

# Beach Cusps and Burrowing Activity of Crabs on a Fine-Grained Sandy Beach, Southeastern Nigeria

Effiom Edem Antia

Department of Geological Oceanography  
Institute of Oceanography  
University of Calabar, P.M.B 1115  
Calabar, Nigeria



## ABSTRACT

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The significance of morphological features have usually been under-emphasized in ecological studies of sandy beaches. One consequence of the latter is the widely-held view that organisms inhabiting beach ecosystems depict an unpredictable longshore distribution pattern. The above is refuted in this present study of burrow density of crab species (*Ocypoda africana* and *Ocypoda cursor*) encountered on cusps along a fine-grained, mesotidal, sandy beach fringing the southeastern coast of Nigeria. Generally, higher burrow densities were observed on transects along cusp horns compared with those of the adjacent bays. In contrast with the cusped foreshore segments, burrow densities on adjacent non-cusped segments were devoid of any predictable pattern. Averages of the mean values of burrow diameter and depth were relatively higher on cusp horn compared with cusp bay. Elevated values of depth-diameter ratio were also evident on the former. The lower burrow depth on bay is related to the moisture needs of the organisms and is a function of the water table. Cusp topography dictates that the latter would be closer to the surface on bays than on horns. The above results elucidate the essence for in-depth evaluation of morphologic characteristics in the course of ecologic studies of beaches.

**ADDITIONAL INDEX WORDS:** *Beach cusps, crab burrows, mesotidal, fine-grained sandy beach, ecologic studies, Nigerian coast.*

## INTRODUCTION

A multi-disciplinary approach to coastal research has, in recent times, increased in dimension. The subject of organism-sediment relationship has consistently engaged the attention of biologists and geologists studying the beach, tidal flat and nearshore environments. This report focuses on the above subject from a geological perspective.

The literature on organism-sediment interaction including those on the distribution of beach fauna in time and space is enormous. Pertinent contributions from both geological and biological perspectives are contained in the following reports: *e.g.* JANSSON (1967), CUBIT (1969), HOWARD and DÖRJES (1972), HILL and HUNTER (1973, 1976), REINECK and SINGH (1973), ELEFThERIOU and NICHOLSON (1975), ECKMAN (1979), CRAIG (1980), HOLANOV and HENDRICKSON (1980), GRANT (1981), BALLY (1983), FLEMMING

and FRICKE (1983), McLACHAN (1983), BOWMAN and DOLAN (1985), and VILAS (1986).

The present study was mainly motivated by the observations of BALLY (1983) and FLEMING and FRICKE (1983). The studies of the former, like most others previously reported, indicated the distribution of a number of macrofauna and meiofauna on sandy beaches to be patchy and that the patchiness was random in occurrence. FLEMMING and FRICKE (1983) have reported on the important role which the morphodynamic beach-states (detailed in WRIGHT and SHORT, 1983) plays in determining the nature of the internal geometry and sedimentary structure of a sandy beach. Consequently, the state of a beach (reflective, intermediate or dissipative) is considered a critical factor in the study of meiofaunal and microfaunal ecology. The peculiar hydrodynamic signatures and scale of beach mobility associated with each of the morphodynamic beach-states elucidate the importance of their evaluation in all aspects of ecologic studies on sandy beaches.

The possible effect of morphological beach characteristics on the distribution of organisms inhabiting the sandy beach ecosystem has not received sufficient attention in previous studies reported in the literature. Concerted efforts in this respect are, however, evident from studies of GRANT (1981) and FLEMMING and FRICKE (1983). With the exception of the reports of CUBIT (1969) and BOWMAN and DOLAN (1985), no other study is known to this author in which faunal distribution has been examined in relation to beach cusps. However, in the above-mentioned studies attention was focussed on faunal distribution at specific levels on cusps. Furthermore, both reports were uninformative on either the dimensional or textural characteristics of beach cusps investigated.

The aforementioned attributes of cusps are very essential for proper assessment of the influence exerted by this and other similar rhythmic shoreline features on the distribution pattern of beach fauna. The preponderance of cusps (at some beach sectors) and their colonization by crabs (of which *Ocypoda africana* and *Ocypoda cursor* were the major species) at the study area further motivated this initial report aimed at evaluating the roles of physico-morphologic beach attributes on faunal distribution.

### Beach Cusp

Beach cusps are sinusoidal morphologic features of beach foreshores. They consist of a seaward projection or horn and a seaward-concave depression or bay. As indicated in studies of ANTIA (1987b), the literature on cusps is vast. Reports dealing on cusp origin and formation are replete with contradictions. On the contrary, remarkable consensus exists on cusp characteristics such as grain-size statistics, permeability and variations in steepness between horns and bays.

The sets of beach cusps investigated were on the average, 15 m long, 0.4 m in relief and with a spacing of 31 m. The horns of cusps, in comparison with the adjacent bays, depicted coarser grain sizes, better sorting, higher permeability rates and steeper slopes. Specifically, the variations in the aforementioned between the horns and bays were: 22%, 19% and 16% for mean, sorting and permeability, respectively; a con-

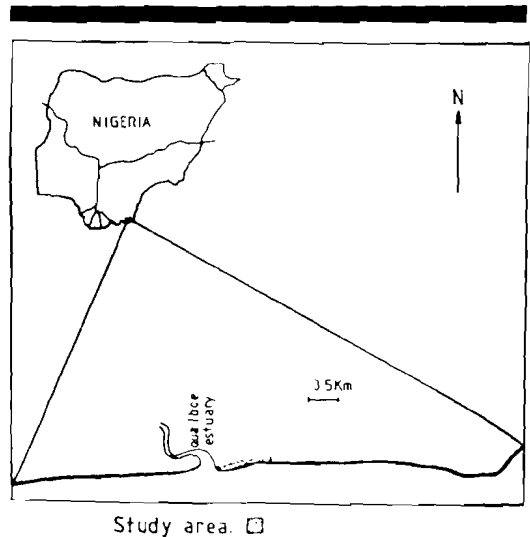


Figure 1. Study area.

trast of  $1^{\circ}$ - $2^{\circ}$  in steepness between bays and horns was usually evident.

### STUDY AREA AND PROCEDURE

The study area (Figure 1), is locally referred to as Ibena Beach. It is located on the southeastern segment of the Nigerian coast. The beach is composed mostly of fine-grained sands; grain sizes however vary between 0.18 and 0.34 mm. The steepest portion of the foreshore is  $8^{\circ}$ - $10^{\circ}$ ; a large proportion of the 50-100 m wide intertidal zone has slopes less than  $4^{\circ}$ .

Tides are semi-diurnal and mesotidal in range (2-4 m). The predominant winds are from the southwest and these generate waves whose breaker heights are usually 30-200 cm. Velocities of wind and longshore current ranged between 5-10 m/s and 0.15-0.8 m/s, respectively. More detailed information regarding variations in the physico-morphologic characteristics of Ibena Beach and, most especially, the ecologic consequences of such variations have been recently documented in ANTIA (1986, 1987a,b). On the contrary, there is a dearth of information on the taxonomy and other biological aspects of fauna in the study area.

The study procedure entailed the establishment of 2 m wide transects of equal length along the axes of horns and adjacent bays of cusps. The transects extended seaward from the

berm crest along the entire cusp length. A total of 16 other transects were also established on foreshore segments devoid of beach cusps. The transects are designated A-P in the eastward direction and cover 6.2 km of beach length. Surf-scaling or reflectivity parameter values of the transect localities given in ANTIA (1987a), these being the basis of the morphodynamic beach classification of WRIGHT and SHORT (1983), indicate a fluctuating tendency between intermediate and dissipative beach-states.

Burrowing activities of the reported crab species in relation to the variations in the morphodynamic beach-states are receiving detailed attention following initial studies of ANTIA (1986). However, for the present study, burrow diameter, vertical depth and density at each of the transects were examined at low tide. The diameter of the burrows was obtained with a rule while vertical depth entailed lowering erect rods of appropriate size into the burrows until the bottom was felt. The length of rod inserted into each burrow was determined with the corresponding burrow diameter.

Density of burrows at each transect was obtained in a manner reported by MYERS (1979). This entailed counting the total number of burrows occurring within a transect and dividing the obtained values with the area of the transect. In all, detailed assessment of burrow density was made on 12 successive beach cusps in March of 1986. In addition, 66 pairs of diameter-depth data of burrows were each obtained from horns and bays of cusps at various times between April and June of 1986.

## RESULTS AND DISCUSSION

Longshore partitioning of the burrow densities of the studied crab species between the horns and adjacent bays of cusps at the study site is given in Figure 2. A first and general impression evident from the latter is elevated burrow density values on horns relative to their adjacent bays. The burrow density pattern for both cusp components was similar. This evident trend is statistically supported by a correlation coefficient value,  $r$ , of 0.8. The regression equation for this relationship is  $Y = 0.87X + 0.17$ , in which the variables  $Y$  and  $X$  denote burrow density of horn and bay respectively.

It is suggested that the low variation between burrow density of horn and bay of the investi-

gated cusps may be a consequence of equally small disparity in textural and related characteristics between the cusp components of this beach. Increased textural inhomogeneity between the cusp components, as reported from comparative studies on the Nigerian coast (ANTIA, 1987b), should result in higher contrast of factors on which crab distribution are likely to depend. Textural differentiation between horns and bays resulting in much higher permeability, wave swash control and ease of burrowing on the horns would naturally enhance crab colonization to the detriment of the adjacent bays and, thus, give rise to a higher statistically significant partitioning of burrow densities between cusp components shown in Figure 2.

While the above result is not considered conclusive, primarily because of the limited time-scale of observation and restricted environmental condition (mesotidal, moderate-high energy), it is instructive in a number of ways. Of particular importance is the amplification of the observations of GRANT (1981). His studies showed that morphologic bedforms such as ripples had a modifying effect on faunal distribution. The pattern whereby a higher number of burrowing crustaceans occurred on ripple crests as against the troughs was considered to be a consequence of active preference by the organisms rather than a passive hydrodynamic sorting.

The studies of GRANT (1981) and the present observations illustrate the fact that ecologic sampling on beaches should always be made with due consideration on possible inhomogeneities in bedform morphology. Thus, the commonly reported unpredictable nature of the longshore distribution pattern of macrofauna on sandy beaches may be, to a large extent, attributable to non-assessment of the inhomogeneities in beach morphology. To account for the modifying effect of beach cusps on the distribution of crabs studied, and by implication burrowing beach fauna, one has to assess cusp characteristics and associated hydrodynamic conditions.

It is obvious that the loosely packed grains on cusp horns will facilitate burrowing when compared with the tight packing of grains typical of cusp bays. Similarly, high rates of oxygen and nutrient cycling most conducive for the survival of burrowing organisms are likely to per-

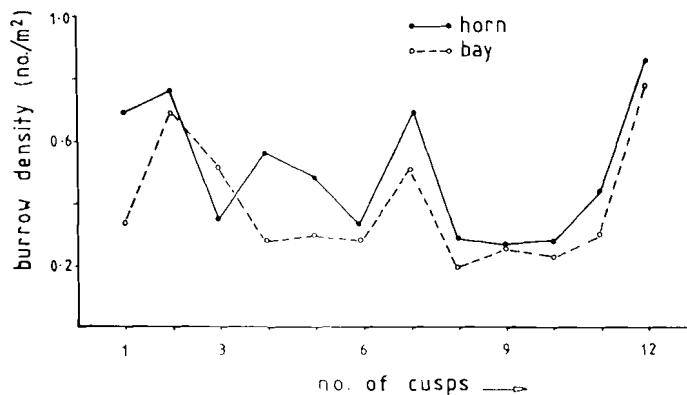


Figure 2. Variations in burrow density on cusps.

sist beneath horns. This is due to the better sorting and higher permeability of sediments comprising the horns than those evident on the bays (ANTIA, 1987b). The relative rates of exchange of oxygen and nutrients with depth at horns and bays are not likely to reverse because sediments at sub-surface of horns and bays both showed similar upward coarsening trend (ANTIA, 1987b). The latter trend in sediment texture has however been shown by CHAFETZ and KOCUREK (1981) to be typical of accumulative cusps.

With respect to hydrodynamics and related factor of sedimentation, there might be a tendency to initially suppose that crabs would be more abundant within cusp bays than on horns because of the less intense wave activity typical of embayments. The latter condition is due to divergence of wave energy from embayments and subsequent convergence at horns or similar seaward projecting shoreline features. Although faunal density studies of BOWMAN and DOLAN (1985) showed the aforementioned tendency, it is important to state that their observations were conducted on macro-scale (spacing > 60 m) cusps. In contrast to the latter, the meso-scale varieties at Ibeno Beach showed turbulent conditions to be associated with cusp bays as against relatively quiet conditions at the horns.

As illustrated in Figure 3, after wave breaking, resulting swash after initial run-up on horns, swings onto adjacent bays by virtue of the disparity in their relief and steepness. Thus, convergence of adjacent swashes at the

bays gives rise to turbulent, channelled or rip-like seaward flow. Interaction of the latter flow with succeeding wave swash especially at high tide may aggravate turbulence leading to large-scale sediment re-working. The sediment re-working process will be enhanced by the meso-tidal and low-lying characteristics of the studied beach. On the contrary, the coarser and better sorted sediments on the horns enhance infiltration of swash thus promoting milder hydrodynamic conditions.

On the whole, horns of cusps are sites of slow but steady sedimentation whereas bays are zones of intense sediment re-working and erosion. The high steepness of horns relative to bay slope supports the above disparity in sediment dynamics over cusps having spacing in the 30-60 m range or lower. In effect, micro- and meso-scale cusped bedforms are incapable of structuring wave energy in a manner that promotes quieter or depositional conditions within cusp bays relative to horns. It is, however, recognized that on very large cusps and other macro-rhythmic shoreline features having spacing over 60 m, their embayments may indeed constitute zones of mild hydrodynamic conditions in contrast with the seaward projections (ridges, promontories, etc.).

The aforementioned pattern of hydrodynamic condition is due to the fact that swinging swashes from adjacent horns or promontories are not well re-inforced as backwash flow within the bays. Moreover, the refraction of waves away from embayments becomes more pronounced. Consequently, backwash flow

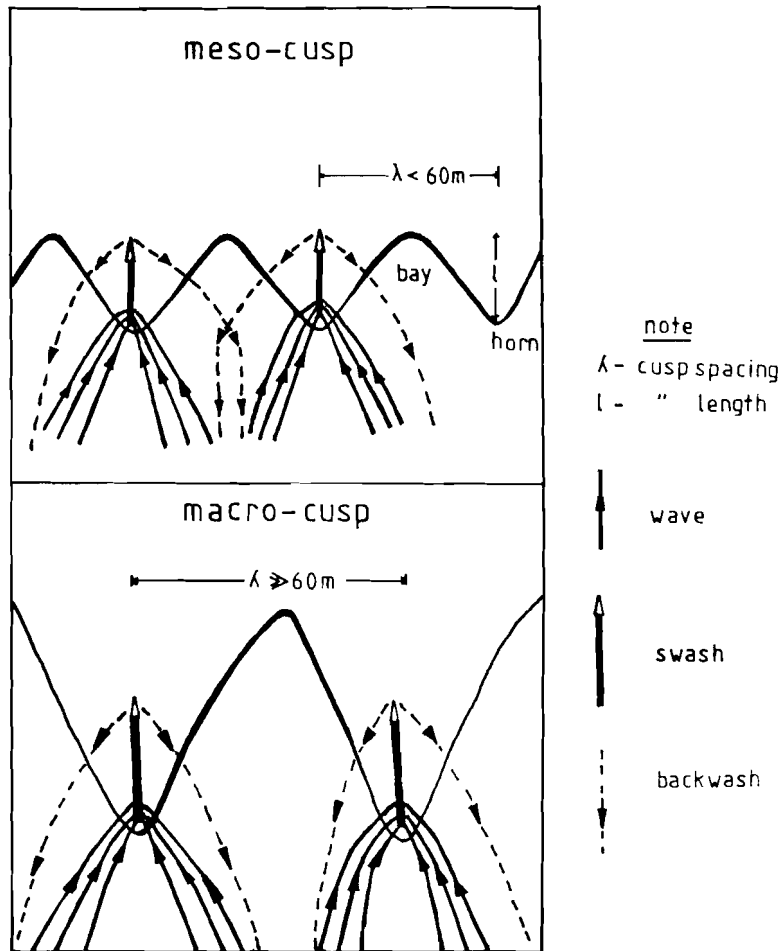


Figure 3. Hydrodynamic patterns on cusps.

within embayments (Figure 3) is smoother and broader in comparison with similar flows on meso-scale cusps.

In contrast to the definite pattern of longshore variation in burrow density over cusped foreshore segments, the non-cusped counterpart given in Figure 4 showed no predictable trend in accord with reports in the literature. As previously stated, efforts are underway to evaluate to what extent the observed irregular longshore distribution of burrow density can be accounted for by the changing values of surf-scaling parameter. The latter incorporates virtually all the physical factors often asserted to control faunal distribution on beaches.

Measured diameter and depth data of bur-

rows on cusps and diameter-depth ratio calculated from these were analyzed and are presented in Table 1. Correlation coefficient,  $r$ , between burrow diameter and depth obtained from data on which Table 1 was made indicates generally higher values on the horns (Figure 5) compared with corresponding bays. Corresponding or adjacent bays as used in this report refer to those on the left of the horns when facing the sea (that is, the bay eastward of a given horn).

Some of the interpretations afforded by Table 1 include the fact that the overall average of the means of burrow diameter and depth was higher on the horn compared with bay. The contrasts were, however, not very remarkable,

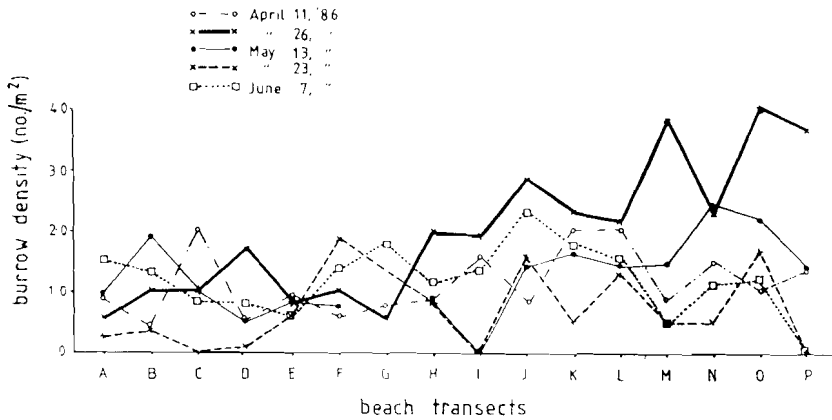


Figure 4. Longshore temporal variations in foreshore burrow density.

Table 1. Mean ( $\bar{x}$ ) and standard deviation ( $\sigma$ ) of burrow dimensions on cusp horn and bay, Ibeno Beach.

cusp no.	diameter		depth		diameter		n
	$\bar{x}$	$\sigma$	$\bar{x}$	$\sigma$	$\bar{x}$	$\sigma$	
1 horn	4.25	3.98	17.91	13.69	0.21	0.11	11
1 bay	2.76	2.59	16.75	14.61	0.19	0.11	12
2 horn	2.95	2.60	20.65	18.34	0.19	0.17	10
2 bay	3.60	3.57	23.50	11.14	0.18	0.13	8
3 horn	4.50	3.16	20.88	10.24	0.31	0.25	8
3 bay	2.89	1.81	14.11	5.43	0.20	0.09	9
4 horn	2.96	1.75	17.2	4.12	0.16	0.07	5
4 bay	1.24	0.84	17.4	9.56	0.09	0.07	5
5 horn	3.76	3.32	32.2	15.73	0.11	0.05	5
5 bay	2.20	1.54	13.00	4.83	0.20	0.14	7
6 horn	5.31	3.51	25.63	17.54	0.22	0.13	8
6 bay	3.33	1.94	17.43	7.03	0.20	0.12	7
7 horn	4.20	2.04	19.00	11.44	0.26	0.10	5
7 bay	4.30	3.37	31.20	13.00	0.17	0.18	5
8 horn	2.80	2.36	11.08	7.61	0.26	0.08	6
8 bay	3.35	2.47	15.91	10.76	0.23	0.09	6
9 horn	3.67	2.39	26.67	10.87	0.13	0.05	3
9 bay	4.67	1.70	26.67	3.40	0.18	0.06	3
10 horn	3.10	1.16	13.00	4.73	0.25	0.11	5
10 bay	2.88	0.74	13.00	7.58	0.33	0.22	4

averaging about 17% for burrow diameter and 7% for burrow depth. However, in terms of variability in burrow diameter, larger standard deviation values (std) were indicated by the horns. Thus, if the size of burrow opening is used as an index of animal size (VILAS, 1986), one can expect larger variations in animal size inhabiting the horns than those on the bays. The burrow depth variability was also higher on the horns than bays.

In contrast with burrow diameter, burrow depth is less reliable as an indicator of animal size. Studies documented by HOLANOV and HENDRICKSON (1980) and WILLIAMS (1983) suggest that burrow depth of organisms are regulated by moisture content of beach sands. The moisture content is primarily a function of sediment texture and beach water table level.

The lower average depth of burrows on bay is as a result of a combination of finer grains, lower permeability and proximity of bay surface to the beach water table. On the contrary, the higher relief of horns (and hence higher elevation between water table and surface of horn) as well as their higher permeability dictate that sand of suitable moisture content for the survival of burrowing organisms would be encountered at deeper depth. The burrows are consequently vertically longer on the horns of cusps than on bays.

Given the variability in burrow diameter and depth on the horns and bays, it was anticipated that both burrow parameters expressed as a dimensionless ratio would provide a means of defining burrows of different organisms and their distribution within the different morphologic elements constituting beaches. Data given in Table 1 indicate that in 70% of the cases, the mean burrow diameter-depth ratio of horns depicted elevated values than their bay counterpart. The full implications of the latter observation to ecological studies of beach macrofauna would be evident from more detailed inventory in time and space.

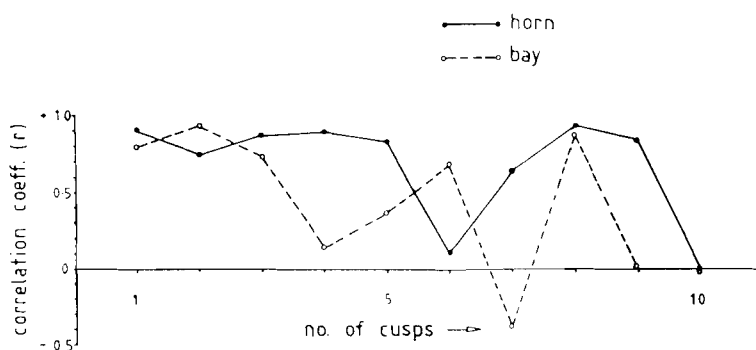


Figure 5. Diameter-depth correlation of burrows on cusps.

## CONCLUSIONS

The information documented in this report corroborated the observations of earlier authors such as GRANT (1981), FLEMMING and FRICKE (1983) and BOWMAN and DOLAN (1985), all of whom have asserted the strong dependence of meio- and macro-fauna distribution on sandy beaches on the morpho-structural attributes of the beach. Macrofaunal density distribution in relation to cusped and non-cusped foreshores herein presented as well as over rippled bedforms (GRANT, 1981) provides a basis for refuting previous opinion that the longshore distribution of fauna within a sandy beach ecosystem is unpredictable. The cusped foreshore segments revealed elevated densities of burrows on the horns than the adjacent bays of cusps. A previous report (ANTIA, 1986) and the current assessment do indicate that the unpredictable longshore burrow density patterns on the non-cusped foreshores may be defined given data on the surf-scaling parameter.

Difficult to explain at the moment is the generally better correlation of burrow diameter and depth on horns than the adjacent bays. On the other hand, the reason for the elevated burrow diameter values on horns than bays is not also known. However the deeper depth of burrowing on horns is predictable given their higher elevation from the beach water table and higher permeability rate than their adjacent bays.

Considering the general variability of values of burrow diameter and depth, the ratio of these

parameters was calculated and found to be generally higher on the horns than bays. Further assessment of this ratio on other morphologic features, different levels of beach and for burrows constructed by different beach organisms or species of the same organism would be quite rewarding to the geologists and biologists. These share the belief that burrows can serve as useful indicators of past and present states of an ecosystem.

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