-	-	-	-	-	-
Bottom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49	-	-	50	-	60	-	16	-	-
Average															33			26		60		16		
Long-term panels	B1	B2	B3	B4	B5	B6	B6	B7	B1	B2	B3	B4	B5	B6	B7	B8	B1	B2	B3	B4	B5	B6	B7	B8
Intertidal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Subtidal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	2	2	2	3	-
Bottom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80	-	-	-	-	-	2
Average																		28	2		2	2	3	2

the monsoon period and early post-monsoon period (June to October), when very low salinity conditions existed clearly indicates the inability of the larvae to settle at these salinities. Further, observations showed a declining trend in the condition index from November to May (Nair, 1984). This lowered condition index is evidently due to spawning in oysters. During this period comparatively high salinities exist and larvae settle in large numbers in the Cochin backwaters.

In the Madras harbour peak settlement of oyster takes place during April and May but settlement is continuous till the end of October (Paul, 1942). In the Pulicat backwaters near Madras, Hornell (1910) observed two peaks in spawning of oysters, the first during August and September and a second one in March and April. According to Awati & Rai (1931) *Ostrea cucullata* spawns in the Bombay coast during October and continues upto the end of June. Awati & Rai (1931) distinguished a regular breeding season from March to June with intense breeding and an irregular season from October to February. Malpas (1933) observed in the Ceylon pearl oyster *Margaritifera vulgaris* two spawning maxima the first during July to August coinciding with the south-west monsoon and the second in December to January, coinciding with the north-east monsoon with an irregular spawning in between the two peak spawning periods. In the Adayar backwaters, Rao (1951) observed spatfall throughout January and during the first week of February when the salinity ranged between 27.3‰ and 29.01‰. In the Ennur backwaters, Rao (1951) observed spatfall at salinities 31.09‰ and 30.21‰ during December in shallow water and deep water respectively when the estuaries maintained connection with the sea. Spatfall in both the backwaters was maximum when the salinity was 29‰ to 31.09‰. Rao (1951) has also observed the breeding of oysters in the Madras harbour for most part of the year with two peaks, one in November-December and the other in May–August as against a single peak observed by Paul (1942). In the Mangalore harbour area, Menon *et al.* (1977) observed continous settlement of oysters throughout the year. However, in the estuarine locality, Menon *et al.* (1977) observed settlement of oysters only during the period November to June. The settlement pattern observed in this study also follows a comparable trend to that observed by Awati & Rai (1931) and Menon *et al.* (1977) from Bombay coast and the estuarine waters of Mangalore respectively. Peak settlement of oysters noticed in this study at stations 1 and 2 was during January and February, during December at station 3 and in April at stations 4 and 5. The salinity of the backwaters during this period ranged from 22.4‰ to 33‰ (Table 1). It is clear that stations 1, 2 and 3 which are nearer to the barmouth recorded peak settlement during December to February while stations 4 and 5 located comparatively at longer distances from the barmouth showed peaks in settlement during April as these stations take longer time to attain the optimum salinity conditions condusive for oyster settlement.

It is well known that temperature fluctuations are chiefly responsible for spawning and setting in European and American oysters (Stafford, 1913; Nelson, 1921, 1928; Churchill, 1920; Prytherch, 1929, 1934). However, in the Cochin backwaters temperature fluctuations are limited (Table 1) throughout the year. As Rao (1951) pointed out "under tropical conditions of our coasts the water temperature of the sea or the backwaters is maintained high throughout the year and does not even fall at any time below the optimum requirement of the oysters." Thus factors other than temperature seems to govern spawning and setting of oysters in the Cochin backwaters. Although temperature has been proved to influence the development and settlement pattern of oysters, in the present study salinity seems to exert more influence by virtue of its wide fluctuations (Table 1). Rao (1951) observed fluctuations between 20.3 and 28‰ at the Adayar estuary when oysters spawned and the optimum salinity of 22 to 26‰ is attained either by evaporation of water or by the influx of freshwater. Hopkins (1931) noticed a correlation beteeen salinity and setting in the oyster *Ostrea virginica* at Galveston Bay, Texas and observed that larval setting is stimulated by a salinity of 20‰. According to Rao (1951) "in the small estuaries and backwaters of our coasts, however, periodical inflow and outflow of tidal and flood waters respectively with the tidal amplitude as small as three feet influence the fluctuation in salinity and consequently of the spawning and setting of the oysters." Panikkar & Aiyar (1939) also attributed fluctuation in salinity to the periodicity of breeding in brackishwater animals. The influence of salinity in the spawning and setting of oysters has been observed by several other workers. Within the normal temperature range, Clarke (1935) observed normal activity of spermatozoa in salinities 5‰ to 40‰ with longest sperm life at 23‰. Ontogenetic development proceeded normally to the first swimming stage in salinities, 14‰ to 39‰. Eventhough development of eggs took place in 14.5‰ to 39‰ salinities no swimming larvae were obtained (Clarke, 1935). In the oyster *O. gigas* spawning was inhibited below 27‰ salinity. Salinities between 23‰ and 28‰ provided optimum conditions for fertilization and development of embryos (Fujiya, 1970). *C. virginica* inhabiting Long Island Sound, USA, attains maturity and spawns at 27.5±1‰ salinity. However, it is uncertain how much these limiting salinities may be affected by the salinity at which the parent oysters develop gonads and spawn. Very few eggs yield straight hinge larvae at 12.5‰ salinity, but larvae reared to setting stage at 27.5‰ salinity can successfully complete metamorphosis in salinities as low as 9‰ or 10‰ (Calabrese & Davis, 1970). Prytherch (1934) observed larvae of *O. virginica* undergoing complete fixation in 12 to 19 minutes in salinities of the range 16 and 18.5‰. However, in salinities above or below 16‰–18.5‰, the process of fixation was prolonged. The evidence obtained during the present study mainly shows that the conditions that pevailed in the estuary during the post-monsoon and pre-monsoon periods are favourable for successful settlement and colonisation by *C. madrasensis*. Further, two important ecological aspects could control colonisation, the total distributional area of a population can have a reproductive centre and a peripheral area subsisting on regular recruitment of larvae from reproductive areas. Salinity may be a master factor controlling settlement (colonisation) within a specific intensity range only and outside that critical range, the importance of salinity decreases to that of a secondary or even teritiary environmental entity, other factors (substrata, larval life and longevity) take over primary distributional control. It is likely that these generalisations hold good for the native population and the settlement pattern of *C. madrasensis* in the Cochin backwaters. The discontinuity in the setting of oysters during the monsoon period at the Cochin backwaters and continous setting during other periods may be attributed to fluctuations in salinity. Panikkar & Aiyar (1939) also noticed discontinuity in the breeding of brackish water animals and attributed this to rains. Rao (1951) observed *C. madrasensis* breeding throughout the year in the Madras harbour with two peaks, one in November–December and another in May–August as against a single peak observed by Paul (1942) and noticed that the two peaks correspond to those of salinity and high temperature of the coastal waters and the two peaks corresponding with the restricted breeding in November–December and March–April in the backwaters.

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