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MACROFAUNAL COMPOSITION AND ZONATION ON SANDY BEACHES AT GAZI, KANAMAI AND MALINDI BAY KENYA

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ABSTRACT

Based on the most conspicuous macrofauna which are the crabs, there are three biological zones on the sandy beaches. In a downward shore direction these are: Ocypode zone, Dotilla zone and Uca-Macrophthalmus zone. These zones are related to tidal level, watertable and texture of sediment. The Ocypode zone extends from around MHWN to even above EHWS. The sediments at the Ocypode zone are loose coarse sand but sometimes firm calcereous sand between MHWS and MHWN. The zone has many burrows of mixed sizes and there are three Ocypode species which burrow here namely, O. ceratophthalmus, O. ryderi and O.cordimanus. These species hardly co-occur and the burrows at any particular portion of beach belong to a single species of the Ocypode.

The Dotilla zone extends between MTL and slightly below MHWN. The texture of the substrate is fine sand. The species occupying this is almost exclusively the Dotilla fenestrata. However, samples of sand collected from the edges of the ebbing and flooding tides were sieved and two species of crabs Hippa adactyla and Emerita austroafricana were seen. The position of the watertable where Dotilla fenestrata was found was 10-20cm from the surface. They were not found where seepage occurred even though the levels were optimal for them.

Slightly below MTL to MLWS, the watertable is usually at the surface and seepage occurs conspicuously. The substrate is muddy sand with small stones. This is the Uca-Macrophthalmus zone. The Uca species were Uca vocans and Uca tetragonon. The Macrophthalmus species were M. grandidieri and M. parvimanus which were the most common and the less common ones were M. milloti and M. bosci. There were 3 species of portunid crabs in the brackish water pools and 8 species of gastropods in the muddy sand. In the silty muddy sand of Malindi beach Echinodiscus bisperforatus was found in large numbers. This is the northern-most occurrence of this species in the Western Indian Ocean.

The present results were compared with those of other parts of the Western Indian Ocean and the significance of their similarities and differences is discussed.

INTRODUCTION

There are some published works on the ecological distribution of the invertebrate macrofauna of sandy beaches in the Western Indian Ocean, e.g. at the coast of Somalia by Vannini (1976, 1980); coast of Tanzania by Hartnoll (1973,1975); coast of Seychelles by Taylor (1968); Aldabra Atoll by Taylor (1971 a); coasts of Madagascar by Crosnier (1962,1965). There are also similar published works done on the coast of Southern Africa which has a tropical faunal component because of the influence of the Mozambique current on that coast (Newell 1957). The ecological studies of the sandy beaches on the coast of Mozambique were studied by Macnae and Kalk (1962); whereas those of the coast of Natal Province in South Africa were studied at Kosi bay by Broekhuysen and Taylor (1959), Richards bay by Millard and Harrison (1953) and Durban bay by Day and Morgans (1956).

The only published studies on zonation of macrofauna of the sandy beaches on the Kenya Coast by Jones (1972) and Icely and Jones (1978) were confined to some species of Uca and two species of Ocypode. The following study was therefore done to provide some detailed information by including several species whose taxonomy is well known so that their distribution can also be compared with others in the earlier mentioned tropical environments. The list of the species whose distributions were described in this study is shown in table 1.

STUDY AREA AND METHODS

The studies were carried out at Gazi, Kanamai and Malindi Bay (figure 1) from April 1986 to December 1986.The Gazi beach is in Gazi Bay which is sheltered from heavy wave action. It receives seasonal river input of freshwater and permanent inflow of underground water which seeps to the seashore (Ruwa and Polk, In press). The watertable oscillates considerably on this beach. The Kanamai beach receives permanent inflow of underground water which seeps to the beach (Ruwa and Polk, in press). The watertable does not considerably oscillate. This beach is about 0.75km to the living reef edge. It is therefore fairly sheltered from heavy wave action. The third locality, Malindi beach is situated in the Malindi Bay which receives inflow from the permanent River Sabaki. The latter carries lots of land based sediments which are deposited in the bay. The seawater in this bay is permanently brown due to silt suspension.
Around Vasco da Gama pillar, the terrestrially based sediment deposits from the river are shallow and the rock platform is visible. There is underground water seeping through the rock platform and where there are stabilized sediments an estuarine beach environment is created.
The zonation accross the beach was studied using the quadrat - transect method and their distribution was related to height of shore, substrate and seepage of underground water to the seashore. The part of the seashore considered as the sandy beach constituted the deposits of sediments of the higher shore levels around the extreme high water spring to the beginning of the marine phanerogram beds on the lower shore.

Transects of width of 2m were sampled accross the beach by making counts of the cryptic or burrowed macrofauna occurring within 2 x 2m quadrats placed consecutively along the transect. Burrows were dug using a shovel and the sediments sieved when necessary in order to discern the types of macrofauna occupying such niches and therefore ascertain the zones of various macrofauna accross the shore. For some transects, counts of crab holes were made and the sizes of the mouths of the crab holes were measured using calipers before digging some of the burrows. Data on the counts of the burrows were used in constructing kite diagrams.

Lines rather than kite diagrams were used to illustrate the distribution of various macrofauna which are highly motile e.g. the crabs and for macrofauna which were either found in small numbers or within narrow horizontal distributions on the beach. The substrate was qualitatively described as coarse sand, calcereous sand, fine silted sand , muddy, sandy-mud and muddy sand. The profiles of the transects were determined by the levelling method described by Southwood (1965) and Day (1974).

The shore elevation were calibrated with respect to the Kilindini datum from several observations made when the sea was calm around neap tide days using the Kenya Ports Authority (1986) tide tables. The heights of the conventional levels of tides as calculated by Brakel (1982) were adopted. The values of these are: Extreme high water spring (EHWS), 4.0m; mean high water spring (MHWS), 3.5.m; mean high water neap (MHWN), 2.4m; mean tide level (MTL), 1.9m, mean low water neap (MLWN), 1.4m; mean low water spring (MLWS), 0.3m.
The identifications of the macrofauna were done using the taxonomic literature of Barnard (1960), Barnes (1970), Crosnier (1962,1965), Clark and Rowe (1971), Day (1974), Oliver (1981), Richards (1984) and Serene (1973).

RESULTS

Accross the sandy beaches, there was a consistent tendency that the higher shore level above MHWN was characteristically made up of predominantly coarse sand substrate at all the localities (figure 2 to 6). The burrowing macrofauna in this habitat were Ocypode spp, namely O. ceratophthalmus at Gazi and Malindi and O. cordimanus at Kanamai (Table 2).
In the middle shore levels of the sandy beach the quality of the substrate was variable. Between MTL and MHWN the substrate could be fine silted sand or sandy mud. Where the watertable was low the substrate was moistened or wet as in the sandy mud habitats. The macrofaunal composition was as follows:
Dotilla fenestrata occupied fine sand habitat (figure 3,4 and 5) lying 10-20cm above the watertable but in sandy mud habitats on mangrove peat(figure 2) where the water table was at the surface Uca lactea occupied such habitats (Table 2).

In the lower shore levels the nature of the substrate between MTL and MLWN was similar to that between MLWN and MLWS (figure 2 to 6). The substrate could be wet fine silted sand or muddy sand. The wetness was due to the watertable being close or at the surface. Water seeping from the surface could form puddles or small pools. The Thalamita spp and Scylla serrata were found in these pools. The muddy sand substrate supported the highest number of species of macrofauna at Gazi and Kanamai beaches (Table 3). Comparisons of the macrofaunal compositions of the three beaches showed that Gazi and Kanamai beaches had more numbers of species and also more numbers of commonly occurring species between them than with the Malindi Bay beach.

Except for the Ocypode spp which wandered away from their burrows the rest of the species of crabs move about only around or close to their burrows. Both Ocypode ceratophthalmus and O. cordimanus were frequently encountered at the lower shore at low tide but when pursued they rapidly escaped to the higher shore levels into their open burrows. In a few cases O. ceratophthalmus decided to burrow (or rather bury) themselves in the muddy sand or sandy mud at the lower levels when pursued rather than escape to their open burrows at the higher shore levels.

The data on sizes of the mouths of burrows (figure 4) could not indicate segregation of the crabs by size even for singly occurring species in particular zones. However, the density of the crab holes (figure 4 and 5) helped to indicate the intensiity of sediment perturbations accross the sandy beaches due to the burrowing activities.

DISCUSSION

Faunal Compositions

Despite the differences in hydrological sources of freshwater flowing to the seashore at Gazi and Kanamai, their faunal compositions (Table 3) are similar in terms of having common species and species diversity. On the other hand comparison of Gazi and Malindi beach faunal compostion show that the latter has low species diversity and that most of the species encountered also occur at Gazi beach. The poor species diversity may be due siltation resulting from silt carried by the permanent River Sabaki which is deposited on the Malindi beaches. It is noteworthy to mention that the occurrence of Echinodiscus bisperforatus at Malindi is of significance in two ways. First, it is the northernmost occurrence in the Western Indian ocean and on the coasts of the islands, it was recorded at the coast of Madagascar by Pichon (1966). However, according to Clark and Rowe (1971) this species has also been recorded in the Red Sea. Secondly, it occurred in similar muddy sand habitats in estuarine environment in all the geographical areas mentioned.

The conspicuous occurrence of some species in some beaches but lacking at others may partly be due to disimilarities in the microenvironments of the habitats and behavioural differences. For example, the presence of large numbers of Uca lactea on Gazi beach but lacking at Kanamai may be due to the presence of mangrove peat at the Gazi beach which makes the microenvironment mangrove like biotope. Uca lactea was similarly found on a beach created on mangrove peat after removal of mangrove trees. Typically Uca lactea is mangrove-associated fiddler crab (Hartnoll 1975).

Uca tetragonon and Dotilla fenestrata which occur at Kanamai and Malindilacked at Gazi beach. The lack of Dotilla fenestrata may be due to the presence of shallow sediment on peat which remained wet throughout the low tide around spring tide days. Hartnoll (1973, 1975) records that Dotilla fenestrata burrows in well drained sand and does not occur in waterlogged substrates.

It is difficult to explain the lack of Uca tetragonon at Gazi and Malindi bay beaches. Uca tetragonon occurs in large numbers with Uca vocans at Kanamai beach but at Gazi and Malindi beaches where Uca vocans similarly occurs, Uca tetragonon was lacking. At all the localities where these Uca spp were seen, there were small stones or coral rubble in the muddy sand substrate. Thus since at Kanamai both species occupied muddy sand with small stones or coral rubble, it would have been expected that Uca tetragonon is also seen at Gazi and Malindi sites because the habitats were similar. At Aldabra Atoll Taylor (1971 a) observed that Uca tetragonon occurred at this Atoll but Uca vocans lacked. This suggests that there may be ecological differences in their niche requirements so that they only co-occur when such requirements for both species are provided for in the biotope. If the biotope offers requirements which suit one of the species then they do not co-occur. Indeed, when the work of Icely and Jones (1978) is consulted the question becomes more complicated because they found out that (i) the two species showed similar preferences for open shore; (ii) there was little difference in the particle size and organic content of the substrate they occupied and finally (iii) their feeding structures showed only minor differences hence they could sample similar texture of sediments.

The distribution of the Ocypode species at various localities may be dictated by behavioural differences. At each sampling site, in Malindi Bay, Kanamai and Gazi, only a single species of Ocypode was encountered. One would therefore wonder whether not more than one species can occupy same area of a beach. On some Kenyan beaches Jones (1972) recorded similar observations in their studies on O. ceratophthalmus and O. ryderi. In their transects they found out that at each locality the burrows were occupied by one of the species only. Night catches of the Ocypode crabs at different localities during low tide when they are found in large numbers showed that 98 - 100% of the crabs caught at each locality belonged to either one of the two species.

This observation is not confined to Kenyan beaches only. Elsewhere, Ocypode ryderi and O. ceratophthalmus wherever they were found together in a beach, only one of them was abundant as observed at Inhaca, Mozambique by Macnae and Kalk (1962); Durban Bay, South Africa by Day and Morgans (1956) and Richards Bay South Africa by Millard and Harrison (1953). At the beach of Sar Uanle dune, Somalia Vannini (1976) observed that in a mixed catch of O. cordimanus and O.ryderi only 7.4% were O. cordimanus and O. ceratophthalmus occurred at different parts of the sandy beaches. At Mahe Seychelles Taylor (1968) found that O. ceratophthalmus occurred in higher numbers than O. cordimanus. The reasons for such disparities could be due to differences in aggresiveness but there is no conclusive evidence yet.

Zoogeography

The faunal distribution of the various species shown in Table 4 contributes to the evidence that many species in the Western Indian Ocean are found in several geographical areas in this region (Taylor 1971b). It is necessary to point out that this study in Kenya was done when presently the taxonomy of tropical invertebrates is better known than at the earlier times when such similar studies were carried out elsewhere in the Western Indian Ocean. The impression that may therefore misleadingly portray that the Kenyan coast sandy beaches have the highest species diversity should not be overlooked.

Zonation

Using the crabs which are the most conspicuous sandy beach macrofauna, there are three biological zones based on their distribution. In a downward shore direction these three characteristic zones accross the beach are easily distinguished and are namely :*Ocypode* zone; *Dotilla* zone and *Uca* - *Macrophthalmus* zone.

The *Ocypode* zone is mainly composed of coarse sand substrate. Three species of *Ocypode* burrow in this zone. These are : *O. ceratophthalmus*, *O. cordimanus* and *O. ryderi*. Characteristically they stay in their burrows at high tide but at low tide they wander about making feeding excursions on the entire beach and especially so during night low tide (Vannini 1980 , Icely and Jones 1972, Hughes 1966). Thus their zone of distribution accross the shore widens at low tide.

The substrate in the *Dotilla* zone is mainly fine to medium grain sized sand (Hartnoll 1973). The watertable in this zone is near the surface e.g 10-20 cm below the surface as recorded in the present Kenyan study; 10 - 15 cm below the surface as recorded at Inhaca Island, Mozambique by Macnae and Kalk (1962).

At the lower end of the beach between MTL and MLWS the watertable is at the surface and the substrate is muddy sand. This portion of the shore experiencing seepage is the *Uca* - *Macrophthalmus* zone. Seepage is a common hydrological process in the Western Indian Ocean e.g at the Somali coast (Chelazzi and Vannini 1980); coast of Kenya (Ruwa and Polk In Press); coast of Tanzania (Hartnoll 1973); Inhaca Island, Mozambique (Macnae and Kalk 1962); Seychelles (Taylor 1968); Aldabra Atoll (Taylor 1971 a) and Madagascar (Pichon 1966). The presence of several same species of macrofauna where seepage occurs (Table 4) adds an interest to the search and understanding of the environment in this region.

The *Dotilla* and *Uca* - *Macrophthalmus* zones are profoundly influenced by the watertable. Lanyon et al (1982) stated that changes in wave regime, shelf-wave activity, tidal fluctuation or mean sea-level variation cause the watertable continually to change position and alter the proportion of beach which is either saturated or unsaturated. This may also partly explain local differences in the species composition at different beaches.

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Table 1. List of species of macrofauna encountered in this study. The species marked with asterisks were found outside the transects. According to Vannini's (1976) review, the species once referred to as O. kuhli in this region is distinctly O. ryderi. The latter species was collected at Gazi whereas the Hippa and Emerita spp were collected at Kanamai.

Family	Species
Ocypodidae	Ocypode ceratophthalmus Pallas
	O. cordimanus Desmarest
	*O. ryderi Kingsley
	Uca lactea de Haan
	U. vocans Linnaeus
	U. tetragonon (Herbst)
	Dotilla fenestrate Hilgendorf
	Macrophthalmus grandidieri A. Milne Edwards
	M. parvimanus Guverin
	M. milloti Crosnier
	M. bosci Audouin & Savigny
Portunidae	Thalamita crenata (Latreille)
	T gatavakensis Nobili
	Scylla serrata (Forskal) - juveniles
Hippidae	*Hippa adactyla Fabreille
	*Emerita austroafricana Schmitt
Naticidae	Natica gualtierana (Petit)
	Polinices mammila (Linnaeus)
Nassaridae	Nassarius arcularius (Linnaeus)
	N. coronatus (Bruguire)
	N. fenwicki Kilburn
	N. margaritifera (Dunker)
Strombidae	Strombus mutabilis Swainson
	S. gibberulus Linnaeus
Neritidae	Nerita polita Linnaeus
Scutellidae	Echinodiscus bisperforatus Leske

Table 2. Distribution of various species in the higher level of the sandy beaches at Gazi, Kanamai and Malindi. The letter (P) indicates where the organism was seen and recorded.

Species	Gazi		Kanamai		Malindi	
	EHWS – MHWN	MHWN – MTL	EHWN – MHWN	MHWN – MTL	EHWS – MHWN	MHWN – MTL
Ocypode cordimanus	–	–	P	–	–	–
O. ceratophthalmus	P	–	–	–	P	–
Dotilla fenestrata	–	–	–	P	–	P
Uca lactea	–	P	–	–	–	–

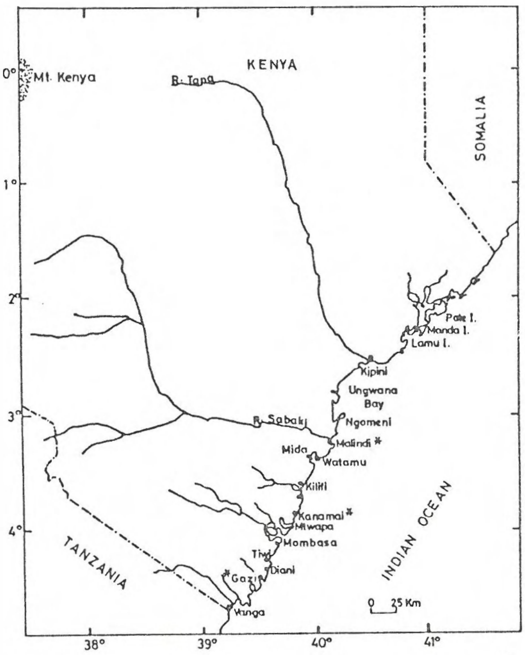

Fig. 1. Map indicating the study sites: Gazi, Kanamai and Malindi along the Kenya Coast

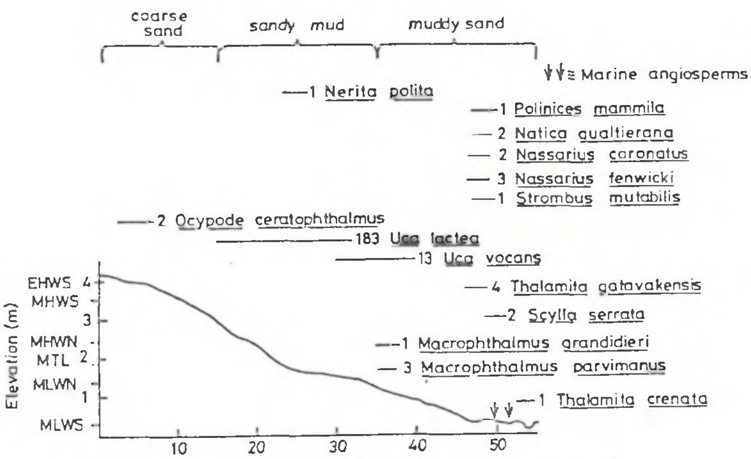

Fig. 2. Distribution of macrofauna across a sandy beach at Gazi

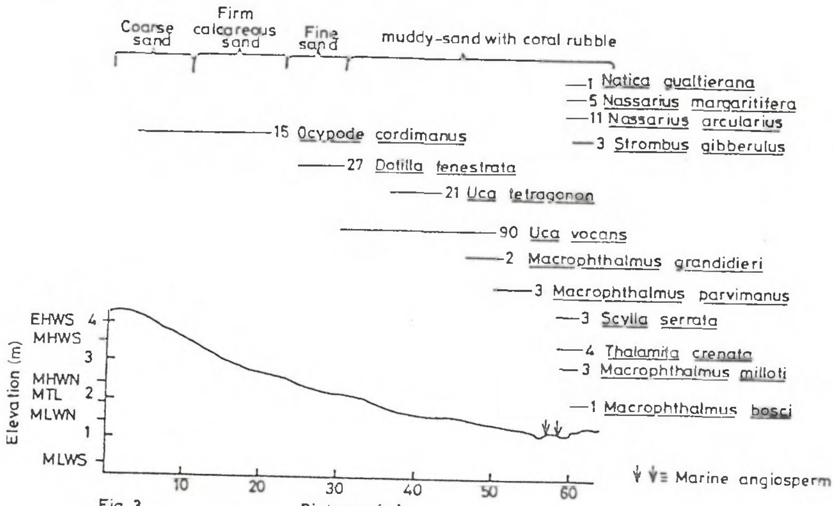

Fig. 3. Distribution of macrofauna across a sandy beach at Kanamai

Table 3. Distribution of various species in the lower levels of the sand beaches at Gazi, Kanamai and Malindi. The letter (P) indicates where the organism was seen and recorded.

Species	Gazi		Kanamai		Malindi
	MLWN - MTL	MLWN - MTL	MLWN - MTL	MLWN - MTL	MLWN - MTL
Uca tetragonon	-	-	P	-	-
U. vocans	P	-	P	P	-
Macrophthalmus bosci	-	-	P	P	-
M milloti	-	-	P	-	-
M.grandidieri	-	P	P	-	-
M. parvimanus	-	P	P	-	-
Scylla serrata	-	P	P	-	-
Thalamita crendta	-	P	P	-	-
T. gatava kensis	-	P	-	-	-
Natica gualtierana	-	P	P	P	-
Nassarius margaritifera	-	-	P	-	-
N. arcularius	-	-	P	-	-
N. fenwicki	-	P	-	P	-
N. coronatus	-	P	-	-	-
Polinices mammila	-	P	-	-	-
Strombus mutabilis	-	P	-	-	-
S. gibberulus	-	-	P	-	-
Nerita polita	P	-	-	-	-
Echinodiscus bisperforatus	-	-	-	-	P

Table 4. Geographical distribution in the Western Indian Ocean region of the sandy beach macrofauna recorded in this survey in Kenya. The letter (P) indicates where the organism was seen and recorded. The sources of records are as follows: Natal Province, South Africa (Barnard 1960; Broekhuysen and Taylor 1959; Day 1974; Day and Morgans 1956; Millard and Harrison 1953; Richards 1984), Mozambique (Barnard 1960; Macnae and Kalk 1962; Richards 1984), Tanzania Barnard 1960; Crosnier 1962, 1965; Hartnoll 1973, 1975), Somalia (Chelazzi and Vannini 1980; Vannini 1976, 1975), Madagascar (Crosnier 1962, 1965; Pichon 1966); Seychelles (Taylor 1968) and Aldabra (Taylor 1971 a). These countries and localities have been abbreviated as follows: South Africa (S.Af.), Mozambique (Moz.), Tanzania (Tan.), Kenya (Ken.), Somalia (Som.), Madagascar (Mad.) Seychelles (Sey.) and Aldabra (Ald.)

Species	S.Af.	Moz.	Tan.	Ken.	Som.	Mad.	Sey.	Ald.
Ocypode zone	P	P	P	P	P	P	P	P
O. ceratophthalmus	P	P	P	P	P	P	P	P
O. cordimanus	P	P	P	P	P	P	P	P
O. ryderi	P	P	P	P	P	P	-	-
Dotilla zone								
D. fenestrata	P	P	P	P	-	P	-	-
Hippa adactyla	P	-	P	P	-	-	-	-
Emerita austroafricana	P	P	P	P	-	-	-	-
Uca-Macrophthalmus zone								
Uca lactea	P	P	P	P	P	P	P	P
U. vocans	P	-	P	P	-	P	-	-
U. tetragonon	-	-	P	P	-	P	-	P
Macrophthalmus bosci	P	P	P	P	-	P	-	-
M. grandidieri	P	P	P	P	-	P	-	-
M. parvimanus	-	-	P	P	-	P	P	P
M. milloti	-	-	P	P	-	P	-	-
Thalamita crenta	P	P	P	P	P	P	P	P
T. gatavakensis	-	-	-	P	-	P	-	-
Scylla serrata	P	P	P	P	P	P	-	-

Natica gualtierana	-	-	P	P	P	-	-	-
Polinices mammila	P	-	P	P	P	-	P	-
Nassarius arcularius	P	P	P	P	P	-	P	-
N. coronatus	P	P	P	P	P	-	P	-
N. fenwicki	P	-	-	P	-	-	-	-
N. margaritifera	-	-	P	P	-	-	-	-
Strombus mutabilis	P	-	P	P	-	-	-	-
S. gibberulus	P	-	P	P	P	-	P	-
Nerita polita	P	P	P	P	-	-	P	-
Echinodiscus bisperforatus	P	-	-	P	-	-	P	-

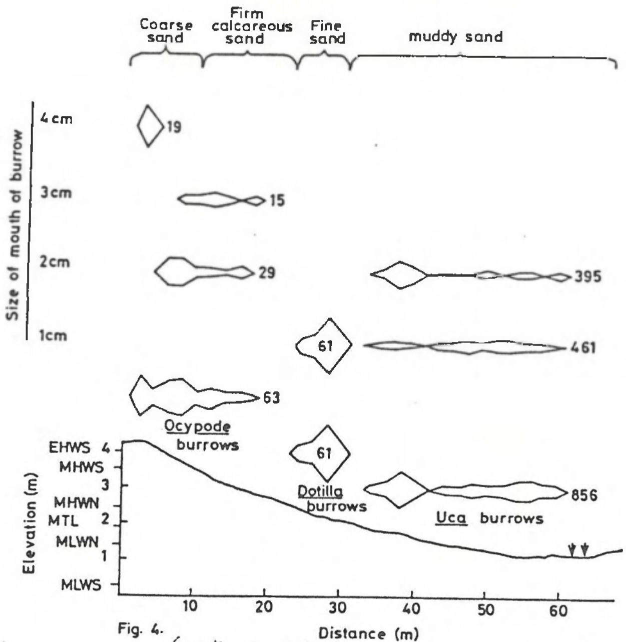

Fig. 4. Count of crab burrows across a sandy beach at Kanamai.

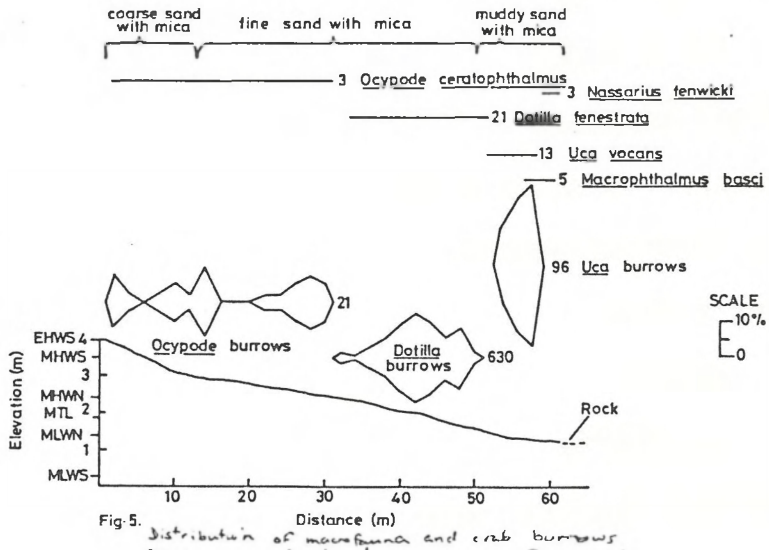

Fig. 5. Distribution of macrofauna and crab burrows across a sandy beach at Malindi Bay near Vasco da Gama pillar.

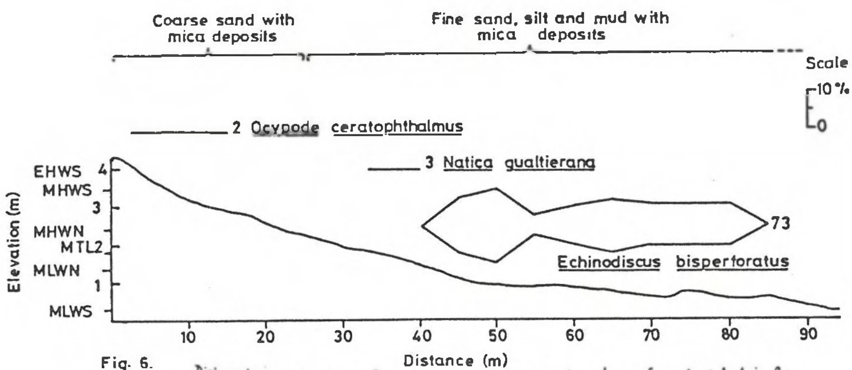

Fig. 6. Distribution of macrofauna across a sandy beach at Malindi.