ZONATION AND BIOMASS OF THE INTERTIDAL MACROFAUNA ALONG A SOUTH AFRICAN SANDY BEACH

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Résumé

La macrofaune intertidale a été récoltée le long de trois lignes de transect sur une plage sableuse à haute énergie, d'Afrique du Sud. On a jalonné chaque transect de 20 à 25 points de collecte et, pour chaque point, on a mesuré la profondeur de la nappe d'eau et la teneur en eau du sable.

La distribution de la macrofaune montre une corrélation avec le gradient d'humidité du sable. Aux pourcentages de 0 à 4 %, 4 i 7 %, 7 à 20 % et de 20 à 26 % d'humidité du sable de surface quatre zones se manifestent. Les espèces caractéristiques de chaque zone sont *Tylos capensis* dans la zone d'humidité de 0 *%-i %, Excirolana natalensis* et *Pontogeloidet latipes* dans la zone de 4 à 7 %, *Donax serra* et *Eurydice longicornis* dans la zone de 7 à 20 % et *Donax sordidus, Bullía rhodostoma, B. pura* et *Gastrosaccus psammodytes»* dans la zone de 20 à 26 %.

Introduction

The distribution of the macrofauna is not as clearly defined on sandy beaches as it is on rocky shores, where distinct zones can be distinguished by the naked eye. The main reason for this is the high physical instability on sandy beaches due to wave action.

Stephens (1929) was amongst the first to recognize that zonation existed on sandy beaches. Various zonation schemes for sandy beaches have since been proposed. Brown (pers. comm. McLachlan) suggests that there are two zones in the intertidal zone, namely the air breathers and the water breathers, above and below the driftline respectively. Dahl (1952) proposed three basic zones, corresponding approximately to the three basic zones on rocky shores, based on the crustacean faunas. These zones are the subterrestrial fringe, the midlittoral zone and the sublittoral fringe. The subterrestrial fringe is the upper zone above the normal water level which is characterized by *Ocypode* crabs in «warm» areas and talitrid amphipods in temperate areas. This zone would correspond with the air breathers of Brown's scheme. The midlittoral zone is wetted on every tide and is characterized by cirolanid isopods. The lower zone or sublittoral fringe has a number of species and crustaceans may be less important here.

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Salvat (1964) used four zones to describe the intertidal area. He defines a drying zone which is rarely reached by salt water except during equinox spring tides, storms or by spray; a zone of retention in which the pore moisture is retained in the sands; a zone of resurgence where there is water movement in the sand but the sand is no tsaturated; and a saturation zone in which the sand is water saturated. Salvat's drying zone corresponds to the supralittoral fauna of Dahl and the air breathers of Brown. The zone of retention, together with the zone of resurgence corresponds to the midlittoral zone (Dahl, 1952) and the saturation zone corresponds o tbe sublittoral fringe suggested by Dahl (1952). The above zonation schemes have all been discussed in the review by McLachlan (1983).

The schemes of Brown and Dahl are based on biological factors while that of Salvatis based on physical factors, mainly the moisture gradient in the sand. Dahl's scheme, with modifications, has been found acceptable in South Africa by McLachlan (1980a), McLachlan ***et al.*** (1981) for most beaches in the Eastern Cape. Bally (1981), however, made use of Salvat's scheme in describing the zonation of the West Coast of South Africa. Both McLachlan (1983) and Bally (1981) suggest that different zonation schemes apply to different beaches. For instance, Dahl's zonation system appears to hold for exposed and semi-exposed beaches, but not always for sheltered beaches (Bally, 1981).

It can thus be seen that views on zonation of the sandy beach macrofauna differ widely from person to person. McLachlan (1983) states that zonation has never really been proved on sandy beaches as no sharp boundaries have been shown and puts this down to a dynamic environment with a highly mobile fauna. The most prominent boundary is that between Brown's air breathers and water breathers which corresponds with Dahl's subterrestrial fringe and with Salvat's dry zone.

The aim of this study was to quantify the intertidal macrofauna biomass of Sundays River Beach in South Africa in a series of transect samples which would simultaneously allow assessment of these different zonation schemes.

Study Area

The Sundays River Beach, which lies approximately 40km east of Port Elizabeth, is á 40km long stretch of uninterrupted beach on the North-eastern side of Algoa Bay, and has moderate intertidal slopes of 1/28 to 1/40 (fig. 1) The intertidal zone is approximately 80m wide and 1,5 to 2,4m high, and some 10m beyond the high water mark it rises to dunes 10m in height. Berms are not usually present. The sand consists of well sorted medium quartz particles with diameters of 225-335m and with a $CaCo_3$ content of 29-47%. There is a trend for the finer sand to occur near the high water mark and the coarser sand towards the low water mark, where wave action is the greatest.

The beach is free of boulders and subtidal rocks although some pebbles occur high above the drift line, just beforethe primary dunes. The drift line is poorly marked as no deposits of stranded algae are found. No reduced layer is present .

The beach is subjected to strong wave action, the fisrt waves breaking approximately 150-200m offshore and being 2-3m in height. There is a well developed surf zone including bars and throughs. The mean spring tidal range in Algoa Bay is 1,61 and the extreme range is 2,1m while the smallest neaps average 0,5m. Temperatures in the shallows have an annual range of 10-23°C (McLachlan *et al.,* 1979b). On a 20 point exposure rating system (McLachlan, 1980b), this beach rates 15,0, which classifies it as an exposed to very exposed beach.

Materials and Methods

The transects were taken along the Sundays River Beach, 10km, 20km and 28km from the river mouth. Each site was chosen to be representative of its part of the beach and, as far as possible, representative of the whole 40km stretch of coastline.

At each site measurements of the beach slope and width were taken along a transect line from the spring low water mark to the primary dunes. Along each transect, approximately 20-25 sampling sites were marked off at 3m intervals. A cylinder measuring $0{,}1m^2$ was inserted into the sand to a 20cm depth at each site and the sand within the cylinder was passed through a 1mm mesh sieve. The specimens remaining in the sieve were collected and kept in 10% formalin for later analysis.

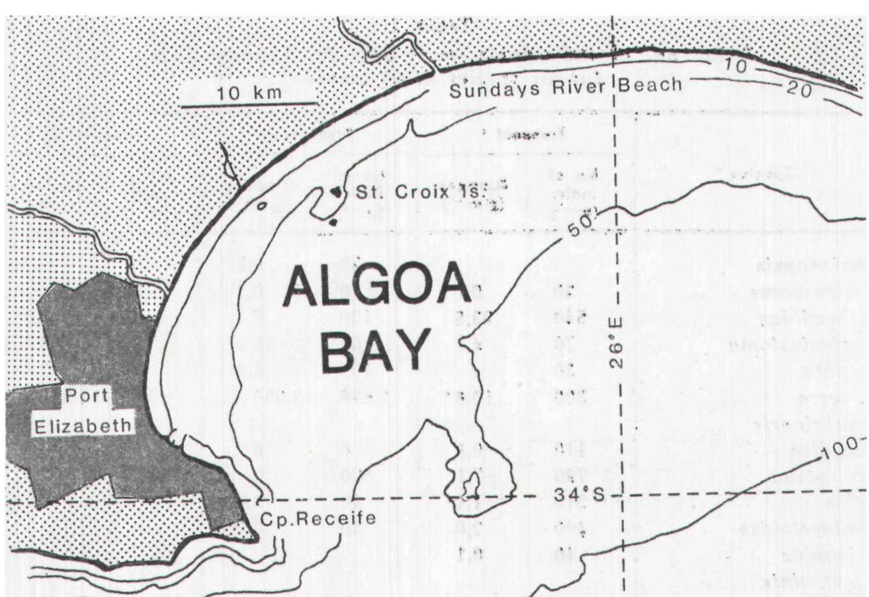


FIG. 1.
Map of Algoa Bay showing the Sundays River Beach.

The first samples were taken just after low tide starting at the spring low mark, moving progressively upwards to the primary dunes. The last sample was taken about 2 hours after low tide, thus compensating for the delay in the occurrence of low tide in the water table (Pollock and Hummon, 1971). At each sampling site surface sand moisture content was measured with the aid of a Speedy Moisture Tester (Thomas Ashwath, England). 1,5 to 3g of sediment, together with a measure of calcium carbide, is shaken in a cylinder and the gas pressure produced is measured. The pressure is proportional to the moisture content of the sediment and is expressed as a percentage (Hulings and Gray, 1971). By sand moisture content the amount of water in the sand is meant, whether it be gravitational, capillary, hygroscopic water or in the form of water vapour. The depth of the water table was measured down to 85cm. Below this depth it was considered to be too deep to affect the macrofauna.

All specimens were identified and the dry weight in each sample was determined by oven drying at 80° C for 24 hours after removal of mollusc shells.

The percentage similarity between sampling sites and transects was calculated using the Bray-Curtis coefficient (Field *et al.,* 1968).

$$C = \frac{2W}{A+B}$$

Where W represents the lesser measures of the species in common to both samples, A represents the total number of specimens in sample A, and B represents the total number of specimens in sample B. Dendograms were constructed using nearest neighbour clustering (Field *et al.,* 1968).

TABLE 1

Total no. of individuals (m^{-1}) and dry biomass ($g.m^{-1}$) for all species at all transects.

Species	Transect 1		Transect 2		Transect 3	
	No. of Indiv. (m^{-1})	Biomass	No. of Indiv. (m^{-1})	Biomass ($g.m^{-1}$)	No. of Indiv. (m^{-1})	Biomass ($g.m^{-1}$)
Gonindopsis			20	0,2	20	0,2g
Gastrosaccus	20	0,1	20	0,1	40	0,5
D. sordidus	540	22,6	120	7	40	2,3
B. rhodostoma	70	4,9	160	15,2	40	0,7
B. pura	30	4	100	4,6	40	0,6
D. serra	300	10,6*	1.520	2.006	1.230	860
Lumbrineris					40	0,6
Eurydice	110	0,5	0	0	100	0,3
Excirolana	790	7.1	320	5	770	2,3
Tylos	310	1.1	40	0,01	240	14,1
Pontogeloides	400	2.0	20	0,005		
Spionidae	40	0.1				
Sipunculate					101	0,1
TOTAL:	2 610	53.0g	2.390	2.039,522	2.560	881,7

* Low biomass value due to the small sizes of *D. serra* in Transect 1.

Results and Discussion

Biomass

Abundance and biomass per running meter of beach are shown in Table 1 for each transect. (The units m^{-1} are as used by previous authors eg. Griffiths, Stenton-Dozey and Koop, 1983). From this Table it can be seen that *Donax serra* makes up 40,2% of the total macrofauna on the beach. It makes up an even larger proportion of the fauna (96,7%) when looking at the biomass figures. This band of *D. serra* lowers the species diversity, but seems common to most exposed or semi-exposed Cape beaches (McLachlan, 1977a). The low biomass figures for *D. serra* in Transect 1 are due to the small size of the *D. serra* in the samples.

The number of species increases from the high water mark to the low water mark, indicating greater stability and more available niches at higher percentages of moisture due to less desiccation, smaller temperature ranges and increased feeding times (Fig. 2).

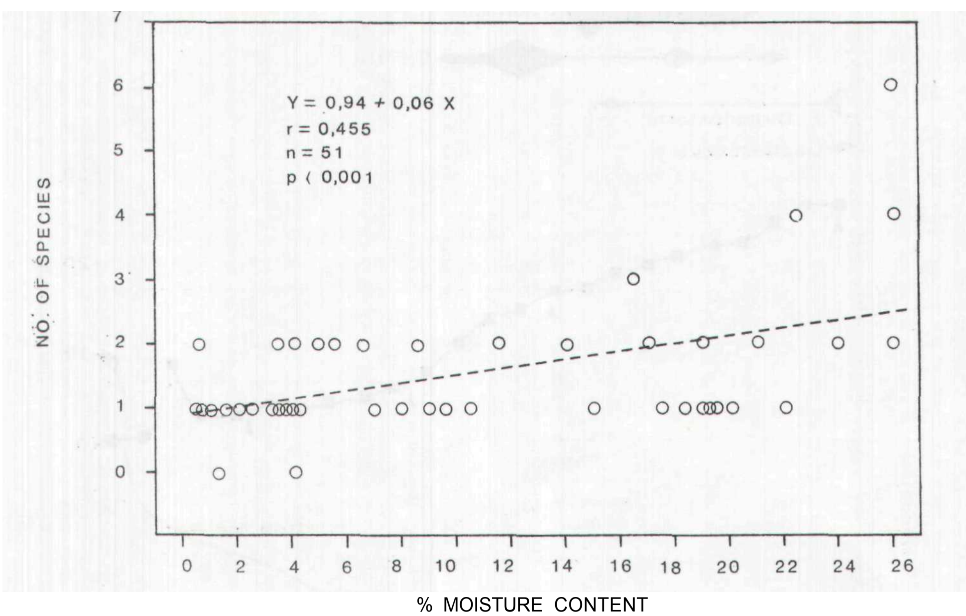


FIG. 2

Increasing no. **of** species with the increase in **%** moisture content.

Zonation

The distribution of species, moisture gradient, water table level, sampling points and profile of the beach can be seen in figs. 3, 4 and 5 for the three transects.

Figs. 3, 4 and 5 show that the moisture gradient in the sand ranges from 26% (saturated sand) at the low water mark and in the glassy layer to 1,0% or 0,5% above the drift line at the high water mark. In Transects 1 and 2 there was a steep rise in the moisture content at, or a few meters above, the drift line. This could be due to the retention of moisture as a result of a greater amount of organic matter deposited at the present drift line or a previous drift-line (as in Fig. 4).

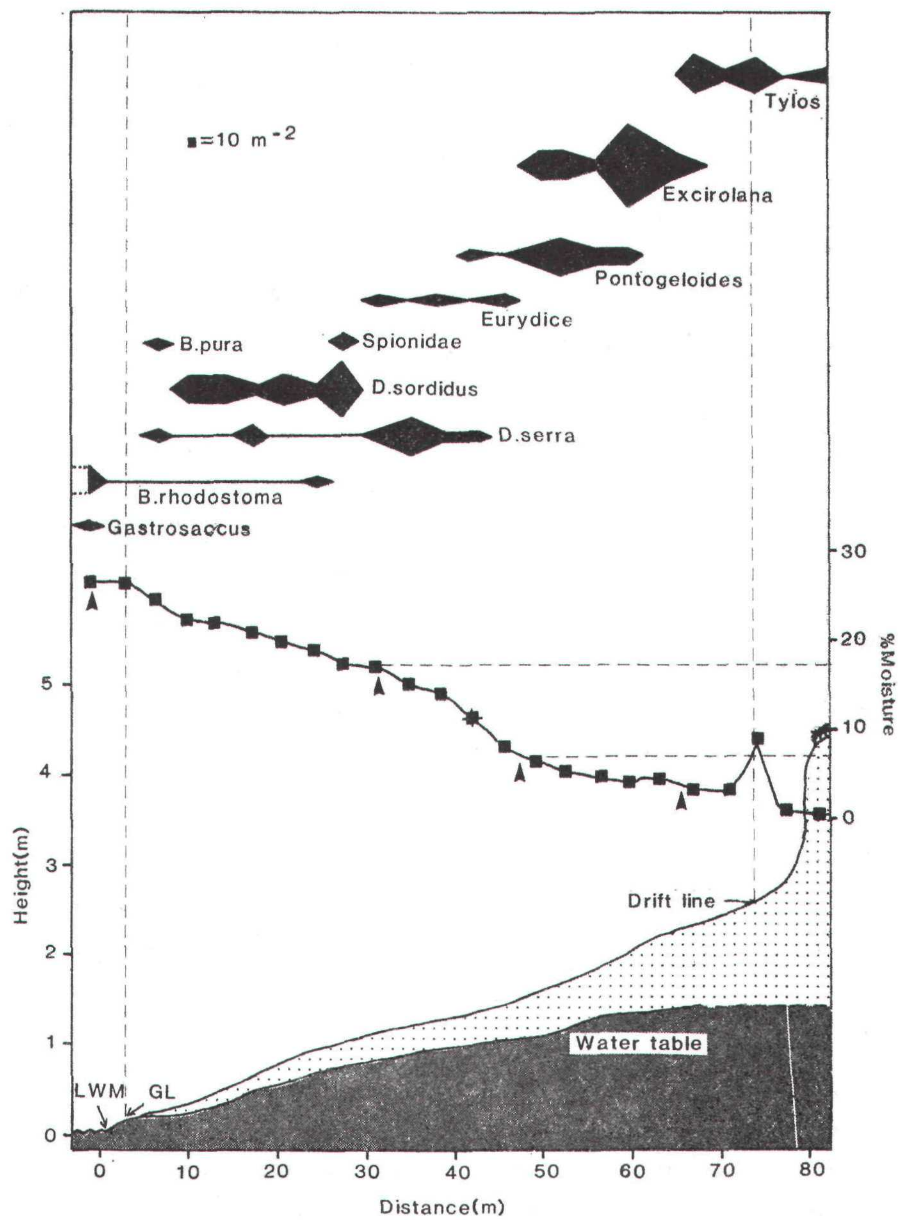
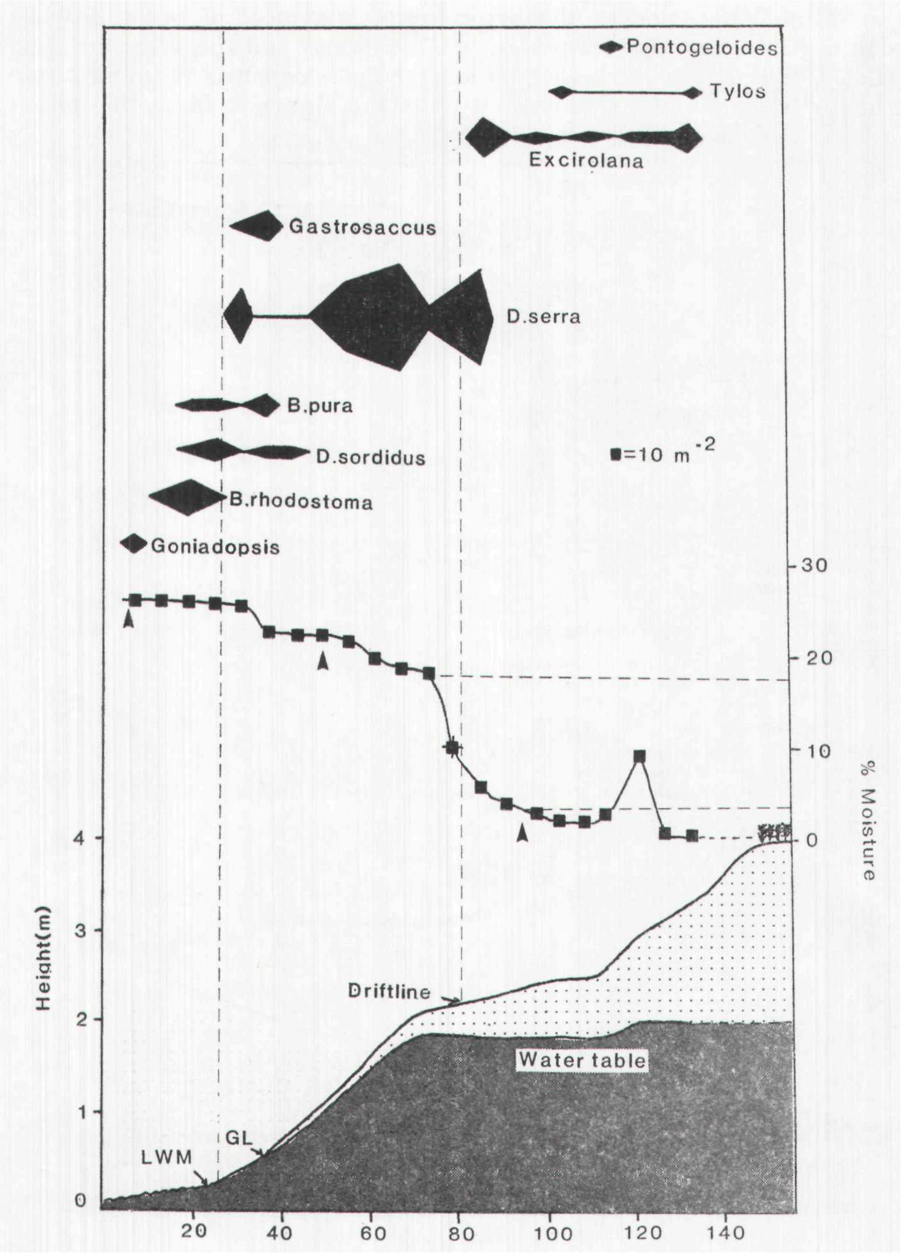


FIG. 3

Kite diagram of Transect 1 showing the water table, beach profile, moisture gradient and distribution of the macrofauna.

• — sampling point — ▪ — median of steep slope — GL — glassy layer — ** — *Scaevola thunberegii* — ⅄ zone division.

Transects 2 and 3, and to a lesser extent 1, show a steep decrease in substrate moisture content of approximately 11-14% over a distance of 15m. These steep decreases all fall between 4% to 18,5% moisture content and in each case the steep gradients correlate with the areas where the water table is situated between 30-50cm below the sand



Distance(m)

FIG. 4

Kite diagram of transect 2 showing the water table, beach profile, moisture gradient and distribution of the macrofauna (Legend as in fig. 3).

surface. In transect 2, the steep moisture gradient and the drift line fall together. The water table follows the profile of the beach fairly closely for approximately 40-100m and then stays at a constant height above sea-level. The horizontal distance from the low water mark, to where the water table maintains this constant height above sea-level depends upon the width and slope of the beach.

The distribution of the macrofauna is typical of other beaches of the Eastern Cape (McLachlan, 1977a ,1980a) and the Western Cape (Bally, 1981). The air breathing isopod *Tylos capensis* is found above the drift line and extends well into the dunes behind the beach

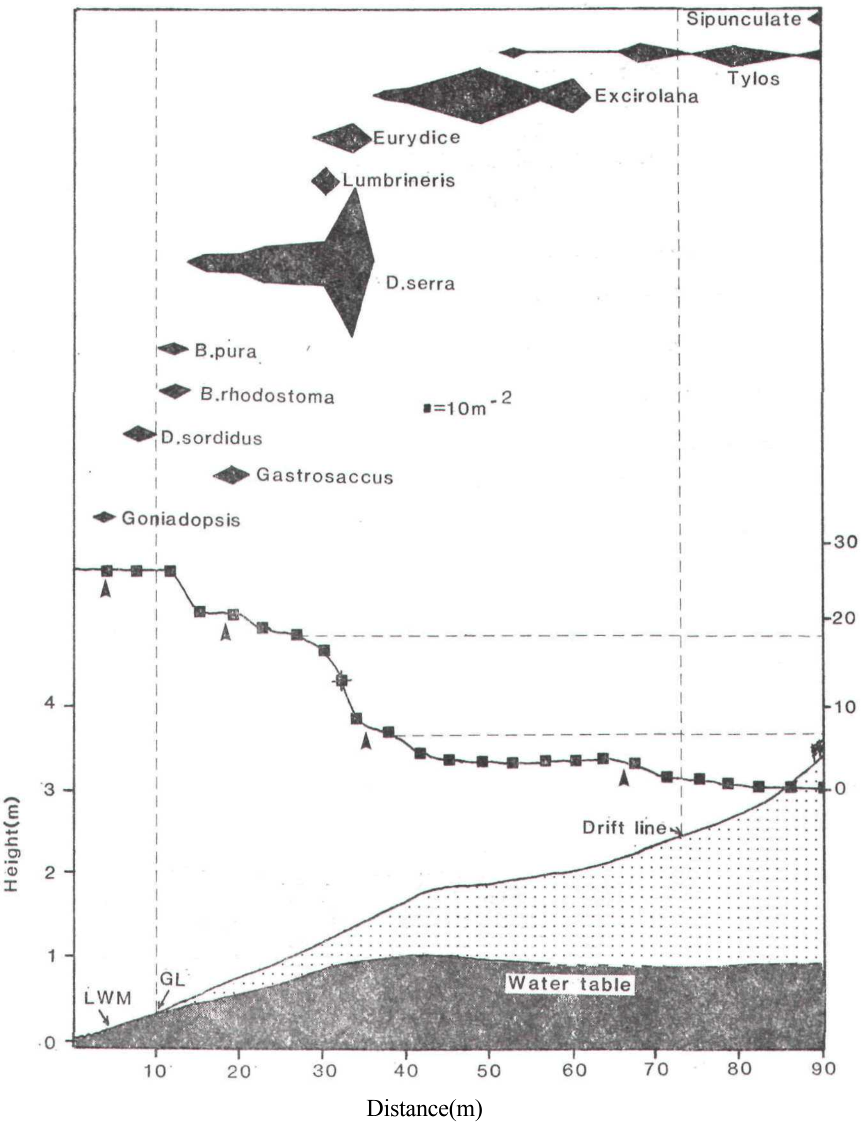
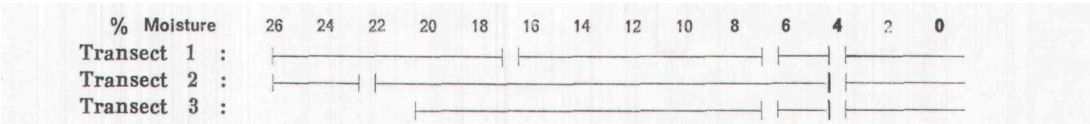


FIG. 5

Kite diagram of transect 3 showing the water table, beach profile, moisture gradient and distribution of the macrofauna (Legend as in fig. 3).

(McLachlan *et al.,* 1981). The water breathing isopods *Excirolana natalensis* and *Pontogeloides latipes* are also found close to, or above the drift line. The isopod *Eurydice longicornis,* the clam *Donax serra* and the polychaete *Lumbrineris tetraura* are found lower down on the shore, usually in the region of the steep moisture gradient mentioned above. Species such as the mysid *Gastrosaccus psammodytes* the polychaete *Goniadopsis incerta,* the clam, *Donax sordidus* and the two whelks, *Bullia rhodostoma* and *B. pura,* are found at or near, the low water mark. It can be clearly seen that the isopods occupy the top, dryer zones of the beach, while the molluscs become more important below the mid-tide mark.

Dendograms showing similarities between sites and possible zonation are given in fig. 6. At the 37% similarity levels, Transects 1 and 3 yield two distinct groups while Transect 2 yields three groups. At the 45% similarity level the larger groups of Transects 1 and 3 yield more groups. Transect 1 can be divided into four groups and Transect 3 into three groups. From the percentage substrate moisture contents at these dividing points, the following scheme can be drawn up:



The division at approximately the 4% moisture content point coincides in all three transects and is fairly close to the drift line in each case. The division at the 7% moisture content point coincides in Transects 1 and 3, which corresponds to the bottom of the steep moisture gradient mentioned earlier. This division does not appear

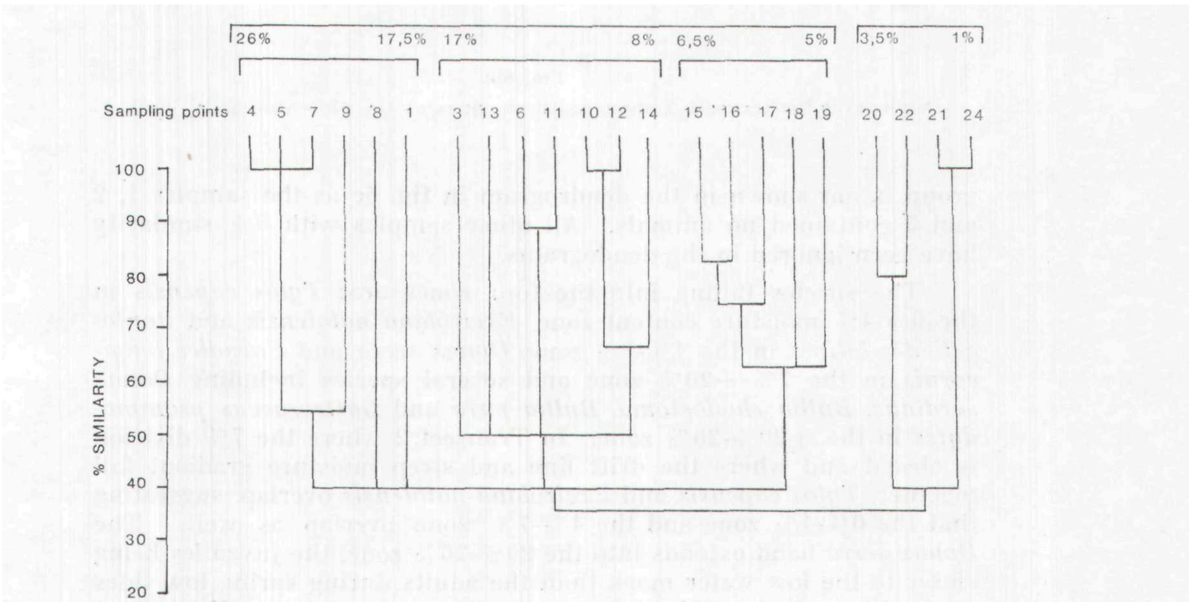


FIG. 6a
Dendogram for **transect 1 showing four z**ones at the 45% similarity level.

in Transect 2 but, in this case, the drift line and the bottom of the gradient fall together, the 4% division point being at the bottom of the gradient. The third division points do not coincide on the three transects but are spread over a range of 17% to 22,5% moisture content. However, each of these three points correspond to the top of the steep moisture gradient. The fourth zone in Transects 1 and 3 and the third zone in Transect 2 extend as far as, or even further than, the saturated sand with a moisture content of 26%. This

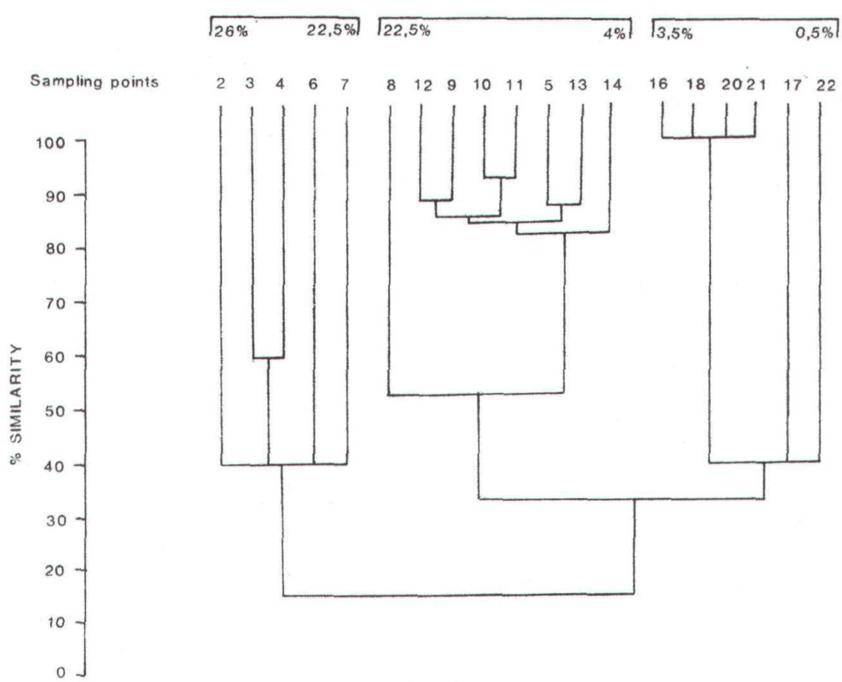


Fig. 6b

Dendogram for transect 2 showing three zones at the 45% similarity level.

group is not shown in the dendrogram in fig. 6c as the samples 1, 2 and 3 contained no animals. All other samples with 0% similarity have been ignored in the dendograms.

The species falling into the four zones are: *Tylos capensis* in the 0%-4% moisture content zone, *Excirolana natalensis* and *Pontogeloides latipes* in the 4%-7% zone, *Donax serra* and *Eurydice longicornis* in the 7%-+20% zone and several species including *Donax sordidus, Bullia rhodostoma, Bullia pura* and *Gastrosaccus psammodytes* in the +20%-26% zone. In Transect 2 where the 7% division is absent and where the drift line and steep moisture gradient fall together, *Tylos capensis* and *Excirolana natalensis* overlap, suggesting that the 0%-4% zone and the 4%-7% zone overlap as well. The *Donax serra* band extends into the 20%-26% zone, the juveniles being closer to the low water mark than the adults during spring low tides (McLachlan *et al.,* 1979a) ,this being the reverse of the West Coast distribution. The 0% to 4% zone corresponds to the air breathers zone of Brown and to the subterrestrial fringe of Dahl. The 4% to 7% zone together with the 7% to 20% zone correspond to the midlittoral zone and the 20%-26% zone corresponds to the sublittoral fringe of Dahl (1952).

Bally (1983) describes beaches of the Western Cape in terms of Salvat's (1964) zonation scheme. He divides them into fine-grained beaches and coarse-grained beaches. Bally's zones of the coarse-grained beaches correspond closely to the above zonation. Two minor

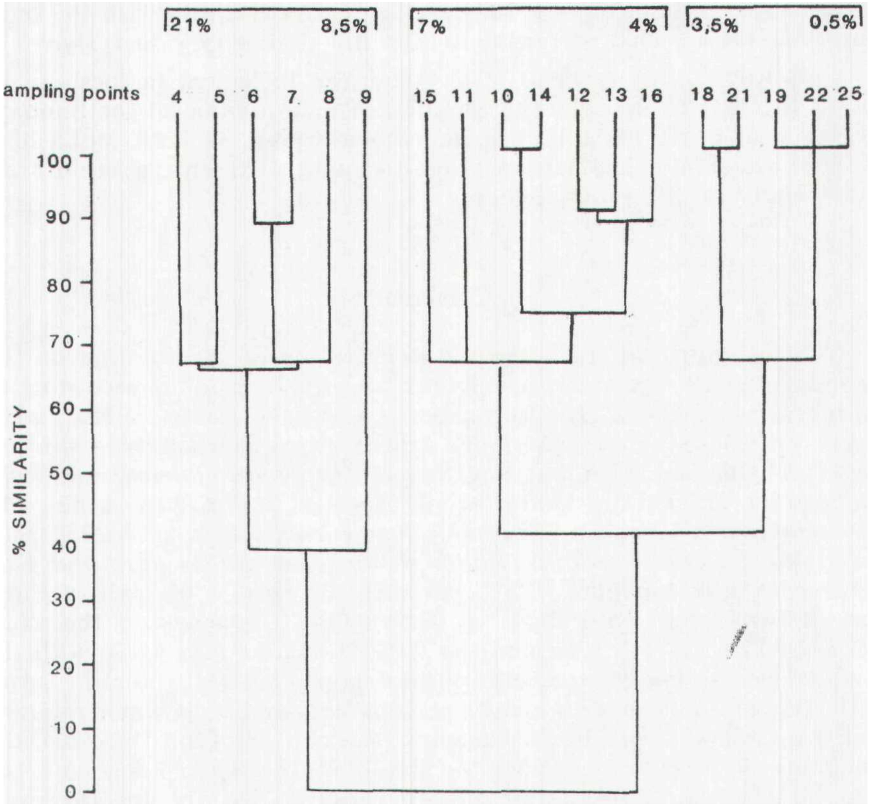


FIG. 6C

Dendogram for transect 3 showing three zones at the 45% similarity level.

differences are that, in the zone of drying *Tylos capensis* is replaced by *Tylos granulatus* and *Talorchestia* spp., and *Eurydice longicornis* extends to the zone of retention. Otherwise the zone of retention corresponds biologically to the 4%-7% zone, the zone of resurgence corresponds biologically to the 7%-20% zone and the zone of saturation to the 20%-26% zone. The 0%-4% zone corresponds to the dry zone. It must be emphasized that the correlation is biological and not physical as Salvat did not measure the percentages of substrate pore moisture for his zonation scheme, he described the various zones characterized by water conditions, and the two schemes can thus not be directly compared. The zonation of Bally's fine-grained beaches does not correspond as closely to the above zonation scheme.

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The percentage similarities between the whole transects were also calculated using the Bray-Curtis measure. The similarity between Transects 2 and 3 is the highest at 65,5%, between Transects 1 and 3 the similarity is 59,4% and between Transects 1 and 2 the similarity is 40,7%.

The high value between Transects 2 and 3 is partially due to the great number of *Donax serra* in these two transects. Transect 1 had relatively few *Donax serra,* followed by Transect 2 and with the most in Transect 3. This corresponds with the similarity values above.

It would thus seem as if physical and biological factors can be used together to describe the zonation of macrofauna on the Sundays River beach. It must be remembered however, as both McLachlan (1983) and Bally (1981) have suggested, that different zonation schemes apply to different beaches.

Conclusions

It appears that the intertidal distribution of macrofauna on the Syndays River beach can be divided up into four zones according to a moisture gradient. The four zones would be a 0%-4% surface sand moisture content zone with *Tylos capensis* as a characteristic species; a 4%-7% moisture content zone with *Excirolana natalensis* and *Pontogeloides laticeps* as characteristic species; a 7%-20% zone with species *Donax serra* and *Eurydice longicornis* and a 20%-26% zone containing *Donax sordidus, Bullia rhodostoma, Bullía pura* and *Gastrosaccus psammodytes.* The characteristic species of each of these zones correspond with those of Bally's (1983) beaches on the West Coast. The 0%-4% zone and the 20%-26% zone also agree with the subterrestrial fringe and sublittoral fringe of Dahl (1952). Salvat (1964) bases his zones on factors such as the amount of water retained in the sand at low tide, the amount of water reaching the zone, the amount of water circulation, the depth of the water table and the method in which gravitational water is lost. He did not, however, measure the percentage moisture content in the substrate. The only comparison between the two schemes would then be the characteristic species of each zone as given by Bally (1983).

None of these zones have sharp boundaries, a common characteristic of all sandy beach zonation schemes. The 0%-4% zone varies from 0%-l% to 3,5%-5,5%, the 4% to 7% varies between 3,5%-5,5% and the 7%-20% zone between 6,5%-8,5% and 17%-22,5% sand moisture content. These zones do, however, correlate with Salvat's zonation scheme. Both biological and physical factors determine the zones and it would thus seem as if Salvat's zonation scheme, based on physical factors, and Dahl's scheme, based on biological factors, can be brought together to describe the division of the Sundays River beach into four zones.

The zones and the moisture in the zones may change considerably with the seasons and with neap tides. The time of day, whether it is night or day, and the tide might also affect the zones as a result of their effect on the moisture gradient.

The abundance and biomass values reported here are as expected for the beach (McLachlan, pers. comm.) and the species composition agrees with that obtained in previous surveys (McLachlan, 1977b).

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Summary

The intertidal macrofauna was sampled along three transect lines on a high energy sandy beach in South Africa. 20-25 Sampling points were marked off along each transect and the water table depth and sand moisture contents were measured at each point.

The distribution of the macrofauna shows some correlation with the sand moisture gradient. Four zones manifest themselves at surface sand moisture percentages of 0%-4%, 4%-7%, 7%-20% and 20 to 26%. The characteristic species falling into each zone are *Tylos capensis* in the 0%-4% moisture content zone. *Excirolana natalensis* and *Pontogeloides ¡atipes* in the 4%-7% zone, *Donax serra* and *Eurydice longicornis* in the 7%-20% zone and *Donax sordidus, Bullia rhodostoma, B. pura* and *Gastrosaccus psammodytes* in the 20%-26% zone.

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