STUDIES ON THE PSAMMOLITTORAL MEIOFAUNA OF ALGOA BAY, SOUTH AFRICA

I. PHYSICAL AND CHEMICAL EVALUATION OF THE BEACHES

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ABSTRACT

As a precursor to a study of the psammolittoral meiofauna of Algoa Bay, the important physical and chemical features of the beaches have been quantified. A sheltered and an exposed beach were selected. It has been found that the sheltered beach has a finer substrate, greater porosity and more chlorophyll *a* than the exposed beach. However, owing to the smaller sizes of the interstices, the sands of the sheltered beach have a slower drainage, a lower oxygen availibility in the interstitial water and shallower water tables than the sands of the exposed beach.

INTRODUCTION

This study on the meiofauna of Algoa Bay (on the south-eastern corner of Africa) forms part of a larger programme which was started at the University of Port Elizabeth and aimed at elucidating the overall structure and function of the Algoa Bay ecosystem. As the shores of the bay are mainly beaches, it was decided to commence the studies in the psammolittoral regions and it was felt that a logical starting point would be a quantitative, temporal study of the meiofauna inhabiting both sheltered and exposed beaches.

This paper, the first in a series of three, contains a physical and chemical description of the beaches and is to be followed by papers on the composition, distribution and biomass of the meiofauna, and analyses of the dominant meiofauna communities.

DESCRIPTION OF STUDY AREA

Algoa Bay lies on the south-eastern corner of Africa near the parallels 34°S and 26°E (Figure 1). The bay is 60 km across its mouth and its 90 km coastline includes 80 km of sandy beaches. Two large rivers, the Swartkops and Sundays rivers, have estuaries opening into the bay. The harbour of Port Elizabeth is situated near the south-eastern corner of the bay.

The prevailing weather and seas enter the bay predominantly from the west and south; the south-western area of the bay lies relatively sheltered behind the mainland of Cape Receife.

Progressing eastwards the beaches become more exposed. A wave-rose for Cape St Francis, 50 km south-west of Algoa Bay, and a wind-rose for Port Elizabeth, both taken from Hanekom (1975) have been included in Figure 1 for comparison. Although the wind blows predominantly from the west and south-west the waves enter Algoa Bay from the south. In the region of Port Elizabeth the wind thus generally tends to antagonize wave action while along the northern shore of the bay the waves are supplemented by the wind (Hanekom 1975). A sheltered and an exposed beach were selected for the study. The two sites were Kings Beach (33°58'S/25°39'E) and Sundays River Beach (33°43'S/25°53'E) respectively (Figure 1). Hanekom (1975), in rating the beaches of Algoa Bay on a scale from 1 to 5 of increasing exposure, gave these two beaches values of 1 and 4 respectively.

Kings Beach is the main bathing beach of Port Elizabeth and extends 1,5 km south-east from the harbour. Near the harbour, pollution by manganese and iron ore dust is visible, but where samples were taken in the centre of the beach there was no visible pollution. Above the high-water mark this beach has a slight berm, sloping gently into a depression 100 m wide. This depression is sometimes filled with water to form a tidal pool after rough seas at spring high tides. Above this tidal pool are some low sand dunes.

The sampling site on Sundays River beach lies 2 km east of the river mouth and during the study period was free from any visible signs of pollution. It has no berm and some 10 m beyond the high water mark it rises into dunes 10 m high. Neither of these beaches has any permanent bar though submerged sand banks occasionally form close inshore.

The two beaches have been compared by evaluation of the following abiotic factors: beach slope and water table depth; substrate particle size; porosity and desiccation of the sand during spring low tide; chlorophyll *a* content of the sand; salinity and oxygen content of the interstitial water and sand and sea temperature. Chlorophyll *a* was selected as an indicator of available food because of the difficulty in measuring organic matter on these beaches. No measurement of interstitial pH was made as the relevance of this to meiofauna is not well known (Hulings & Gray 1971). Further, no attempt was made to measure the thixotropy or dilatancy of the Kings Beach or Sundays River sands as this is of importance mainly to the macrofauna (Chapman 1949).

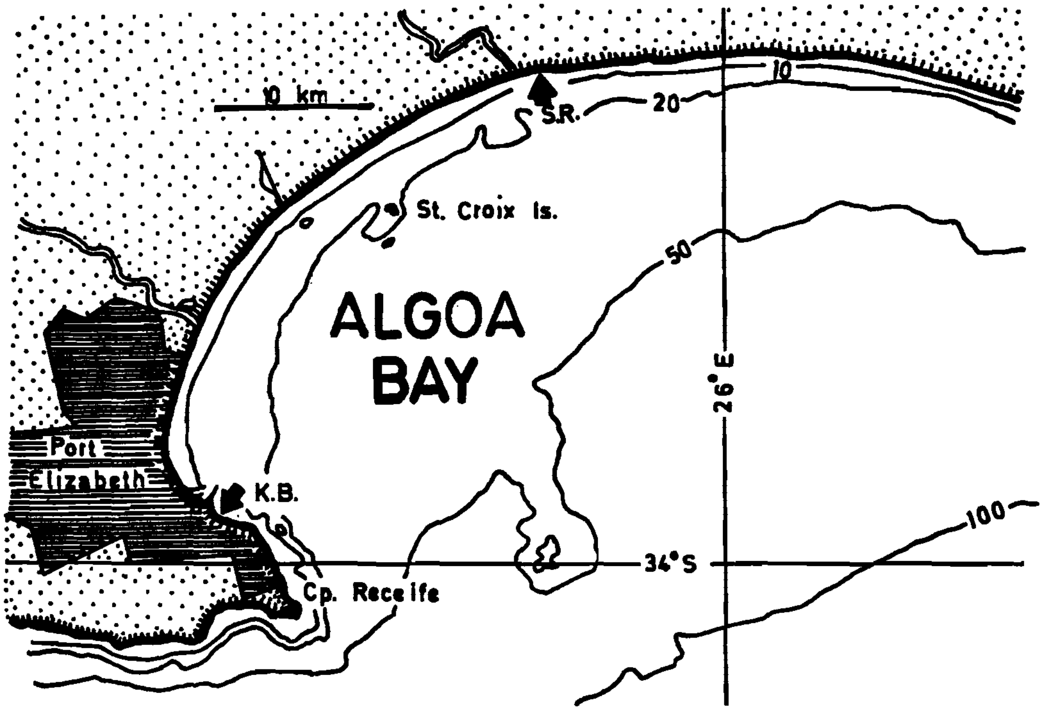
METHODS

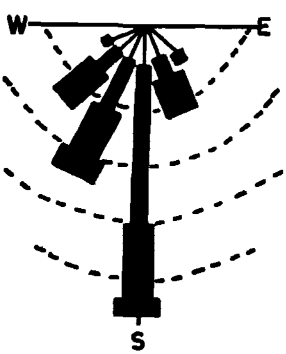
Beach slopes

Following the method of Day (1969) the profiles of the two beaches were plotted on three occasions over a period of a year. The mean spring tide range in Algoa Bay is 1,61 m and the extreme range approximately 2,1 m (data from the Port Elizabeth Harbour). The height above

FIGURE 1

Map of Algoa Bay showing depth contours (m) and the King's Beach (K.B.) and Sundays River (S.R.) sampling stations. Wave-rose compiled by Hanekom (1975) from data collected by the Cape St Francis Lighthouse-keeper between 1967 and 1972. Wave direction is shown by compass points, wave height by the relative thickness of the lines and the percentage of the time that waves came from each direction (average over 6 years) is shown by the number of 10% arcs crossed. Wind-rose also compiled by Hanekom (1975) from wind data gathered at the Port Elizabeth airport during the years 1936 to 1941.





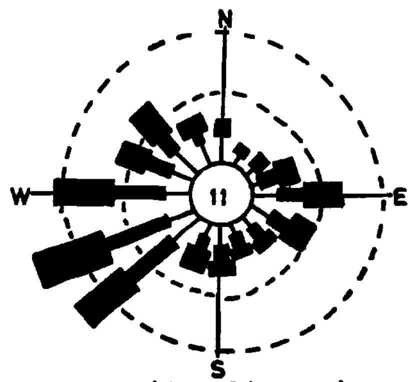
WAVE ROSE (Cp. St. Francis)

Key:

0 - 0,9 1,0 - 1,9 2,0 - 2,9 3+

Wave Heigh (m)

Arcs Represent 10 % Intervals



WIND ROSE (Port Elizabeth)

Key:

08 -13 14 - 24 25 - 61 62+

Wind Strength (km)

Arcs Represent 5% Intervals

(Percentage of calm within circle)

LWS that was surveyed was approximately 2,5 m in all cases and within this range three levels were selected to represent the low, mid and high tide levels. For practical purposes the lowest level taken was 0,3 m above LWS. The mid and high tide levels were 1,0 m and 1,9 m above LWS respectively. These three levels will henceforth be referred to as LW, MW and HW respectively.

Sampling

Care was taken throughout the programme to avoid taking any samples during or shortly after rain or storms as this might have markedly affected the beaches (Brown 1971).

For analysis of the physical properties of the sand, four vertical sets of cores were taken at each tide level on both beaches during spring low tides. A stainless-steel, hand-operated corer was used. This corer took samples with a cross-sectional area of 10 cm^2 and a length of 30 cm. These dimensions were selected for their convenience relative to both surface area calculations and the size of the core. Each 30 cm core was bisected into two 15 cm cores and the four cores at each tide level and depth were combined to form a duplicate pair of mixed cores. Cores deeper than 30 cm in the sand were taken by digging steps (Hulings & Gray 1971). Thus at each tide level a vertical series of 15 cm cores could be collected from as deep as practically possible.

The vertical depths sampled in the substrate were 45 cm, 60 cm and 90 cm at LW, MW and HW respectively. On Kings Beach the maximum depth that could be sampled depended on the depth of the water table. Because of the soft, liquid nature of the sand below the water table it could not be dug away to any great depth. Therefore the higher the tide level and the deeper the hole that had to be excavated to reach the water table the less was the depth of penetration through the water table. Thus samples extended 43 cm below the water table at LW, 48 cm at MW and 28 cm at HW on Kings Beach. Although samples could have been taken deeper at Sundays River owing to the greater depth of the water table there, it was decided to keep to the same depths as Kings Beach for easier comparison of results.

Water tables

The water table levels were measured at every time of sampling during spring low tides. This was done by measuring the depth below the sand surface of the pools of water that formed in the holes excavated for sampling.

Substrate particle size.

Sand samples of 50 g were analysed for particle size following the method of wet sieving and using sieves whose mesh corresponded to the Wentworth scale. The results were analysed by plotting phi-cumulative curves (Morgans 1956).

Porosity

The amount of water held by the sand at saturation, *i.e.* the porosity, was determined by placing approximately 30 g of sand in a measuring cylinder and adding just enough water to cover it. The cylinder was then gently tapped for two minutes, the excess water drained off for 20 seconds and the sample weighed. This was done at laboratory temperatures of 20–25°C.

After oven-drying at 105°C for 24 hours the sample was reweighed and the loss in mass expressed as a percentage of the original wet mass. This may be considered to represent the porosity (Webb 1958).

Desiccation of the sand

The degree of desiccation of the sand at the time of spring low tide was determined as follows: substrate samples collected as described under 'sampling' were sealed in air-tight glass jars and transported to the laboratory within 1,5 hours. Each sample was then thoroughly mixed and a subsample removed and weighed in a preweighed crucible. After oven-drying at 105°C for 24 hours the sample was reweighed. The percentage loss in mass on drying was then calculated as a percentage of the porosity determined above. This gave the percentage saturation of the sand during spring low tide. The degree of desiccation of the sand would no doubt vary under different conditions of temperature and wind, but for comparison of the beaches it was felt that a single series of determinations done on a warm day would give a good indication of the maximum desiccation.

Chlorophyll a

Samples collected in January 1975 were analysed for chlorophyll *a* following the method outlined in Hulings & Gray (1971). This was done in order to obtain an idea of the amounts of available food in the sand. Methods of organic matter analysis (*e.g.* Walkley & Black method in Morgans 1956) had been tested and found to be less sensitive than the above method for chlorophyll *a* determination. This has been verified by Brown (1971) who found that the Walkley & Black method was too insensitive for the small amounts of organic matter found on Cape beaches. For this analysis subsamples of 5 g and 10 g of oven-dried sand were used. This was done only once in order to compare the different levels and beaches. Owing to the large differences found and the nature of this study, seasonal variations in chlorophyll *a* were not taken into account.

Interstitial water analysis

Interstitial water samples were collected by syringe using 30 cm long, 18-gauge, stainless-steel needles. These needles were sealed at the tips but had eight 70-μm pores bored in the sides near the tips (Thum pers. comm.). Disposable plastic syringes that could be sealed with plastic caps were used. These syringes were selected for easy handling but had the disadvantage of being slightly permeable to oxygen and consequently were standardised against glass syringes and corrected for oxygen diffusion. In no case was a correction of more than 5 per cent necessary. All samples were analysed within two hours of collection.

Salinities were determined on a freezing-point osmometer accurate to 1 mOsm (0,03‰) and converted to parts per thousand after standardisation with chloride titrations. This was done on two occasions for each beach (10.6.74 and 17.12.74 for Kings Beach and 6.7.74 and 17.12.74 for Sundays River) as well as just after fairly heavy rain on Kings Beach (22.2.74). Owing to distance and the fact that rain never coincided with sampling trips, interstitial salinities at Sundays River were never recorded after or during rain.

The oxygen content of the interstitial water was measured on a 'Radiometer Copenhagen

Acid-Base Analyser' and was converted to percentage saturation. The temperature and salinity values necessary for this were taken at the time of collection. This was done only once, during January 1975.

Temperatures

Temperatures were monitored at regular intervals over a period of a year (January 1974 – January 1975), by means of a portable thermistor which was calibrated by a mercury thermometer accurate to 0,1°C. Temperatures were read at depth intervals of 30 cm in the sand, the shallowest reading being taken at 1 cm beneath the sand surface. At LW, however, it was taken at 1 cm, 30 cm and 45 cm. Many more temperatures were taken at Kings Beach HW than at other stations as three-weekly samples for mystacocarids were being taken there. Sea temperatures were read in the shallows (0,5 m deep) on each occasion.

RESULTS

Beach slopes

The results of the three beach surveys are shown in Figure 2. Included in this figure are the HW, MW and LW sampling levels as well as an index of the levels of the water tables during spring low tides.

From the beach slopes it can be calculated that the gradient on Kings Beach varied between 1/24 and 1/27 while that of Sundays River varied between 1/32 and 1/36. Not only was Kings Beach steeper, but the gradient between MW and HW (mean = 1/15) was more than twice as steep as that between MW and LW (mean = 1/36). The slope on Sundays River was more uniform (MW to HW mean = 1/24; MW to LW mean = 1/40), the upper gradient being slightly less than twice as steep as the lower one. Whereas Sundays River continues this slope right up to the dunes, Kings Beach flattens out above HW to form a shallow tidal pool. The intertidal region of both beaches shows a concave shape as is common for Cape beaches (Brown 1971). The slopes were relatively stable and no drastic changes in gradient occurred as were reported by Brown (1971) to occur during storms.

Water tables

Water table levels are shown in Figure 2. The depths are actually at their lowest some time after low tide (Emery & Foster 1948) but these values are close to maximum. Water tables at Kings Beach are considerably shallower than at Sundays River.

Substrate particle size

Results of the sand particle analysis are shown in Table 1. Here the results have been tabulated as prescribed by Morgans (1956) and expressed in terms of phi-units (McManus 1963). In calculating the means for the different tide levels, however, median particle diameters (Md) have been expressed in both phi-units (ϕ) and μm.

It can be seen that except for some of the MW and LW samples taken at Sundays River all of the median particle diameters fall in the range of fine sand (ϕ = 2–3 or 250–125 μm).

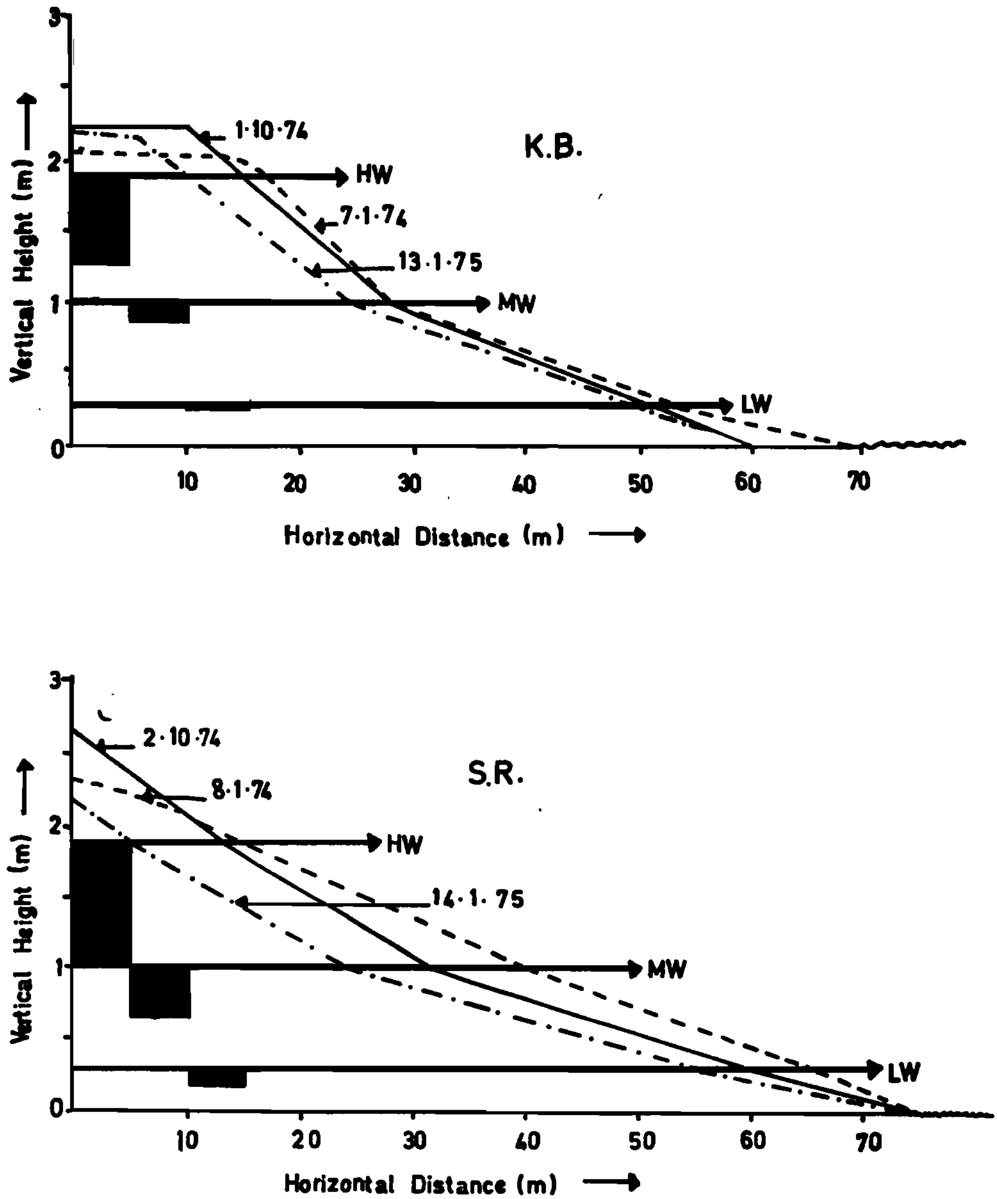


FIGURE 2

Beach slopes on three occasions, sampling levels and mean water table depths (solid bars) during spring low tides at Kings Beach and Sundays River. The length of the solid bars below the horizontal lines indicates the depth of the water table at each sampling level.

The Sundays River MW 45–60 cm and LW 15–30 cm and 30–45 cm samples are coarser, falling in the range of medium sand (ϕ = 1–2 or 500–250 μm) on the Wentworth scale. The Sundays River sands in general are coarser than those of Kings Beach having median particle diameters of 223–266 μm as opposed to 200–218 μm for the different tidal levels. On both beaches there was a clear tendency for the finest sand to occur near HW and the coarsest towards LW.

All phi-quartile deviation values (QD ϕ) obtained from the cumulative curves are relatively low, indicating good sorting and a high percentage of the substrate particles falling within a

TABLE 1

Results of particle analysis of substrata from Kings Beach and Sundays River. All values in phi-units except where stated in μm. See text for explanation of terms.

Station and Depth (cm)	*Md ϕ*	*QD ϕ*	*Sk ϕ*	*Grade:*	*Station Mean*
KINGS BEACH					
HW 0–15	2,30	0,25	0,00	Fine sand	
HW 15–30	2,35	0,33	+ 0,03	Fine sand	
HW 30–45	2,35	0,30	0,00	Fine sand	Md = 2,33 ϕ
HW 45–60	2,35	0,25	0,00	Fine sand	= 200 μm
HW 60–75	2,35	0,25	+ 0,02	Fine sand	
HW 75–90	2,30	0,32	+ 0,02	Fine sand	
MW 0–15	2,50	0,15	0,00	Fine sand	
MW 15–30	2,25	0,20	0,00	Fine sand	Md = 2,30 ϕ
MW 30–45	2,25	0,20	0,00	Fine sand	= 204 μm
MW 45–60	2,20	0,18	+ 0,03	Fine sand	
LW 0–15	2,20	0,15	0,00	Fine sand	
LW 15–30	2,15	0,18	− 0,03	Fine sand	Md = 2,20 ϕ
LW 30–45	2,25	0,20	0,00	Fine sand	= 218 μm
SUNDAYS RIVER					
HW 0–15	2,35	0,20	0,00	Fine sand	
HW 15–30	2,20	0,20	0,00	Fine sand	
HW 30–45	2,10	0,20	0,00	Fine sand	Md = 2,17 ϕ
HW 45–60	2,00	0,22	+ 0,03	Fine sand	= 223 μm
HW 60–75	2,25	0,23	− 0,03	Fine sand	
HW 75–90	2,10	0,25	0,00	Fine sand	
MW 0–15	2,10	0,22	+ 0,03	Fine sand	
MW 15–30	2,05	0,37	− 0,03	Fine sand	Md = 1,90 ϕ
MW 30–45	2,00	0,36	+ 0,01	Fine sand	= 266 μm
MW 45–60	1,45	0,45	0,00	Medium sand	
LW 0–15	1,95	0,40	+ 0,03	Medium sand	
LW 15–30	1,90	0,37	− 0,03	Medium sand	Md = 1,95 ϕ
LW 30–45	2,00	0,42	− 0,03	Fine sand	= 260 μm

narrow range around the median, *i.e.* 75 per cent of the particles fall within 0,25 ϕ on either side of the median in most cases. This sorting is best at Kings Beach LW and lowest at Sundays River MW. Phi-quartile skewness values (Sk ϕ) are extremely low, indicating equal sorting of particles both larger and smaller than the median.

Porosity and desiccation of the sand

Table 2 lists the porosity values of all the tide levels and depths that were sampled. Included in Table 2 is the percentage saturation of the sand during spring low tide on a warm day.

The percentage saturation of these sands during spring low tide is also shown in Figure 3. Kings Beach sands have greater porosities (20–29 per cent) than Sundays River sands (17–22 per cent) but retain much more water when the tide goes out. In fact, the sand at Sundays River MW has approximately the same percentage saturation as that at Kings Beach HW during spring low tide (Table 2). This indicates a greater permeability and drainage at Sundays River than on Kings Beach.

Chlorophyll a

The results of the chlorophyll *a* analyses of the substrata are given in Table 3.

This reveals much higher chlorophyll *a* values at Kings Beach than Sundays River and in fact all of the Sundays River values fall below the limit of sensitivity of the method used (0,2 mg chl *a*/kg dry sand). Kings Beach chlorophyll *a* values reached a peak around HW 45–60

TABLE 2

Porosities of Kings Beach (KB) and Sundays River (SR) sands and the percentage saturation of the same sands during spring low tide. All values calculated on a mass/mass basis and expressed as percentages.

Station and Depth (cm)	*Porosity*	*% Saturation*	*Station and Depth (cm)*	*Porosity*	*% Saturation*
KB; HW 0–15	20	46	SR; HW 0–15	19	29
KB; HW 15–30	21	82	SR; HW 15–30	20	34
KB; HW 30–45	21	85	SR; HW 30–45	19	66
KB; HW 45–60	21	97	SR; HW 45–60	20	73
KB; HW 60–75	20	100	SR; HW 60–75	17	90
KB; HW 75–90	25	100	SR; HW 75–90	17	98
KB; MW 0–15	25	100	SR; HW 0–15	20	55
KB; MW 15–30	25	100	SR; HW 15–30	21	85
KB; MW 30–45	25	100	SR; HW 30–45	19	96
KB; MW 45–60	26	100	SR; HW 45–60	20	100
KB; LW 0–15	24	100	SR; HW 0–15	18	98
KB; LW 15–30	27	100	SR; HW 15–30	21	100
KB; LW 30–45	29	100	SR; HW 30–45	22	100

cm and again at LW 0–30 cm. The MW values are somewhat lower. Although the Sundays River values are very low they nevertheless tend to be highest in the upper 30 cm at MW and LW.

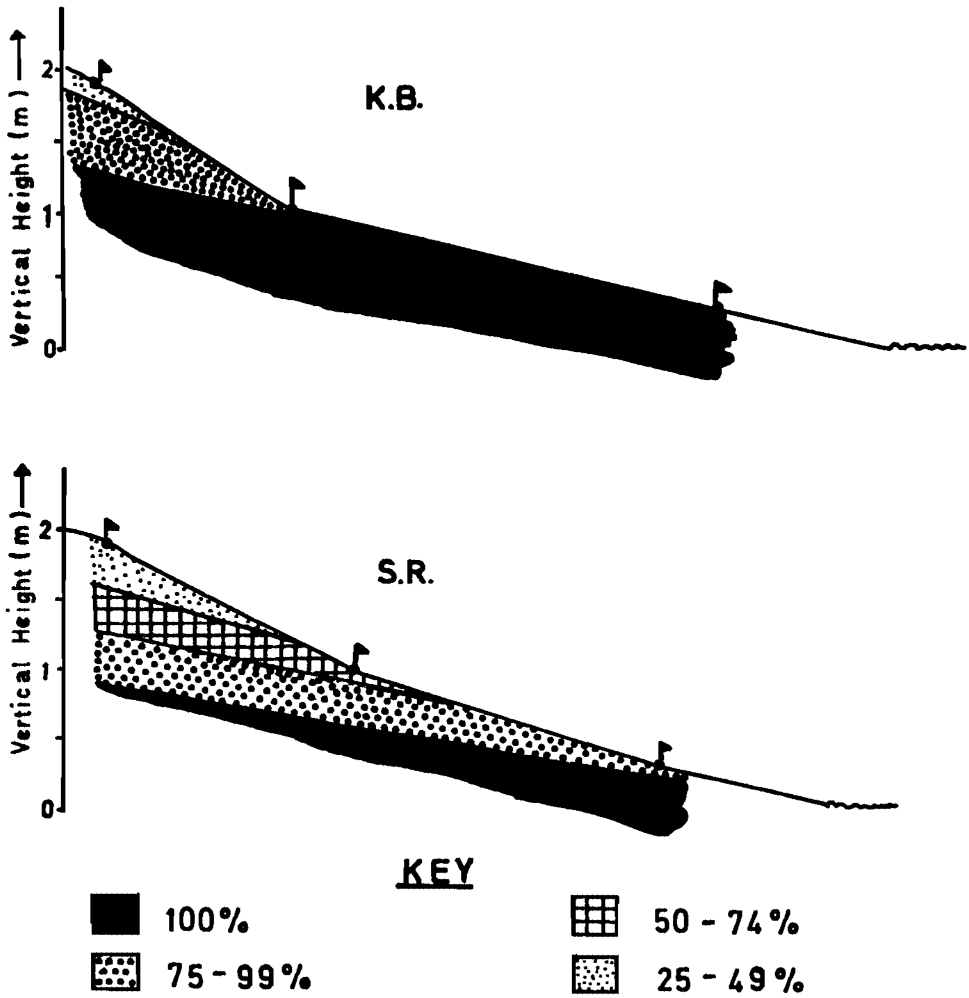


FIGURE 3

Percentage water saturation of the sand during spring low tide at Kings Beach and Sundays River. Flags indicate LW, MW and HW sampling levels.

TABLE 3

Chlorophyll *a* content of the Kings Beach (KB) and Sundays River (SR) sands during January 1975.

Station and Depth (cm)	*mg chl. a/kg dry sand*	*Station and Depth (cm)*	*mg chl. a/kg dry sand*
KB; HW 0–15	0,13	SR; HW 0–15	0,03
KB; HW 15–30	0,51	SR; HW 15–30	0,00
KB; HW 30–45	0,68	SR; HW 30–45	0,01
KB; HW 45–60	1,52	SR; HW 45–60	0,01
KB; HW 60–75	1,00	SR; HW 60–75	0,03
KB; HW 75–90	0,95	SR; HW 75–90	0,03
KB; MW 0–15	0,41	SR; HW 0–15	0,10
KB; MW 15–30	0,43	SR; MW 15–30	0,09
KB; MW 30–45	0,20	SR; MW 30–45	0,06
KB; MW 45–60	0,61	SR; MW 45–60	0,05
KB; LW 0–15	1,15	SR; LW 0–15	0,08
KB; LW 15–30	1,38	SR; LW 15–30	0,10

Interstitial water analysis

Salinity values obtained for the interstitial water of Kings Beach and Sundays River are listed in Table 4. Included here are two sets of values for each beach as well as a series taken on Kings Beach just after rain on 22.2.74. The absence of shallow values from the HW levels was due to the desiccation of the sand. It was only on 22.2.74, when the sand had been moistened by rain, that shallow interstitial water samples could be taken at Kings Beach HW.

Raised salinities occurred at the higher tide levels on Kings Beach during low tide while Sundays River salinities were much more stable. After rain, salinities in the upper 5 cm at Kings Beach HW were greatly reduced while the other tide levels were virtually unaffected. Diluting effects of rain on the interstitial water are thus very limited, both in space and in time.

The degree of oxygen saturation of the interstitial water during spring low tide is illustrated in Figure 4. This shows a clear pattern with the Sundays River interstitial water consistently richer in oxygen than that of Kings Beach. On Kings Beach 90 per cent saturation occurs only in the upper 50 cm of sand near HW and deeper down or towards LW this drops rapidly to below 30 per cent. At Sundays River, however, 90 per cent oxygen saturation penetrates to more than 1 m at HW and the lowest value, recorded at LW 45 cm, was 35 per cent.

It would be expected that the interstitial water on and just beneath the surface at all tide levels would be close to 100 per cent oxygen saturation owing to its contact with the air. It must be remembered, however, that these values were recorded during low tide when the interstitial water would have been seeping out of the sand. Interstitial water near the surface at LW would therefore have been draining out from higher levels and deeper in the substrate and hence its relatively low percentage of oxygen saturation.

TABLE 4

Salinities of interstitial water from Kings Beach (KB) and Sundays River (SR). The Kings Beach values for 22.2.74 are for samples taken after rain. All values are in parts per thousand. *Key:* *: too deep to take samples; †: samples not taken; –: sand too dry to take samples.

Station and Depth (cm)	*BEACH AND DATE* K.B. 22.2.74	K.B. 10.6.74	K.B. 17.12.74	S.R. 6.7.74	S.R. 17.12.74
HW 1	1,7	—	—	—	—
HW 2	2,5	—	—	—	—
HW 5	26,2	—	—	—	—
HW 10	33,1	—	—	—	—
HW 20	*	51,5	—	—	—
HW 30	34,5	42,6	—	—	—
HW 60	34,9	38,7	36,6	35,5	—
HW 90	*	*	36,3	37,8	—
HW 100	*	*	*	*	34,9
MW 1	31,2	37,0	*	37,1	†
MW 10	33,5	†	†	35,8	†
MW 30	34,1	40,9	38,0	32,6	35,3
MW 60	*	48,2	36,6	*	34,9
LW 1	32,2	31,5	30,1	35,1	35,0
LW 10	34,0	33,0	†	35,5	†
LW 30	34,7	31,5	30,3	37,0	34,9
LW 45	34,8	41,9	†	35,7	35,3
Sea Water	34,0	34,8	35,0	35,7	35,0

TABLE 5

Temperatures recorded on Kings Beach at 22h30 on 2.9.74.

Station and Depth (cm)	*Temp. (°C)*	*Station and Depth (cm)*	*Temp. (°C)*
Air above sand at HW	5,7		
Sea water	13,9	MW 0 cm	7,5
HW 0 cm	5,0	MW 1 cm	8,2
HW 1 cm	5,7	MW 30 cm	13,9
HW 30 cm	10,1	LW 0 cm	9,1
HW 60 cm	11,0	LW 1 cm	10,5
HW 90 cm	11,3	LW 30 cm	15,1

Temperatures

Morning temperatures on Kings Beach are illustrated in Figure 5. Not included in Figure 5, however, are temperatures that were taken at 22h30 on 2.9.74 which was one of the coldest nights of the year. The temperatures recorded on that occasion are given in Table 5.

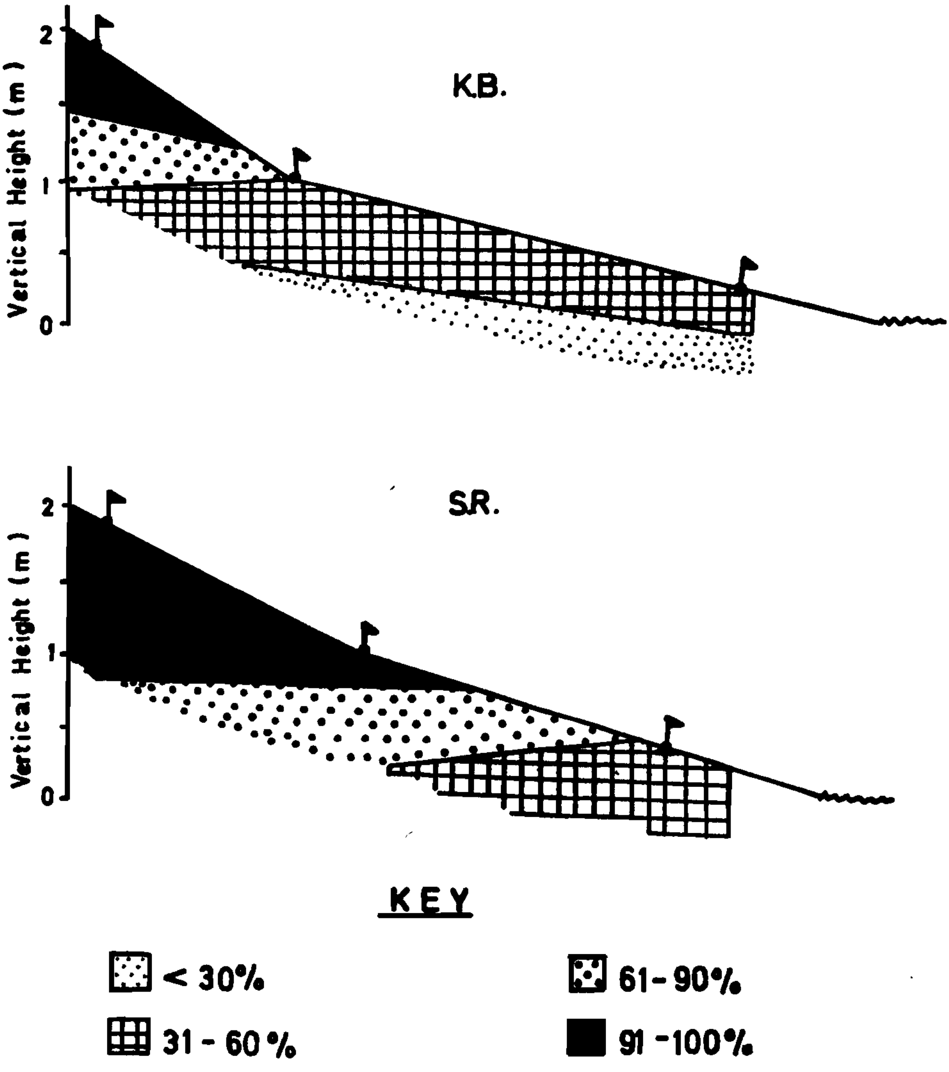


FIGURE 4
Percentage oxygen saturation of the interstitial water of Kings Beach and Sundays River during spring low tide. Flags indicate LW, MW and HW sampling levels.

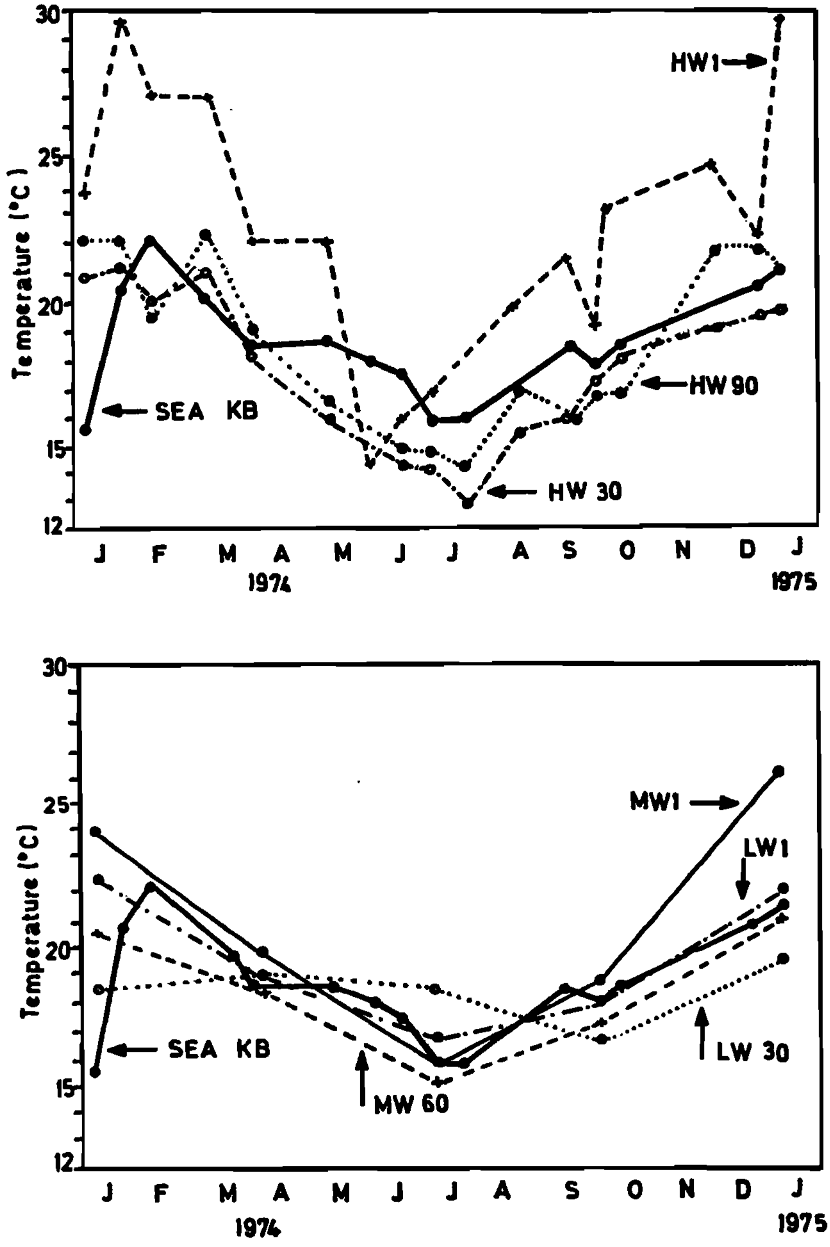


FIGURE 5

Mid-morning temperatures recorded during spring low tide on Kings Beach. Numbers following tide levels refer to depths in substrate (cm). HW temperatures above; MW and LW temperatures below.

Temperatures were only recorded at Sundays River on four occasions. As all of these values (except one record of 31°C at HW 1 cm) fell within the range recorded on Kings Beach, they have not been presented here. It is highly unlikely that temperature conditions will vary much between these two beaches and the range recorded on Kings Beach is considered representative of that experienced on all the beaches of Algoa Bay.

As would be expected (Johnson 1965), sand temperatures showed a wider range the further from the water and the nearer the sand surface they were taken. On Kings Beach, HW 1 cm showed the widest range of 5,7–30,0°C (Figure 5 and Table 5) while LW 30 cm showed the smallest range of 15,1–19,5°C (Figure 5 and Table 5). The sea temperature range recorded in the Port Elizabeth Harbour for 1970–1972 was 13,5–25,4°C with the highest values in January and the lowest in July and August. The range recorded on Kings Beach was 13,9–22,2°C (Figure 5 and Table 5), which is a close approximation of the harbour values.

DISCUSSION

The physical and chemical comparison of Kings and Sundays River beaches has revealed a number of differences relating mainly to the degree of exposure.

It is interesting that the more sheltered beach, Kings Beach, had a steeper gradient than Sundays River, as the reverse is generally considered to be the rule (Hedgpeth 1957, Eltringham 1971). Brown (1971), however, found that the more exposed beaches of the Cape Peninsula were not always the steepest. It would thus appear that there is not always a direct relationship between degree of exposure and beach slope.

The sand-particle size differences between the two beaches did, however, correspond to exposure as expected (Hedgpeth 1957). The overall median particle diameter on Kings Beach was 207 μm as opposed to a coarser 250 μm at the more exposed Sundays River. Furthermore, both beaches showed a tendency for the sand to become finer at higher levels. This has also been found by Ganapati & Rao (1962), Brown (1971) and Hanekom (1975). While Kings Beach sand-particle diameters remained stable with increasing depth in the substrate the Sundays River sands became coarser with increasing depth and on a number of occasions a bed of pebbles and boulders was encountered at 60–70 cm at MW and 90–100 cm at HW. It thus appears that Sundays River is underlaid by a bed of pebbles and boulders and this must greatly increase the drainage of the sand. As no such coarse layers were encountered on Kings Beach, this, together with the general coarseness of the sand at Sundays River, explains why Sundays River has a much deeper water table than Kings Beach. Where the water table lies approximately 65 cm deep at Kings Beach HW it averages 100 cm at Sundays River HW. Water table levels generally lag 1–3 hours behind the tides (Emery & Foster 1948) so that the water table depths recorded in Figure 2 are slightly less than the maximum depths.

A number of conclusions can be made from Table 2. Kings Beach sands have a greater porosity than Sundays River sands (20–29 per cent as opposed to 17–22 per cent). However, they drain slower and thus desiccate less, indicating smaller pore spaces and lower permeability. It is well known that finer sands generally have a greater porosity but smaller pore space and lower permeability or drainage than coarser sands (Webb 1958; Eltringham 1971; Hulings &

Gray 1971). The increased amounts of organic detritus in fine sands also tend to clog the interstices and slow down drainage (Eltringham 1971). As stated above, drainage at Sundays River is increased by the presence of an underlying boulder bed. The greater capillarity of the finer Kings Beach sands (Emery & Foster 1948) must also be partly responsible for their higher water content during spring low tides.

Kings Beach sands were found to have a much higher chlorophyll *a* content than Sundays River sands (Table 3). Microscopic examination of numerous samples from both beaches has revealed large quantities of detritus on Kings Beach, especially at HW, and much less detritus but numbers of large centric diatoms on Sundays River. The sheltered conditions of Kings Beach must be more favourable for the deposition of detritus and debris than the exposed conditions at Sundays River. (The proximity of Kings Beach to Port Elizabeth and thus the possibility of a certain amount of organic pollution can, however, not be ruled out.) Kings Beach chlorophyll *a* is probably derived mainly from detritus while that at Sundays River mainly from diatoms.

Meadows & Anderson (1966) found the microflora of sand grains to be concentrated near the sand surface between mid and low water. This further suggests that the Kings Beach chlorophyll *a*, which is most plentiful at HW 30–90 cm, is derived from detritus. This probably washes up around the HW mark where it slowly breaks down and sinks into the sand to the depth of the water table. This would explain the peak values at HW 45–75 cm which is the depth range to which the water table drops during spring low tides. Another possible source of this detritus could be the tidal pool above HW on Kings Beach. When filled with water this shallow pool may support a rich microflora which later dies and drains down through the intertidal zone. High chlorophyll *a* values near the surface at Kings Beach LW are most likely derived from a combination of detritus and micro-algae.

Salinity values in Table 4 show that the interstitial water on Kings Beach becomes hypersaline while that at Sundays River tends to remain close to that of the sea during low tide. This is probably due to a number of factors. Because of the good drainage at Sundays River, little water remains near the sand surface to evaporate to hypersalinity when uncovered by the tide. On Kings Beach water from the tidal pool may become hypersaline and drain down through the intertidal zone thus raising salinities there. Also, the greater capillarity of the Kings Beach sands probably brings a steady flow of water to the surface to be evaporated by the sun during low tide.

The effects of rain on interstitial salinities are minimal and only the upper 5 cm near HW on Kings Beach were notably affected (Table 4). This has also been found by Reid (1939), Smith (1955) and Brown (1971). Thus, as found by other workers (McIntyre 1969), the greatest salinity variations occur highest on the beach. Although not measured, the greater permeability of Sundays River sands would suggest that rain would have a much greater diluting effect there.

Brafield (1964) found that drainage was the most important factor affecting interstitial oxygen. Lowered oxygen values result from poor drainage which is due to a large proportion of fine grains in the sediment. This explains the much lower interstitial oxygen values on Kings Beach than at Sundays River. As drainage increases towards HW due to greater intertidal height, so oxygen values were highest far from the water and near the sand surface. Reduced permeability causes grey, deoxygenated layers in the sand (Webb 1958) and this explains the occurrence of such layers just below the levels of sampling on Kings Beach, *i.e.* 45 cm at LW and 60 cm at MW. Webb (1958) even used the depths of these layers as a means of estimating the permeability of sands.

From the temperature data (Figure 5 and Table 5) it may be concluded that except for the surface layers at HW, temperatures within the intertidal sands remain within a fairly narrow range and no extremes are experienced on Kings Beach or Sundays River. Frost never occurs on these beaches and the temperature of the deeper sand seldom rises above 21°C. It is therefore exceedingly unlikely that temperature could have any great direct influence on the meiofauna of Algoa Bay.

In conclusion it may be stated that the most important abiotic difference between these two beaches is drainage. The sheltered Kings Beach, with its fine sand and low permeability, has poor drainage relative to the exposed Sundays River which has coarser sand and is underlaid by a bed of boulders and pebbles. Drainage is therefore mainly related to substrate particle size and in its turn affects interstitial oxygen, salinity values and desiccation of the sand during low tide.

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