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Effect of Tides on Settlement of Oysters and Barnacles in Pichavaram Mangrove of the Southeast Coast of India

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Abstract: The settlement pattern of barnacles, *Balanus amphitrite amphitrite* (Darwin) and oysters *Crassostrea madrasensis* (Preston) and *Saccostrea cucullata* (Born) on the stilt roots of the mangrove tree *Rhizophora apiculata* (Blume) bordering the intertidal region of Pichavaram mangrove (Lat. 11° 27 N Long. 79° 47 E) has been studied with reference to the tidal oscillation. Vertically, settlement was found to be abundant on stilt roots occurring at low tide than at mid and high tide levels. This differential settlement could be attributed to the adaptability of these organisms to their tolerance to extended period of either tidal submersion or emersion. Vertically both the oysters settled preferably at the bottom of part stilt roots indicating their inability to tolerate long period of exposure. *S. cucullata* occurred above the level of *C. madrasensis* suggesting that the former could tolerate comparatively a more extended period of exposure. Settlement was high during late post monsoon and early summer coinciding with the abundant of high phytoplankton, the optimal temperature and salinity, for the growth and breeding of these benthic organisms.

Key words: Tidal variation, barnacles, oysters, settlement, mangrove, fouling

INTRODUCTION

The tidal oscillations result in the submergence and emergence of the inter-tidal region and consequently influence the fauna and the flora. Since the duration of the submergence and emergence are time relative, organisms in the low tide level experience extended period of tidal submergence compared to those organisms inhabiting high tidal levels. These organisms that are subject to longer duration of submergence and *vice-versa* are capable of successful survival in their respective tidal levels by various adaptive features such as tolerance to desiccation, avoiding predators, etc. (Nybakken, 1997). Barnacles and oysters are considered to be the dominant macrofoulers of tropical waters. Marine fouling is an economically important process along the maritime states in India. Knowledge on ecology of fouling organisms, a perquisite for the successful anti-fouling measures, is still lacking in Indian waters. Although enough work has been done on the components of the marine fouling community and also their regional distribution and abundance in relation to the seasons, the influence of tides on their ecology is not much known.

They have been extensively studied on intertidal rock platforms (Crisp, 1974; Rainbow, 1984). Barnacles are also common elsewhere (e.g., in mangrove forest) but there have been few studies examining the processes that determine the distribution and abundance living in these areas (Coates and Mckillup, 1995; Ross and Underwood, 1997). Patterns among substrata may also be formed by larvae habitat selection at settlement (Davis, 1987; Raimondi, 1988) Working on ascidians in subtidal habitats and barnacles on intertidal rock platforms.

Their distribution in the temperate marine rocky shores are known to be influenced by the tidal amplitude exhibiting preference to specific zonation. In the mangrove environment barnacles and

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oysters are found to settle on the stilt roots of *Rhizophora apiculata*, that border along the inter-tidal region of the mangroves. The present study is an attempt to know whether any settlement preferences related to tides are shown by these macrofoulers settling on the Pichavaram mangroves roots of *R. apiculata* as it is a limiting substrata for settlement in a mangrove environment and subject to tidal immersion and emersion.

MATERIALS AND METHODS

In the present study stilt roots of the mangrove tree *R. apiculata* of Pichavaram mangroves have been taken as the substrata of barnacles and oysters as they are found to be the dominant epifaunal components that settle on them. This study was carried out in two stations during September 2000 to May 2001. Horizontal and vertical distribution of these two organisms within the inter-tidal regions have been studied. The barnacle and oyster distribution was studied by sampling the stilt roots at high, mid and low tide levels. Monthly samples of barnacles and oysters from three stilt roots at high, mid and low tide levels have been counted after cutting them at mud lines of each station and brought to the laboratory. In addition the number of barnacles and oysters at three different equal heights viz., top, centre and bottom parts of each stilt roots at each tidal level was also determined for vertical distribution study.

Study Area

Pichavaram mangroves (Lat. 11° 27' N; Long 79° 47' E) (Fig. 1) represent a heterogeneous mixture of mangrove elements, which lies amidst the Vellar and Coleroon estuaries and is Located 250 km south of Chennai city on the southeast coast of India. It consists of small and large islets covering, 1,100 ha of the total area, in which 50% is covered by the forest; 40% by the water ways and the remaining 10% by the sand and mud flats (Krishnamurthy and Jeyaseelan, 1983; Kathiresan, 1987). The dominant flora here is *Rhizophora* and it is a healthy sign of this mangrove forest based on vegetation.

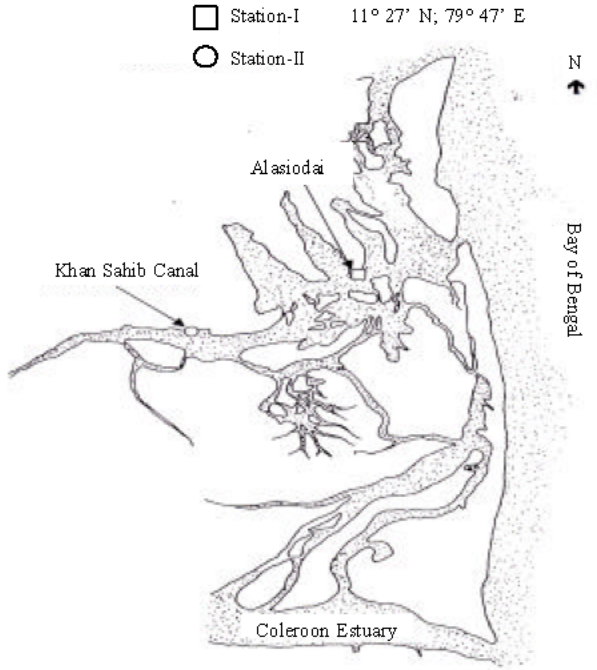

Fig. 1: Showing sampling sites along the *Pichavaram mangroves*

Pichavaram mangrove has been categorised in to 3 zones namely *Rhizophora* zone, *Avicennia* zone and back mangrove zone (Muniyandi, 1986). They produce tonnes of organic plant detritus supporting the faunal resources. Pichavaram mangrove forest also harbours a variety of fauna especially the commercially important shell and finfishes which migrate from the sea for feeding and spawning. The benthic fauna consists mostly of estuarine species, which includes crabs, hermit crabs shrimps, tanaids, isopods, amphipods etc.

Station 1 is situated in the north east of mangrove locally called Alasiodai. Influence of neritic water is higher in this region. Nature of the sediment is sandy silt. Species of *R. apiculata*, *Bruguiera* sp and *Avicennia marina* are dominantly distributed. A thick algae vegetation of *Hypniea musciforms also* is present here. Oyster forms dominant in beds this station (Inter-tidal span, 30 m).

Station 2 is located near Khan Sahib Canal having a great influence with fresh water form Coleroon estuaries. Nature of the sediments is clay sand. The species like *A. marina*, *R. apiculata*, *Acanthus ilicifolius* and *Excoecaria agallocha* are densely present. A part from the mangroves sea grasses (*Hallophila ovalis*) and seaweeds (*Hypniea* sp) are abundant (Inter-tidal span, 15 m).

These stations were chosen for their proximity in relation to the neritic waters. The first station was close to the coastal waters of Bay of Bengal and experiences the tidal water twice a day during the high tide, while the second station is farther away from the coast and is influenced more by the freshwater inflow.

RESULTS

Station 1

Table 1, show horizontally, the number of barnacles were maximum (61.5%) at the low tide level and were found to decrease from the mid tide level (30.6%) to high tide level (7.8%). Barnacles settlement was observed throughout the year with the maximum during March (15.9%) and minimum during November (1.6%).

Concerning the monthly settlement of the barnacles, there is not much variation in their numbers except during November (1.6%) when there was a least number of barnacles. Barnacles showed an increasing trend gradually in other months recording the maximum (15.9%) during March and (14.5%) during January. There is also a difference in settlement of barnacles at different heights viz., bottom, center and top of the stilt roots, at each tidal level in all the months. The barnacles have been found to settle just above the mud line except during November and at the upper level during November. At each stilt root at every tide, heavy settlement of barnacles were observed at the lower part of the root followed by the center and top. Barnacles were found to settle only on both low and mid tide levels during all the months except during September, October 2000 and January 2001. The three months of monsoon season when they were also found settled in few numbers at the high tide level.

Table 1: Monthly settlement (numbers and percentage) of barnacles and oysters at high, mid and low tide levels at Station I during September 2000 to May 2001

	Low tide		Mid tide		High tide			
Months	Barnacles	Oysters	Barnacles	Oysters	Barnacles	Oysters	Barnacles total	Oysters total
Sep 2000	35 (35%)	24 (42%)	37 (37%)	16 (28%)	28 (28%)	17 (29.8%)	100 (13.4%)	57 (13.4%)
Oct	35 (39.3%)	24 (36.3%)	42 (47.1%)	22 (33.3%)	12 (13.4%)	20 (30.3%)	89 (12%)	66 (15.6%)
Nov	5 (41.6%)	-	7 (58.3%)	-	-	-	12 (1.6%)	-
Dec	34 (45.9%)	31 (55.3%)	40 (54%)	18 (32.1%)	-	7 (12.5%)	74 (9.9%)	56 (13.6%)
Jan 2001	50 (46.2%)	29 (55.7%)	40 (37%)	15 (28.8%)	18 (16.6%)	8 (15.3%)	108 (14.5%)	52 (12.2%)
Feb	66 (88%)	34 (87.8%)	9 (12%)	9 (12.1%)	-	-	75 (10.1%)	43 (10.1%)
Mar	94 (79.6%)	29 (54.7%)	24 (20.3%)	24(45.2%)	-	-	118 (15.9%)	53 (12.5%)
Apr	52 (82.5%)	39 (88.6%)	11 (17.4%)	5 (11.5%)	-	-	63 (8.5%)	44 (10.4%)
May	85 (83.3%)	27 (51.9%)	17 (16.6%)	25 (48%)	-	-	102 (13.7%)	52 (12.2%)
Total	456 (61.5%)	212 (50.1%)	227 (30.6%)	134 (31.6%)	58 (17.8%)	52 (12.2%)	741	423

Table 2: Settling of oysters (*C. medrasensis* and *S. cucullata*) at different heights of *R. apiculata* at Station I during September 2000 to May 2001

	Low tide				Mid tide				High tide			
	C. madrasensis		*S. cucullata*		*C. madrasensis*		*S. cucullata*		*C. madrasensis*		*S. cucullata*	
Months	No	Height (cm)	No	Height (cm)	No	Height (cm)	No	Height (cm)	No	Height (cm)	No	Height (cm)
Sept 2000	24	1-7	-	-	16	1-7	-	-	17	1-8	-	-
Oct	24	14-28	-	-	22	10-20	-	-	20	6-12	-	-
Nov	-	-	-	-	-	-	-	-	-	-	-	-
Dec	-	-	31	5-23	-	-	18	10-28	-	-	7	1-15
Jan 2001	29	8-24	-	-	15	2-23	-	-	8	1-7	-	-
Feb	6	1-14	28	1-42	-	-	9	1-18	-	-	-	-
Mar	7	2-28	22	2-32	5	2-20	19	2-20	-	-	-	-
April	7	5-29	32	5-35	-	-	5	3-24	-	-	-	-
May	5	2-27	5	2-38	-	-	25	3-33	-	-	-	-
Total	102 (45.7%)	-	118 (58.7%)	-	58 (26%)	-	76 (37.8%)	-	45 (20.1%)	-	7 (3.4%)	-

Table 3: Monthly settlement (numbers and percentage) of barnacles and oysters at high, mid and low tide levels at Station II during September 2000 to May 2001

	Low tide		Mid tide		High tide			
Months	Barnacles	Oysters	Barnacles	Oysters	Barnacles	Oysters	Barnacles total	Oysters total
Sep 2000	28 (35.8%)	21 (31.3%)	27 (34.6%)	-	23 (29.4%)	-	78 (10%)	21 (31.3%)
Oct	32 (39.5%)	8 (11.9%)	25 (30.8%)	-	24 (29.6%)	-	81 (10.4%)	8 (11.9%)
Nov	7 (9.8%)	-	55 (77.4%)	-	9 (12.6%)	-	71 (9.1%)	-
Dec	64 (33.1%)	-	82 (42.4%)	-	47 (24.3%)	-	193 (24.8%)	-
Jan 2001	50 (53.1%)	-	34 (36%)	-	10 (10.6%)	-	94 (12.1%)	-
Feb	19 (48.7%)	33 (49.2%)	17 (43.5%)	-	3 (7.6%)	-	39 (5%)	33 (49.2%)
Mar	46 (46.9%)	5 (7.4%)	29 (29.5%)	-	23 (23.4%)	-	98 (12.6%)	5 (7.4%)
Apr	36 (85.7%)	-	6 (14.2%)	-	-	-	42 (5.4%)	-
May	50 (62.5%)	-	30 (37.5%)	-	-	-	80 (10.3%)	-
Total	332 (42.7%)	67	305 (39.3%)	-	139 (17.9%)	-	776	67

Table 1 and 2, show horizontally, the number of oysters were maximum (50.1%) at the low tidal level and continued to decrease from the mid tidal level (31.6%) to high tidal level (12.2%). The monthly variation in settlement of total oysters. At station 1 there is not much variation in their numbers except during February and April when there was less settlement of oysters, reaching the highest percentage (13.4%) during September and October (15.6%). Oysters were found to settle on both low and mid tide levels in all the months except during November. Almost in all the months the oysters have been found in bottom and settled only at the lower level. Although both species occurred in all the months *S. cucullata* was predominately settled at low (58.7%) and mid tide (37.8%) levels when compared to *C. madrasensis* at low (45%) and mid (26.1%) tide levels. On the other hand *S. cucullata* was significant at high tide level while *C. madrasensis* dominated in more numbers. In general there is a tendency of more *S. cucullata* settling on the *R. apiculata* during the summer that part on Premonsoon months.

Station II

Table 3, show horizontally the numbers of barnacles were maximum (42.7%) at the low tide level and were found to decrease from the mid tidal level (39.3%) at low tidal level (17.9%). There was not much variation in their numbers except during February and April when there was a less number of barnacles recorded. Reaching the maximum (24.8%) during December and minimum during February (5%) and April (51.4%). Barnacles were present throughout the year at the mid and low tide level, except for April and May when they were absent at high tide level. Almost in all the months the barnacles have been found to settle just above the mud line except during November.

Table 4: Settling of oysters (*C. medrasensis* and *S. cucullata*) at different heights of *R. apiculata* at Station II during September 2000 to May 2001

	Low tide			
	C. madrasensis		*S. cucullata*	
Months	No	Height (cm)	No	Height (cm)
Sept 2000	21	6-20	-	-
Oct	8	6-13	-	-
Nov	-	-	-	-
Dec	-	-	-	-
Jan 2001	-	-	-	-
Feb	-	-	33	1-9
Mar	-	-	5	1-8
April	-	-	-	-
May	-	-	-	-
Total	28 (43.2%)		38 (56.7%)	

They were noticed to settle only at the upper during November. On each stilt roots at every heavy settlement of barnacles were observed at the lower part of the roots followed by the centre and the top.

Table 4, relatively station II did not support oysters settlement during most of the months of the study period. Settlement were found maximum *S. cucculata* (56.7%) and minimum in *C. madrasensis* (43.2%) were found low tide level. Only during premonsoon and later during early post monsoon, there were mangrove settlements. Similar to barnacles at each level most of the oysters were found to settle near the bottom region of the stilt roots than at the middle and top.

DISCUSSION

Pre-settlement such as survival and transport of larvae, the settlement processes like habitat selection may play a larger role in controlling species distribution of intertidal benthic organisms (Grosberg, 1981; Strathman *et al*., 1981; Underwood and Denley, 1984; Caffey, 1985; Connell, 1985). In Pichavaram mangrove forest the horizontal distribution of barnacle *B. amphitrite amphitrite* and also the oysters *C. madrasensis* and *S. cucullata* apparently distribute in relation to the tidal oscillation, one of major physical factors that influences in the benthic organisms of the intertidal region.

Both the species of barnacle and oysters are abundantly settled on the roots of *R. apiculata* that are close to the lowest tidal level. The preferences of settlement at low tidal level naturally related to the extended period of immersion compared to the high tidal level where the duration of tidal immersion is lesser and on the other hand the exposure to atmosphere is longer. Longer exposure to atmospheric temperature at high tidal level naturally is not favourable for balanoid barnacles and oysters since both are not adapted to extended period of desiccation (Connell, 1985).

In the present study also vertical settlement of both barnacle and oysters exhibited predominant clustering at the bottom part of the stilt roots. But the barnacles were found just above the oysters at the centre of the stilt root, the oysters mostly preferring to settle below the barnacles. Similar pattern of differential settling in the present study with regard to the height on the mangrove stilt root of *R. apiculata* could also be attributed to conditions prevailing in other mangrove environment. There could also be the competition for food and space as factors controlling the differential vertical settling in the present study. The vertical distribution of barnacles on the pneumatophores of *Avicennia marina* in southern Australia (Satumanatpan *et al*., 1999 a, b) are also similar to the present study. The oysters are also found to settle only at the bottom of the stilt roots. The barnacles are found just above the mud line, on the oysters as well as on the centre and top of the roots. The barnacle *B. amphitrite amphitrite* appers to compete with the oysters for settlement space at the bottom part of the stilt roots, for they are found to settle on the oysters, *C. madrasensis*, at that level. There is always the smothering effect of over growing of oysters on these barnacles.

The reason for this type of vertical differentiation in the settlement between these two species namely, *C. madrasensis* and *B. amphitrite amphitrite* could be attributed to their ability to tolerate the physical and biological factors influencing their distribution and survival in the intertidal environment. Compared to *B. amphitrite amphitrite*, *C. madrasensis* does not possess the metabolic ability to withstand extended period of emersion. On the other hand *B. amphitrite amphitrite* is capable of with sanding extended period of emersion and consequently desiccation to some extent. Therefore, higher upon the roots of *R. apiculata*, barnacle were more abundant than the oysters and also it was observed (Ross and Underwood, 1997) that the barnacle select to concentrate at middle heights compared to the top parts of the roots.

In Pichavaram mangroves the oyster *C. madrasensis* is predominantly cluster at the bottom part of the stilt roots near the mud line. The barnacle *B. amphitrite amphitrite* settle at all the three heights viz., bottom, centre and top parts, but were abundant in the centre and top parts of the stilt roots. This differential height preference may obviously be due to both the tolerance to extended submergence and to extended emersion respectively of the oyster at the bottom and the barnacle at the centre and the top of the stilt roots. It is also obviously related to the respective adaptive feature of these species to utilize water movement in the mangrove habitat where the surface water will have higher velocity of tidal currents. In the present study, it is also observed two species of oysters viz., *C. madrasensis* and *S. cucculata* occur together on the stilt roots of the mangrove *R. apiculata*. Interestingly both the species exhibited preferences to height, *C. madrasensis* always occurred below *S. cuccullata*. In the present study *S. cuccullata* was found above *C. madrasensis* suggesting competition for space result in the difference in their distribution pattern.

In conclusion it is evident that in Pichavaram mangroves both the barnacle *B. amphitrite amphitrite* and the two oysters *C. madrasensis* and *S. cuccullata* establish themselves on the stilt root of the mangrove tree *R. apiculata* through a process of differential settlement. The differential settlement is fundamentally correlated to tidal oscillation, which periodically exposes and submerge the intertidal zone of the mangrove subjecting these organisms to the regular extended period of submergence at low and emersion at high tidal levels respectively. Such differential settlement helps the species probably to avoid post-settlement phenomena such as predation, competition and desiccation due to tidal oscillation. There is ample scope for further experimental studies to confirm the above-presumed probability.

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