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Field demonstration of a tidal component in the rhythmic vertical migrations of *Grapsus maculatus* (Brachyura: Grapsidae) on a rocky shore in Kenya

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SUMMARY

The vertical migrations of *Grapsus maculatus* Hoffman were investigated. The results indicated a highly significant positive correlation ($r \simeq 0.9748$) between the mean height of the crab population above datum and the tidal heights which clearly confirms that their position on the cliffs is highly related to the water level. Further analysis was made to determine the range within which the mean height of the crab population occur at the 95% confidence limits for various tidal heights, 0.8 - 3.4 m.

INTRODUCTION

A large population of the crab *Grapsus maculatus* Hoffman, inhabiting the rocky cliffs at Mkomani, Mombasa conspicuously and periodically migrates vertically up and down the cliffs following the tidal rhythm. When the tide is on the ebb, the crabs move slowly downwards and scatter on the horizontal reef platform at low tide. Conversely, as the tide rises the crabs gradually migrate to higher levels on the cliffs and some take refuge in crevices above the water level.

Such tide-related migrations of shore crabs are not uncommon (Palmer 1974). Grapsid crabs are known to exhibit tide-related migrations and stay just above the water's edge which is their characteristic habitat (Banerjee (1960; Frith and Alexander 1978). These rock dwelling grapsid crabs are mostly active during low water (Frith and Alexander 1978). Since these movements of grapsid crabs have been described qualitatively as evidenced from the papers of Hartnoll (1975) and Frith and Alexander (1978), the present study was carried out to at least provide quantitative observations on the vertical migrations of the grapsids, in this present case *Grapsus maculatus*. Emphasis was placed on correlating the migratory behaviour of *G. maculatus* to the tidal cycles, so as to be able to define their positions above the water level. Toxonomic history of this species have been recorded by Barnard (1950), Barnejee (1960), Crosnier (1965) and Hartnoll (1975).

MATERIALS AND METHODS

The observations were carried out in the creek at Mkomani near the Old Harbour, on the mainland North of Mombasa from January to June 1980. The rocky cliffs at the sampling site rise vertically from about 1.2 to 8 m above datum. A small erosional platform extends nearly horizontally about 4 m seaward. As regards the tides operating on the Kenya sea-shore, they are semi-diurnal. There are characteristically two low and two high tides in every daily tidal cycle and some details are described by Brakel (1980).

A sampling site with a large population of about 100 crabs of *G. maculatus* which characteristically migrated together in a group was chosen. The vertical surface of

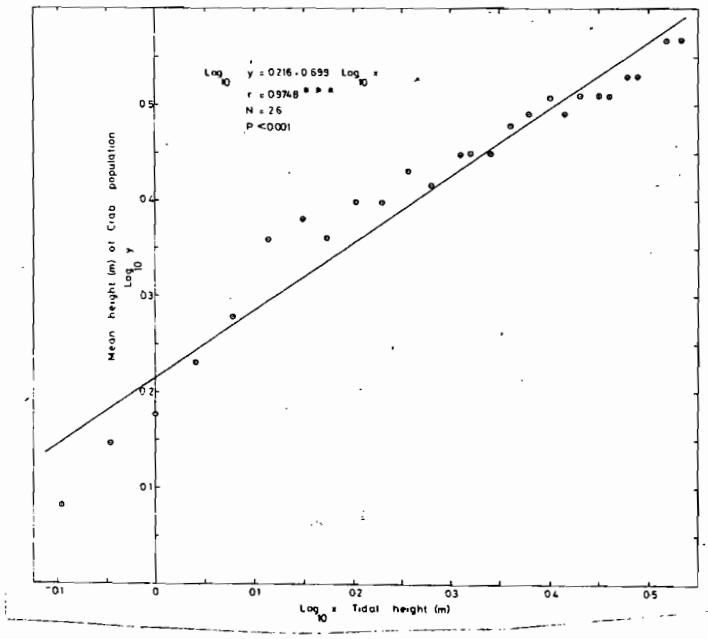

Figure 1. Relationship between mean height of *Grapsus maculatus* population and tidal height at Mkomani, Mombasa

Table 1. Mean heights of the *G. maculatus* with their standard errors (SE) and range at the 95% confidence limits

Tidal level (m)	Number of observations, N	Mean height, $\bar{Y}$ (m) of crabs with SE $\bar{Y}$	95% confidence limits of $\bar{Y}$ (m) ($\bar{Y} \pm t\,SE_{\bar{Y}}$)
0.8	8	1.2 ± 0.08	1.0 – 1.4
0.9	19	1.4 ± 0.09	1.2 – 1.6
1.0	18	1.5 ± 0.09	1.3 – 1.7
1.1	7	1.7 ± 0.10	1.5 – 1.9
1.2	10	1.9 ± 0.12	1.6 – 2.2
1.3	9	2.3 ± 0.13	2.0 – 2.6
1.4	13	2.4 ± 0.10	2.2 – 2.6
1.5	9	2.3 ± 0.11	2.0 – 2.6
1.6	13	2.5 ± 0.08	2.3 – 2.7
1.7	8	2.5 ± 0.06	2.4 – 2.6
1.8	18	2.7 ± 0.05	2.6 – 2.8
1.9	15	2.6 ± 0.03	2.5 – 2.7
2.0	17	2.8 ± 0.07	2.7 – 2.9
2.1	15	2.8 ± 0.07	2.7 – 2.9
2.2	14	2.8 ± 0.06	2.7 – 2.9
2.3	15	3.0 ± 0.07	2.9 – 3.1
2.4	20	3.1 ± 0.05	3.0 – 3.2
2.5	12	3.2 ± 0.07	3.0 – 3.4
2.6	11	3.1 ± 0.04	3.0 – 3.2
2.7	17	3.2 ± 0.03	3.1 – 3.3
2.8	10	3.2 ± 0.06	3.1 – 3.3
2.9	8	3.2 ± 0.04	3.1 – 3.3
3.0	10	3.4 ± 0.04	3.3 – 3.5
3.1	9	3.4 ± 0.06	3.3 – 3.5
3.3	8	3.7 ± 0.04	3.6 – 3.8
3.4	9	3.7 ± 0.04	3.6 – 3.8

the study site was marked at 0.25 m, successive levels with water proof red paint which could be easily recognized. These heights were standardized to heights above datum after determining the height above datum of the lower-most horizontal band from where the rock began to be vertical. This was done when the sea was calm and the Kenya Ports Authority (1980) tide tables were used for computations of tidal heights and standardizing. The pattern of vertical movements of the crabs was studied as the crabs moved across these marked levels.

Since the crabs are highly agile and disperse haphazardly when approached at close range, the observations were made from a floating pontoon adjacent to the study site at about 10 m away. The observations were carried out during day time at 0800, 1000, 1130, 1400 and 1530 h local time. Due to the break of waves on the cliffs and the high motility of the crabs, the latter could not be accurately counted, hence the distribution of the crab population on different levels above the water was expressed in percentages by careful visual estimation at each time of observation.

It was possible to make good visual percentage estimates of the crab distributions among the levels which the whole crab population occupied at each time of observation because the crabs moved closely together in a group and concentrated in a band about 0.5 m wide. At each time of observation the tidal level was calculated and the corresponding mean height of the whole crab population above datum was also calculated as follows: If at the time of observation it was estimated that k_1, k_2, k_3 % .... etc. (whose sum = 100%) of the whole crab population occupied the levels whose mean elevations above datum were, y_1, y_2, y_3 .... etc., respectively, then the mean height of the crab population was:

$$y = (k_1 y_1 + k_2 y_2 + k_3 y_3 \ldots\ldots)/100$$

Later the range of the mean height of the whole crab population for each tidal height at the 95% confidence limit and their correlation were calculated. The range helped to elaborate the "certain distance". the crab population could maintain above water level with respect to the latter.

RESULTS

The high positive correlation (r) between the mean height of the *G. maculatus* population and the tidal heights is shown in figure 1. A linear regression line was calculated to further describe the relationship after a $\log_{10}$ transformation of the data (figure 1). The crabs stayed at a certain distance above the water level as shown in table 1, where the standard errors (SE) of each mean height of the crab population are also given. The ranges at the 95% confidence limits, computed to indicate the range within which the mean heights of the crab population could be observed in relation to various tidal heights are as shown in table 1.

Although the mean heights of the crab population related to tides below 0.8 m and above 3.4 m were calculated, they were, however, not included because of the reasons given below. The topography of the cliffs below 1.2 m made the determination of the elevations of the crabs above datum difficult and subject to errors. Observations of the mean heights of the crab population at tidal heights above 3.4 m were ignored because the data was scanty.

DISCUSSION

The high positive correlation $r = 0.9748$ which is significant even at $P < 0.001$ clearly confirms that the migrations are closely associated with the tides. During these investigations it was also observed that *G. maculatus* are inefficient swimmers and when covered by water they crawl offshore and climb the cliffs. Their poor ability in swimming could be one of the reasons why they keep in phase with tides. Waves are also capable of dislodging them from the rocks because they lack suitable structures which could help them to cling firmly to the rocks.

This suggests that staying at a safe distance above the water level (table 1), where they could easily avoid waves is advantageous. In fact at times, the crabs were seen to have moved higher than expected when the waves were very violent.

The necessity of movement of these crabs to lower levels at low tides could be essentially associated with feeding. On several occasions during the study, the crabs were observed to move actively and feed on organisms on the narrow reef at low tide. It was noticed that the larger crabs which were more active moved to relatively higher levels. Other species of crabs whose movements at low tide are known to be related to feeding include the well studied fiddler crab, *Uca* spp (Palmer 1974). Their activity at low tide shows some similarity to *G. maculatus*. *Uca* spp. which are burrowing crabs are most active at low tides and emerge from their burrows during this period to feed and court (Amos 1966; Palmer 1974). However, during the investigations signs of courtship in *G. maculatus* were overlooked. Some other shore crabs, e.g., *Carcinus maenas* show contrasting behavioural activity at low tide. At low tides during the day this species burrows or stays under rocks but will venture out under the water at high tides during daytime (Palmer 1974).

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