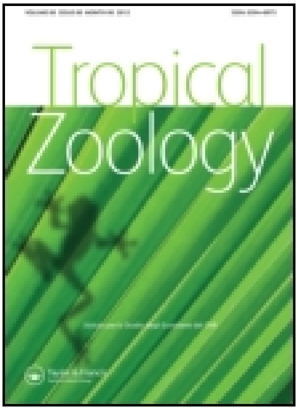

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Patterns of spat settlement recorded for the tropical oyster Crassostrea cucullata (Born 1778) and the barnacle, Balanus amphitrite (Darwin 1854) in a mangrove creek

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Patterns of spat settlement recorded for the tropical oyster *Crassostrea cucullata* (Born 1778) and the barnacle, *Balanus amphitrite* (Darwin 1854) in a mangrove creek

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The spatfall patterns of the oyster, *Crassostrea cucullata* (Born 1778) and the barnacle, *Balanus amphitrite* (Darwin 1854) on cemented coconut shells were studied in relation to shore levels and monsoon seasons in East Africa. Both oysters and barnacles settled most frequently above the Mean Tide Level (MTL). About 75.6% of the oyster and 96.9% of the barnacles occurred above the MTL. Thus below MTL, the oyster spat had a better niche advantage over the barnacles. However, at the latter levels the oysters faced heavy competition from fouling organisms, which were mostly spirobids, serpulids, bryozoans, hydrozoans and sponges. The spat of both oysters and barnacles showed seasonality in their settlement. About 93.1% of the total oyster spat settlement occurred in the South East Monsoon (SEM) and the number of spat at peak settlement was 12.6 times the total spat settlement in the North East Monsoon (NEM). As regards the barnacles, 86.4% of the total barnacle spat settlement occurred in SEM and the number of spat in the peak settlement was 3.4 times the total settlement in NEM. Oysters and barnacles on the cemented coconut shells had a wider vertical distributional range than those found on mangrove trees.

KEY WORDS: monsoon seasons, spat settlement, oyster, barnacles, shorelevel, mangrove.

INTRODUCTION

The tropical oyster *Crassostrea cucullata* (Born 1778) and the barnacle *Balanus amphitrite* (Darwin 1854) are intertidal macrofauna found on many types of hard substrates such as the pneumatophores of mangrove trees, rocks, and man made structures (e.g. jetties, ship hulls, beacons, floating pontoons, etc.). Littoral organisms found on the Kenyan coast exhibit large vertical distributional ranges on the shores (Ruwa 1984, Oyieke & Ruwa 1987) mostly because of Kenya's large tidal range, 4 m (Brakel 1982). The vertical range of distribution of *Crassostrea cucullata* on rocky cliffs is about 2.7 m wide. However, *Balanus amphitrite* lacks a distinct zone because they are rarely encountered on rocky cliffs (Ruwa 1984). The rareness of *B. amphitrite* on rocky cliffs may be due to the occurrence of numerous muricacean gastropods which prefer feeding on cirripeds (Taylor 1976). In mangrove fringes where both *C. cucullata* and *B. amphitrite* are both common but muricacean gastropods are uncommon, the vertical distributional range of the *C. cucullata* on the trees is about 1.4 m and for *B. amphitrite* about 0.5 m (Ruwa in press).

For such sessile organisms, the availability of the individuals in the locomotory phase, right quality of substrate and subsequent successful settling is coupled with a complex interplay of various biotic and abiotic factors that will dictate the size of the vertical distribution in the intertidal zone (Malouf & Breese 1977). A review of seasonality by McClanahan (1988) indicates the ecological importance of the monsoons in East African marine waters. There are two monsoon seasons, namely the South East Monsoon season (SEM), from March to October and North East Monsoon season (NEM) from November to February. Attempts are made in this paper to describe the settlement patterns of *C. cucullata* and *B. amphitrite* in relation to shore levels and monsoon seasonal climate patterns. Due to the fact that zonation studies in the intertidal zones are based on adults or sub-adults rather than the youngest recruits, the present studies will also help to show the extent of zonal change with respect to the upper and lower limits of the recruits.

MATERIALS AND METHODS

The study was carried out at Gazi, South of Mombasa, Kenya (Fig. 1) between April, 1986 and February, 1988. The investigations included studying short and long-term spat settlement patterns of the oyster *Crassostrea cucullata* (Born 1778) and the barnacle *Balanus amphitrite* (Darwin 1854) on artificial substrates, distribution of naturally occurring populations of these two species on mangrove trees and the distribution by size of *Crassostrea cucullata* on mangrove trees. Tests of significance used for the various settlement patterns were as described by Zar (1974).

Short-term settlement patterns

Weekly total cumulative counts of the spat of *C. cucullata* on coconut shells coated with cement, as the clutch, were made in April and May, 1986 in order to determine the intensity of spatfall, during the long rains when the peak spatfall occurs (Van Someren & Whitehead 1961). The clutch consisted of 20 hemispherical cemented coconut shells of similar sizes which were strung at 25 cm intervals using a thick robust nylon string. The string was suspended from a strong *Rhizophora mucronata* Lam. pole in the creek waters to support the string of shells in a vertical position. The mangrove pole was additionally supported by an oyster rack for reinforcement. The clutch once set up was left in place. The first two shells from the bottom remained submerged at all

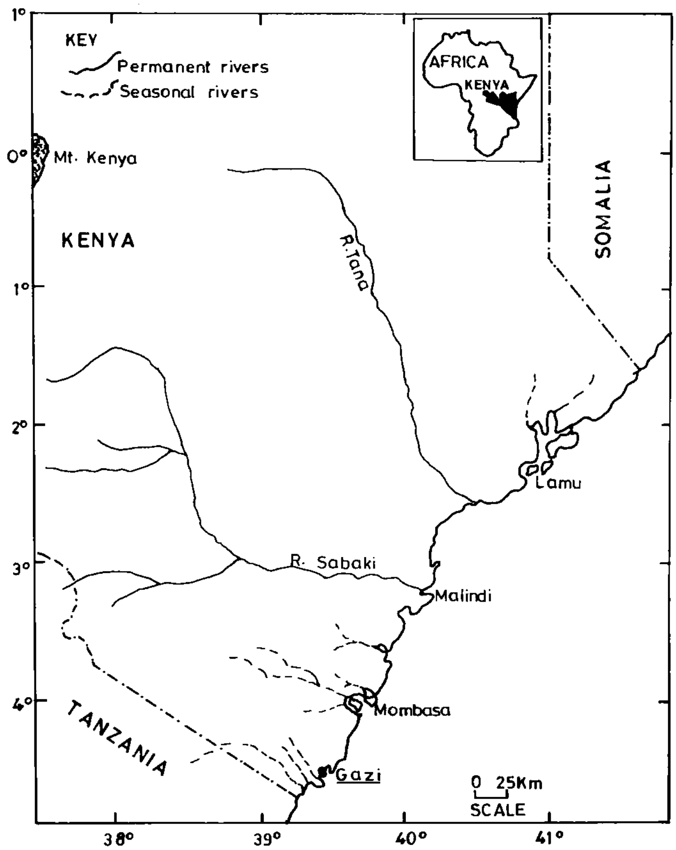

Fig. 1. — Map of the Kenyan coast to show location of the study site.

low tides. The positions of the coconut shells were calibrated in relation to the Kilindini tide datum using the KENYA PORTS AUTHORITY (1986) tide tables. Counts were made during low tide and they were total cumulative counts with time since the first spatfall. Records of numbers of spat on the top and underside of each coconut shell were kept separately.

Long-term settlement patterns

A further set of four strings of cemented coconut shells were prepared and used to study the long-term settlement patterns of spatfall of the oyster *C. cucullata* and the barnacle *B. amphitrite* in SEM and NEM seasons. The strings were supported vertically in the creek waters by the same procedures. The first two shells from the bottom were always submerged even at low tides. Three strings were set up in creek waters in the following three periods during which they stayed in place for SEM: (a) April to May 1987, (b) June to July 1987 and (c) August to September 1987. The fourth string was set up in November 1987 and remained till February 1988 during the NEM. It was not necessary to introduce further strings in NEM because the spatfall was scanty. Total counts of the spat of the two species on each shell and level were made at the end of each period, again recording separately the settlement on the top from that of the underside. The calibration of the positions of the coconut shells in relation to the Kilindini harbour datum was determined using the KENYA PORTS AUTHORITY (1987, 1988) tide tables.

Distribution of the oysters and barnacles on trees

The vertical distribution of the oysters and barnacles on the mangrove *Sonneratia alba* J.Sm. at the edge of the creek was studied. *S. alba* has a firm bark and pneumatophores that support settling organisms for years before the bark drops off. Thus settling organisms can live long enough to breed before bark falls. Counts of the oysters and barnacles were made at 25 cm intervals round the trunk and going up the three from its base. The levels in relation to the Kilindini datum were calibrated using the tide tables.

Distribution of oysters by size

Groups of oysters in 25 cm wide vertical bands round the tree were measured starting from the base of the mangrove tree *S. alba* going upwards. The variable measured was the maximum shell lengths of the individual oysters of *C. cucullata* using vernier calipers. The mean shell length and standard error of the mean (SE) for each group at each level were then computed.

RESULTS

Short-term settlement patterns

Settlement was detected after about 2 weeks from the time the clutch was placed in the creek. Kite diagrams were used to illustrate the distribution of spatfall in relation to shore levels (Fig. 2). To facilitate comparisons of the abundance of the spatfall at the different shore levels with time, the relative percentages of spatfall used to construct the kite diagrams were based on the total number of the spat on both the top and undersides of the coconut shells at the end of the investigations. It was observed that recruits were more abundant on the undersides of the coconut shells than on top (t-test, $P < 0.001$). In the 1st week of initial spatfall the undersides attracted 75.7% of the total recruitment in that week whereas at the end of the investigations in the 7th week the undersides had 80.4% of the total accumulated number of spat.

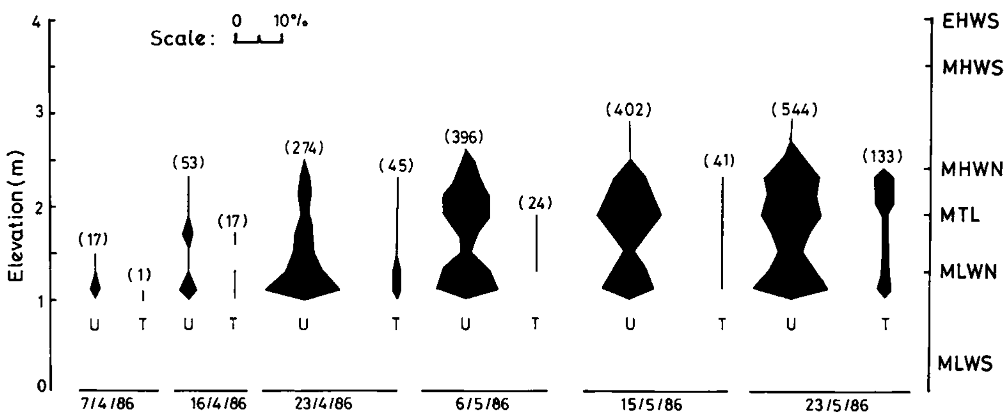

Fig. 2. — Oyster spat settlement on cemented coconut shells at Gazi, Kenya in April and May, 1986. The total counts of spat are as indicated by the numbers in parentheses and are cumulative numbers from the time of first settlement. The letter U stands for underside and T for topside of the coconut shell.

Long-term settlement patterns

To illustrate the spatfall patterns in the different periods in SEM and NEM in relation to shore levels kite diagrams were constructed (Figs 3 and 4). To compare the spatfall of the oyster in SEM and NEM the percentages for constructing the kite diagrams were calculated in relation to the total number of spat in the three period during SEM (a) April to May, 1987; (b) June to July, 1987; and (c) August to September, 1987; and during NEM from November, 1987 to February, 1988. Similarly the same procedure was undertaken to facilitate the interpretation of the barnacle settlement. Comparisons of the recruitment (Figs 3 and 4) for equal 4 month periods, April to July in SEM and November to February in NEM, indicated that settlement of both oysters and barnacles was significantly higher during SEM (t-test, $P < 0.001$). It was observed that 93.1% of the total oyster spat settlement occurred in SEM and that the number of spat during the period of peak settlement was 12.6 times the total settlement of oyster spat in NEM; 86.4% of the total barnacle settlement occurred in the SEM and the number of spat during the period of peak settlement was 3.4 times the total settlement of barnacle spat in the NEM. A comparison of the settlement of spat on the top and under sides of the coconut shells showed that the settlement of oyster spat was great on the undersides of the coconut shells in both seasons (in both cases t-test, $P < 0.001$). However, settlement of barnacles on either side of the coconut shells was not significantly different in the SEM but were significantly different in the NEM, with the undersides having higher numbers of recruits (t-test, $P < 0.001$). Comparing distributional ranges of the oyster and barnacle spat, it was found that both had a similar distributional range with almost 100% overlap through varying population densities within the range. Both oysters and barnacles settled in greater numbers above the mean tide level. About 96.9% of the barnacles and 75.6% of the oysters occurred above the mean tide level.

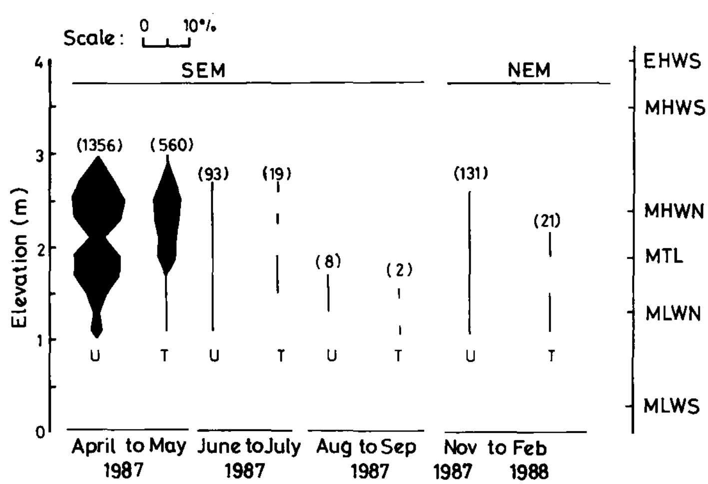

Fig. 3. — Oyster spat settlement on cemented coconut shells at Gazi, Kenya during South East Monsoon (SEM) from April, 1987 to September, 1987 and North East Monsoon (NEM) from November, 1987 to February, 1988. The numbers in parenthesis stand for total numbers of spat counted in each period.

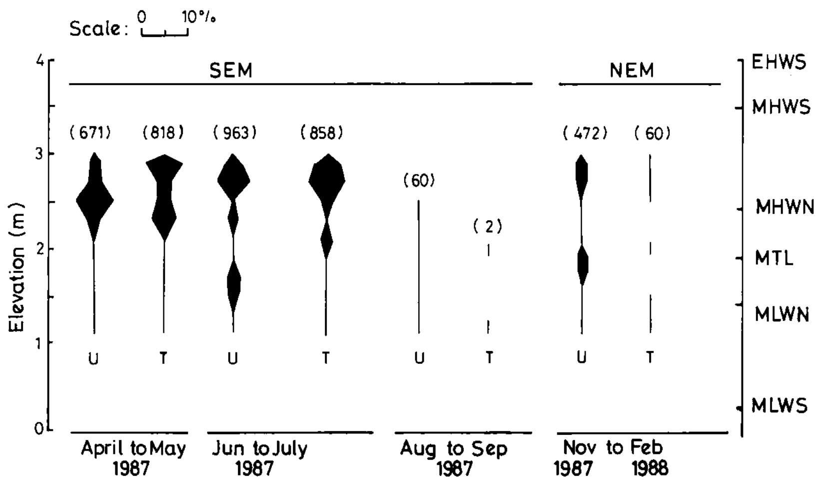

Fig. 4. — Barnacle spat settlement on cemented coconut shells at Gazi, Kenya during South East Monsoon (SEM) from April, 1987 to September, 1987 and North East Monsoon (NEM) from November, 1987 to February, 1988. The numbers in parenthesis stand for total numbers of spat counted in each period.

Distribution of oysters and barnacles on trees

The distributional ranges of oysters and barnacles overlapped (Fig. 5), with oysters exhibiting a wider zone. Oysters were more abundant between MTL and MHWN. The population density of barnacles on mangroves was very low and their rareness below MHWN was conspicuous.

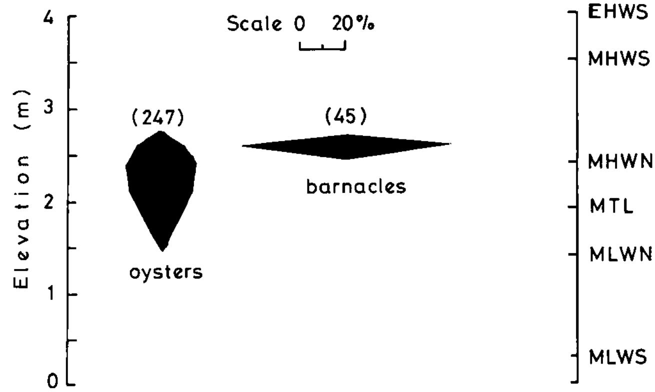

Fig. 5. — Distribution of oysters and barnacles on a mangrove tree *Sonneratia alba* J.Sm.

Distribution of oysters by size

The distribution of oyster sizes by tidal height on the mangrove tree exhibited a size gradient pattern, with the largest occurring at lower levels especially below the mean tide level (Fig. 6).

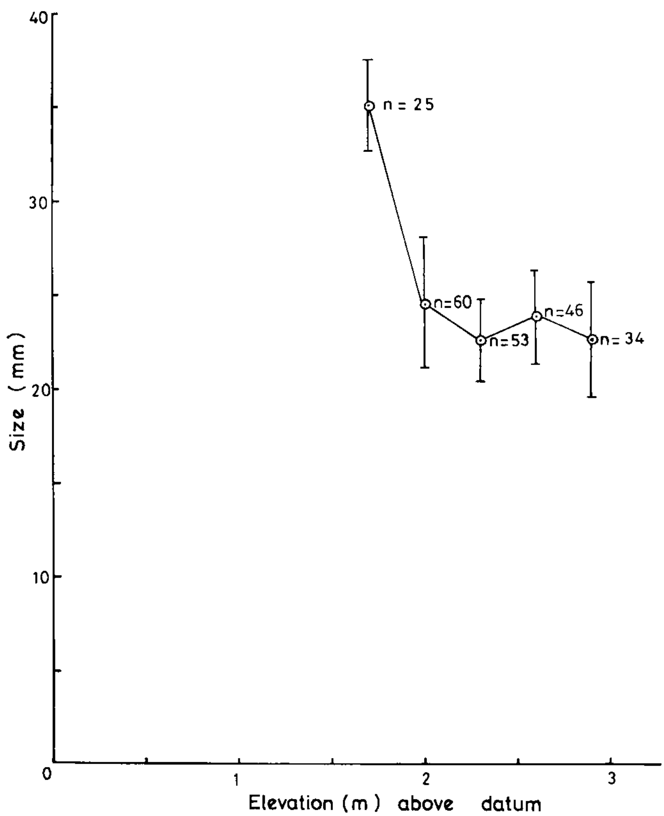

Fig. 6. — Distribution by size of oysters on a mangrove tree *Sonneratia alba* J.Sm.

Fouling

The lower level coconut shells had various fouling organisms namely: spirobids, serpulids, bryozoans, hydrozoans and sponges. The spirorbids and serpulids were common to about MLWN with bryozoans, hydrozoans and sponges dominating below 1.0 m above datum.

DISCUSSION

The recruitment of the spat of both the oyster *Crassostrea cucullata* and the barnacle *Balanus amphitrite* occurred throughout the year but both showed a first major peak in SEM and a second minor peak settlement in NEM. VAN SOMEREN & WHITEHEAD (1961) recorded similar observations for the settlement of spat of *C. cucullata* at Mida Creek, Kenya.

The triggering mechanisms for spawning by intertidal oysters and barnacles are similar (NAIR 1967, KORRINGA 1976). This may explain the occurrence of the planktonic forms and the peaks of both *C. cucullata* and *B. amphitrite* at similar periods. It is clear from the present study that even though the recruitment is heavier in SEM than in NEM, the most abundant recruitment is observed in certain periods of seasons for both species. These periods correspond with the long rain periods mostly in May/June and short rain periods mostly in October/November along the Kenyan Coast (RUWA 1993).

The present discussions are based on a study on what settles on the clutch but for a better comprehension of their seasonal variations further studies on gonadal cycles, planktonology, food of the adults, subadults and their planktonic forms need to be undertaken. Such studies will help to explain the significance of this reproductive strategy which links peak recruitment to particular periods of the two seasons.

The discriminatory and gregarious behaviour of spat of oysters and barnacles, preferring shaded niches and settling in groups is well documented (CRISP 1976). The latter explains why the undersides of coconut shells have a more profuse settlement than the top sides.

The smaller distributional range and lower upper limits of the oysters and barnacles living on mangrove trees compared to those on rocky cliffs (RUWA 1984) whose ranges are larger and upper limits higher can be explained by the differences in the physical conditions of the environment as described by LEWIS (1964) i.e. severe wave action in exposed environments like rocky shores will lift the upper limits and subsequently increase the vertical distibutional range whereas in sheltered creeks where the mangrove vegetation is also a wave energy breaker there is no increase in the upper limits. However, lower limits in both exposed and sheltered sites are principally dictated by biological factors (CONNELL 1972). First, the mangrove trees are rooted at high shore levels between Mean Low Water Neap (MLWN) and Extreme High Water Spring (EHWS) (RUWA 1993), thus limiting the possible lower limits of both the oysters and barnacles that settle on mangroves to about MLWN. At the Gazi mangrove forest, growth of sponges around the pneumatophores of the mangrove roots is very common and this excludes oysters and barnacles where the growth is thick. Common predators at the lower levels, near the bases of mangrove trees and among the pneumatophores are notably the xanthid crab *Epixanthus dentators* (White 1847) and the grapsid crab *Metopograpsus messor* (Forskal 1775). The latter was found opening very young oysters and devouring their flesh. The muricacean gastropods found preying on barnacles were *Morula fenestrata* (Blainville 1832) and *Thais savignyi* (Deshayes 1844).

The distributional ranges of the oysters and barnacles on mangrove trees compared to those obtained on the cemented coconut shells showed clearly that the ranges on the coconut shells were wider because the lower limit for the coconut shells was much lower than the lower limit on mangroves at the lower shore which is about the

MLWN (RUWA 1993). However, with the oysters the widest ranges occurred on rocky shores (RUWA 1984) whereas for barnacles the widest range of distribution occurred on the cemented coconut shells. It is also possible that the oysters and barnacles have wider distributional ranges on cemented coconut shells than on the mangrove trees due to a lack of predators and grazers on the coconut shells. The string clutch appeared to exclude many predators.

The maximum shell length of the *C. cucullata* in the wild is 65 mm (VAN SOMEREN & WHITEHEAD 1961) but in crowded conditions they are stunted. The size gradients observed across the vertical range of the tree have also been recorded on rocky cliffs by OKEMWA et al. (1986) and are not due to settlement patterns but are related to differences in growth rates associated with height at shore level (RUWA 1990). Through experimental translocation of oysters to different levels in the intertidal zone RUWA (1990) demonstrated that growth was faster at lower levels than at higher levels, hence the higher frequency of larger individuals at lower levels. With longer feeding hours at the lower levels provided by longer immersion hours (MORTON 1977) oysters can grow faster and to a larger size during their fast growing phase than those at higher levels. There is also therefore an evolutionary advantage for oysters that successful settlement below MLWN, which allows them to grow faster and become large individuals with higher fecundities than their counterparts of the same age at higher shorelevels. However at such lower levels they have to compete for space with spirobids, serpulids, bryozoans, hydrozoans and sponges which can easily exclude them.

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