THE ECOLOGY OF SOUTH AFRICAN ESTUARIES.

Part VIII. KOSI BAY ESTUARY SYSTEM

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(With 1 figure in the text and Plates V and VI)

The topography of the Kosi Bay Estuary System is described and observations on the physical and chemical factors are tabulated. The estuary is partly tidal and there is a salinity gradient ranging from 3·3‰ in the top part to 33‰ near the mouth. On the basis of these factors and ecological and topographical factors, the system is divided into seven regions. The fauna and vegetation of six of these regions are described. A total of 216 species of animals was found and is listed in the appendices. The composition and distribution of the fauna are discussed and compared with those of Richard's Bay. It is concluded that the distribution is similar but the composition is very different, probably due to difference in substrata as salinity and other conditions are rather similar in both.

Contents

Introduction

In July 1949 a team of six biologists from the Department of Zoology of the University of Cape Town revisited the St. Lucia Estuary and Richard's Bay in order to investigate any differences which might have resulted from the floods since the previous visits. On that occasion the present authors joined the Third Tongoland Expedition organized by the Natal Society for Preservation of Wild Life and Natural Resorts, to carry out an ecological survey of Kosi Bay Estuary. It was thought that the results of such a survey might be of considerable interest in connection with work already carried out on St. Lucia and Richard's Bay Estuaries (Day, Millard and Broekhuysen, 1953; Millard and Harrison, 1953).

Kosi Bay was reached in the evening of 11 July and work was started the next day and continued until the 19th when we had to leave to rejoin our team at St. Lucia. Due to the short time available (eight days), the difficulties with boats, and the fact that the work had to be done by only two people, the

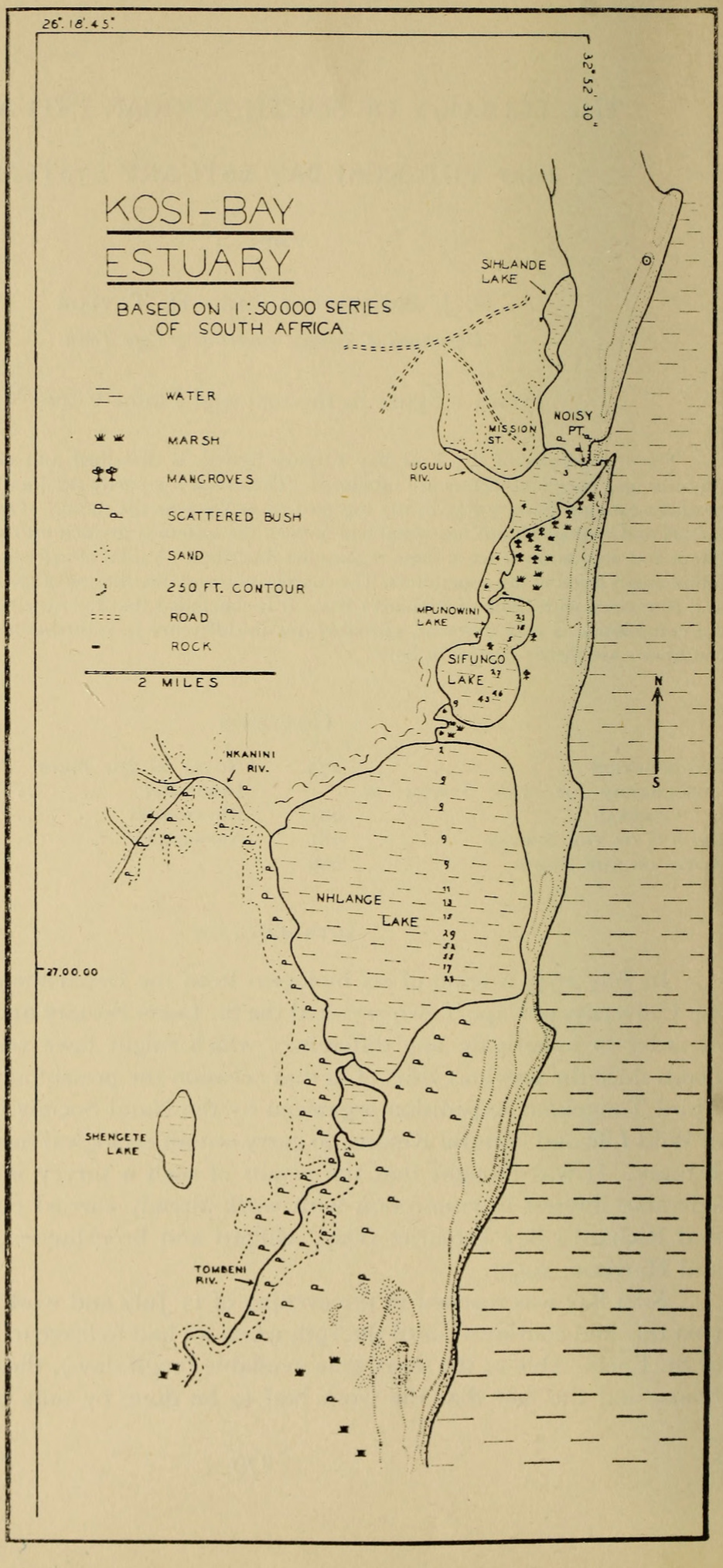

FIG. 1.
A map of the Kosi Bay Estuary System based on the 1 : 50,000 series of South Africa.

The depth is given in feet.

extent of the survey was limited. As the boat and canoe were too light for dredging, we could only work the shores and shallow water. We feel, however, that a fairly comprehensive knowledge of the main biological characteristics of these shores and shallow waters has been obtained. Mr. G. D. Campbell collected the majority of the species of fish given in the Appendix C (Campbell and Allanson, 1952).

Topography of the Kosi Bay Estuary System

It consists chiefly of three lakes, e.g. Nhlange Lake, Sifungo Lake and Mpunowini Lake (fig. 1). The system runs from south-west to north-east and opens into the sea 2 to 3 miles south of Oro Point (indicated but not named on the map) which is in Portuguese territory. A narrow channel broadening into a shallow tidal basin connects Mpunowini Lake with the sea. Four rivers flow into the system: (*a*) the Tombeni River which enters Nhlange Lake at the south-west point, (*b*) the Nkanini River which enters the same lake on the west side, (*c*) the Ugulu River which enters the northern tidal basin at a point south-west of the Mission Station and (*d*) a small stream from Sihlande Lake which enters the same basin just east of Noisy Point. The whole system from the southern shore of Nhlange Lake to the mouth is 7 to $7\frac{1}{2}$ miles long.

Results of the Survey

The system can be divided into seven sections, based on the physical, chemical and biological factors.

These are as follows:

I. The mouth of the estuary (the section east of Noisy Pt.).

II. The tidal basin, which is the section between Noisy Pt. and the mouth of the Ugulu River.

III. The shallows between the Ugulu River mouth and Mpunowini Lake.

IV. Mpunowini Lake.

V. Sifungo Lake.

VI. The winding narrow channel between Sifungo Lake and Nhlange Lake.

VII. Nhlange Lake.

During the eight days at our disposal we only managed to cover the first five sections though a few observations were made in the other two.

The physical and chemical properties of the water in the different sections have been tabulated in Appendix A.

I. The Mouth of the Estuary

A short straight channel, about 15 to 20 yards wide, running from west to east, formed the connexion with the sea. This channel formed the outlet of a

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basin bordered by sandy shores except on the south-east side where there was an outcrop of limestone and more to the south a beach covered with limestone pebbles. In the centre was a sandbank exposed during low water. By marking on a stick the lowest and the highest water level which occurred during eight days between spring and neap tides, it was found that the maximum tidal range opposite the mouth was 2 to 2½ feet. As can be seen from Appendix A the salinity varied considerably but approaching that of ordinary sea water. For the pH and temperature we can also refer to Appendix A. The water was extraordinarily clear as in all parts of the system. The 'rocky outcrop' and the 'pebble beach' were particularly rich in animal life. A large variety of molluscs and crabs were found, some of which were restricted to this area and the pebble beach was rich in Polychaet worms. For detailed information the reader is referred to Appendixes B and C. The sandy shores and the central sandbank were rather poor and even the sand-crab *Ocypode ceratophthalmus* was not common.

II. The Tidal Basin between Noisy Pt. and the Ugulu River

As can be seen from figure 1, this area was much larger than the previous one and there was a striking difference between the two shores. Except for a narrow twisting channel between 3 and 4 feet deep at low water, the basin was extremely shallow. Moreover Native fishtraps (pl. V, A) stretched across the whole area and made navigation, even in a small craft, extremely difficult The tidal range was about 1½ to 2 feet. The water was brackish (see Appendix A), while the pH and temperature in shallow pools cut off at low water were high.

The East shore

The northern part was a short narrow stretch of sandy beach with scattered mangroves. Southwards the shore widened out and formed extensive shallow pools and banks of sandy mud with large patches of dense mangroves (pl. V, B) including *Avicennia officinalis* and *Bruguieria gymnorhiza*. At a slightly higher level there was a zone of rushes—*Juncus kraussi*—which in part was very wide and stretched up to where the bush started to grow.

The three following zones were clearly marked:

(i) *Juncus zone*. Inhabited by many crabs burrowing in the ground and considerable numbers of *Littorina scabra* living on the leaves.

(ii) *Mangrove zone*. This was fairly extensive. It included the dense mangrove growth in the middle and the higher parts of muddy sandbanks separated by shallow water. The most striking features were the many crabs (up to 31 holes per square yard under the mangroves) and the two whelks *Pyrazus palustris* and *Cassidula labrella*. *P. palustris* was common just below the dense mangroves, but was rather patchy (Pl. VI, A). *C. labrella* lived among the thickest mangroves and seemed to prefer the shade. There was a certain

amount of overlap between the two. The barnacle—*Balanus amphitrite*—was quite prominent on the mangrove trunks and fishtrap sticks.

(iii) *Zone below mangroves.* Consisted of gently sloping sandy mud with hardly any vegetation. This area was fairly rich with many Polychaets (see Appendix B), the Sipunculid *Siphostoma australe* and the bivalve *Loripes clausus* which must have been very abundant in the past judging by the many empty shells. The hermit-crab *Clibanarius longitarsus* and the prawn *Panaeus japonicus* were both common.

The West shore

This was a narrow beach bordered by a belt of *Juncus* which on the landward side was replaced by *Phragmites* growing in a swampy surrounding. Just above the reeds scattered young mangroves occurred. Most of the crabs found on the east shore also occurred here among the *Juncus* and some of the *Sesarma eulimene* were in berry. Seining in the shallows revealed the prawn *P. japonicus* and young of several fish such as *Mugil* sp., *Therapon jarbua*, *Gobius giuris* and *Ambassis commersoni*.

III. The Shallows between the Ugulu River Mouth and Mpunowini Lake

These shallows form the connexion between the tidal part of the estuary and Mpunowini Lake. Although some mixing between fresh and brackish water seemed to occur in this region, it was definitely much less than in the area previously described (see Appendix A). The tidal range was probably not more than 4 to 5 inches. The channel was 4 to 6 feet deep and the shallow water bordering it was obstructed by many fishtraps.

The eastern shore was very similar to that of the previous section, with a wide zone of dense mangroves at the water's edge and *Juncus* at higher levels. Near Mpunowini Lake there were only few mangroves and *Juncus* grew down to the edge of the water while a green filamentous alga became quite common along the margins at the entrance to the lake. On the western shore the mangroves were rather patchy but the *Juncus* zone remained distinct. About halfway along the shallows *Phragmites* appeared at the water's edge. These reed-beds later became quite extensive and at the entrance of the lake they were several yards wide with a forest of mangroves behind and above them. The bivalve *L. clausus* was not found alive but many empty shells were embedded in the sandy mud at the northern end of the shallows. The large whelk *Pyrazus palustris*, although common at the northern part of the shallows, petered out towards Mpunowini Lake and the individuals which did occur were stunted. *C. labrella*, so characteristic on the mud under dense mangroves of the previous section, was gradually replaced by *Assiminea bifasciata*. *Balanus amphitrite* disappeared just south of the Ugulu River mouth. *Littorina scabra*, however, persisted at and above extreme high-water level and on the leaves of mangroves

almost to the entrance of Mpunowini Lake. The sand-prawn *Callianassa kraussi* first appeared near the northern end of the shallows and became abundant about half-way down, where 45 to 180 holes per square yard were counted. Large numbers of Polychaet worms were noticed at this point. Crabs were common not only under the mangroves in the northern part but also in the *Juncus* zone on the western shore *Hymenosoma orbiculare* made its first appearance in the narrow channel Amphipods such as *Chiltonia capensis*, *Melita zeylanica* and a species of *Grandidierella* and Isopoda including *Cirolana fluviatilis*, *Dies monodi* and *Synidothea variegata* also appeared and soon became common. The first specimen of the bivalve *Modiolus capensis* appeared here and the presence of *Chironomid* larvae in the sand indicated a strong fresh-water influence.

IV. Mpunowini Lake

This lake was the smallest of the three and the northern part was mainly shallow (about 3 feet deep). The deepest part was along the eastern shore where a depth of 21 feet was recorded. We also found a definite layering in these deeper waters with a surface salinity less than half that of the bottom. There was also a vertical temperature difference of at least $1\frac{1}{2}^{\circ}$ C. Details of the physical and chemical conditions are given in Appendix A. There were indications of a tidal range of about 4 inches at the northern entrance.

The northern shore was a narrow sandy beach with *Juncus*, grass and scattered palms growing on the bank above. This vegetation harboured many large crabs (*Sesarma meinerti*). The shallow water contained more algae including two filamentous green species and one brownish one and amphipods and isopods were numerous.

The eastern shore consisted of reed-beds with scattered mangroves in between. Young fish (*Therapon jarbua*), prawns (*L. pacificus*) and many isopods and amphipods were seen in the shallows. Above and beyond the reeds were numerous holes inhabited by *S. meinerti*.

The western shore was covered with mangroves, two species of rushes, palms and grass growing at and above high-water level. At the southern end, near the connexion with Sifungo Lake the brack grass *Ruppia maritima* made its first appearance. *Littorina scabra* was still common along this shore and *Modiolus capensis* had become more numerous. *Callianassa kraussi* was common or abundant along the whole of this shore and 153 to 162 holes per square yard were counted.

V. Sifungo Lake

The connexion between Mpunowini Lake and Sifungo Lake consisted of two short channels separated from each other by an island covered with dense mangroves. The large crab *S. meinerti* occurred in great numbers on this island and was collected by Natives as food, while the small periwinkle *A. bifasciata*, common in the area between the Ugulu River mouth and

Mpunowini Lake, was present in its characteristic habitat. The two channels were fairly deep at the northern end but where they ran into Sifungo Lake they were blocked by a shallow sandbank only covered by a few inches of water.

The north-western part of the lake was only a few feet deep, but towards the middle of the eastern side depths up to 46 feet were recorded. The water was exceptionally clear. Salinity determinations of surface- and bottom water samples indicated the existence of some layering but not as striking as in the previous lake (Appendix A). The bottom water was 3° C. warmer than the surface.

The northern and southern shores were narrow beaches of clear sand while the western and eastern shores were fringed by dense reeds with mangroves growing behind them. The three algae seen in Mpunowini Lake were present but the one like a broad *Enteromorpha* seemed to peter out and a new green alga —*Chara macropogon*—appeared for the first time. *R. maritima* now became common. Two species of isopods were common and three species of amphipods were collected one of which (*Urothoë serrulidactylus*) was restricted to this area. *Modiolus capensis* had now become fairly common in places and *A. bifasciata* was still present in the north-western corner of the lake. The bivalve *Psammobia ornata* appeared to be common in the shallow water among the reeds and it is remarkable that the only other place where this species was collected was on the sandy shore of the mouth of the estuary (see Appendix B). There was one common Polychaet. The sand-prawn *Callianassa* was still abundant and from 117 to 171 holes per square yard were counted.

VI. Channel between Sifungo Lake and Nhlange Lake and Nhlange Lake itself

Since only one short visit was made to these regions, information regarding them is incomplete. As shown in pl. VI, B, a narrow winding channel fringed by tall reeds connected the two lakes. Its depth averaged 6 feet or even 11 feet in places. Nhlange Lake, which had a diameter of approximately 3 to 4 miles, is separated from the sea on the south-eastern side by a low sandbar only a few hundred yards wide. We heard rumours that the lake was over 60 fathoms deep in one spot but we know of no published records. We, therefore, took a series of depth-soundings which have been entered in figure 1. From this it can be seen that the maximum depth we found was 52 feet. The greater part of the lake appeared to be 9 feet or less. It is still possible, that greater depths occur in the western part of the lake where soundings were not taken. The figures in Appendix A indicate that the water had a very low salinity and appeared to be uniform from surface to bottom. The sole collection made was where the channel entered the lake. Large rushes and *R. maritima* were very common here. The mussel *Modiolus capensis* was abundant, attached to *Ruppia*, also a fresh-water sponge, possibly an undescribed species of *Desmospongia*. The fresh-water crab *Rhynchoplax bovis* and the shrimp *Caridina nilotica* were common,

also two amphipods (*Melita zeylanica* and *Talorchestia ancheidos*). The only isopod was *Sphaeroma annandalei*, which was restricted to this lake (Appendix B).

We may summarize by saying that the Kosi Bay System is an exceptionally clear estuary. Although on the whole rather shallow, there are some very deep parts and some of these show a distinct vertical layering. The mouth was strongly saline and the 'rocky outcrop' and 'pebble beach' are very rich. The Tidal Basin, which shows a considerable drop in salinity, is characterized by a typical mangrove fauna and burrowing animals of tidal mud flats. There are indications of serious silting in recent times, probably accelerated, if not originally caused, by large numbers of Native fishtraps. Some of these have stimulated the growth of mangroves. The shallows between Ugulu River mouth and Mpunowini Lake have a small tidal range, a low salinity and a brack-water fauna. Mpunowini Lake showed a distinct layering in the deeper parts. The surface salinity was low. There was a slight increase of algal growth and a further decrease in the number of species of animals. Sifungo Lake was generally similar to Mpunowini Lake but the vertical salinity gradient was not striking although the temperature gradient suggested layering of the water. The surface salinity is somewhat lower than that of Mpunowini Lake. The fauna of the two lakes is essentially the same with minor changes in abundance.

Notes on the Fishes

Although we did a little seining, when time permitted, few records of fish could be obtained. However, members of the Tongoland Expedition and especially Mr. G. D. Campbell concentrated on the collecting of different species of fish by angling and seining. Their results from Kosi Bay and some other areas such as Lake Sibayi, Nyamiti and Kangazini Pans, etc., have already been published (Campbell and Allanson, 1952).

In Appendix C all records of fish caught in the Kosi Bay Estuary System, excluding the rivers running into it, have been listed. It is interesting to compare this list with the list of species recorded from Richard's Bay by Millard and Harrison (1952). It appears that only 22 species occur in both estuaries; 38 occur at Kosi Bay but not at Richard's Bay and 54 occur in Richard's Bay and not at Kosi Bay. Of the 38 species restricted to Kosi Bay, 19 were collected near or on the 'rocky outcrop' at the mouth of the estuary. The relatively large number of species which occurred either in the one or in the other but not in both estuaries is interesting. The fact that Richard's Bay had extensive *Zostera* beds which provided shelter and food while no *Zostera* occurred at Kosi Bay, and the fact that Kosi Bay had small rocky and pebble patches, which did not occur at Richard's Bay may account for the difference in species in the two estuaries. It should also be remembered that the water in the Kosi Bay System seemed to be clearer than that of Richard's Bay and on the whole was very much less saline.

Notes on the Birds

Aquatic birds may be important in the ecology of estuaries. During the short time in which the present survey was carried out, any birds wholly or partly dependent on water were recorded. The total number of species tabulated in Appendix D is 36. The figures in the different columns are the maximum numbers seen in the area at any one time. The number of species is relatively low possibly because the Kosi Bay System was visited during the winter when most palaearctic waders had left for their northern breeding quarters. From Appendix D it will be seen that the mouth of the estuary was the poorest in bird life. The large numbers of Avocets and relatively large numbers of Whimbrels are interesting.

Discussion

Of all the estuaries which have been investigated along the coast of Natal (Durban Bay, St. Lucia and Richard's Bay) none is actually comparable with the Kosi Bay System. Although Kosi Bay shows a gradual salinity gradient from slightly brack water at the top to almost sea water near and at the mouth, it is unique in that the major part contains brack water and that it is divided in such distinct parts interconnected by narrows. This seems to be the first time that the fauna of long stretches of brack water has been studied in the ecology of South African estuaries.

Of the other Natal estuaries studied Richard's Bay perhaps comes nearest to Kosi Bay, although the topography is very different and the largest part contained water which was much more saline. Both, however, have a gradual salinity gradient and are relatively 'clear water' estuaries. Moreover they are near enough to each other to expect considerable numbers of identical species.

Comparing the two estuaries we find that the total number of animal species—excluding birds—recorded from Kosi Bay is 173 and for Richard's Bay 183.

Although the value of these figures is limited as they are so dependent on the thoroughness of the Kosi Bay survey, their similarity is rather striking.

In Table I the distribution of the different phyla over the different parts of the Kosi Bay System has been analysed. No information for Nhlange Lake is given as this area was very inadequately covered.

From this table it is clear that the largest number of species occurred in 'the mouth of the estuary'. Millard and Harrison (1952) found that at Richard's Bay 'the middle reaches' were by far the richest. As they point out (p. 174), number of species alone cannot give an idea of richness of the population. Reference to Appendices B and C of the present paper and Appendix B of the Richard's Bay paper will show that many species were common or limited to the regions under consideration.

TABLE I. DISTRIBUTION OF DIFFERENT PHYLA

	Estuary Mouth			Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake
	Sandy shore	Pebble beach	Rocky outcrop				
Porifera	0	2	0	0	0	0	0
Coelenterata	0	0	3	0	0	0	0
Annelida	1	6	0	8	5	1	1
Crustacea	4	17	8	10	21	9	13
Mollusca	8	23	6	9	6	2	3
Ascidia		1					
Pisces		35		18	6	2	3
TOTAL		114		45	39	14	20

The difference in distribution of the animals in the two systems is rather striking and asks for an explanation. Considering the salinity of the water, the 'mouth of the estuary' at Kosi Bay seems to be similar to the 'middle reaches' of Richard's Bay. In the case of Kosi Bay there is no *Zostera* providing shelter and food, but there are small patches of rocky and pebble substrata which provide shelter and suitable attachment for sedentary species. In Richard's Bay there is extensive *Zostera* growth but no rocky and pebble substrata.

It therefore seems, that salinity together with the presence of shelter, food and suitable attachment are responsible for the abundance of animals in the regions under consideration.

It seems interesting to compare the actual species occurring in both systems. In Table II the species occurring in both estuaries and those occurring in one of the two only have been tabulated.

TABLE II. COMPARISON OF SPECIES AT KOSI BAY AND RICHARD'S BAY

PHYLUM	NUMBER OF SPECIES		
	Present in both	Present in Richard's Bay only	Present in Kosi Bay only
Porifera	0	0	3
Coelenterata	?	8 or 11	?
Annelida	1	7	12
Crustacea	23	34	30
Insecta	0	5	2
Mollusca	5	12	32
Ascidia	0	0	1
Pisces	22	54	38
TOTAL	51	123 120	118

From this table it is obvious that the fauna of both systems is very different and that only 51 species occurred in both the estuaries. This is the more striking as both estuaries as regards salinity conditions are to a certain extent similar. This suggests the conclusion that type of substratum may be more important than salinity especially in Mollusca.

Acknowledgements

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To these, and the systematists who have helped with the identification of the material the authors tender their sincere thanks. Professor J. H. Day has been kind enough to criticize the manuscript, and his helpful suggestions are much appreciated. The method of work was on the whole similar to that described for other papers in the series.

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Appendix A

The physical and chemical factors of Kosi Bay Estuary. In each column the lowest and the highest figure represent the extremes, the other in the middle is the average. The number of records on which this average figure is based is shown as superior figure. Where surface and bottom samples were taken, these figures are given separately. The pH figures are without the salt-error and therefore somewhat too high.
* Shallows cut off between mangrove banks.
** Boggy place just above H.W.S.

Area	Salinity %	Water temperature in ° F.	pH	Turbidity (Secchi Disc.)
Mouth of Estuary	$21{\cdot}2$–$28{\cdot}7^{3}$–$32{\cdot}9$	$19{\cdot}2$–$20{\cdot}5^{12}$–$22{\cdot}0$	$8{\cdot}5$–$8{\cdot}5^{7}$–$8{\cdot}7$	
Tidal Basin	$9{\cdot}9$–$13{\cdot}3^{2}$–$16{\cdot}6$	$21{\cdot}3$–$23{\cdot}8^{5}$–$26{\cdot}0$*	$7{\cdot}4$**–$8{\cdot}4^{7}$–$9{\cdot}2$*	
Shallows between Ugulu River mouth and Mpunowini Lake	$9{\cdot}9^{1}$	$18{\cdot}0$–$18{\cdot}7^{4}$–$19{\cdot}9$	$8{\cdot}3$–$8{\cdot}4^{3}$–$8{\cdot}5$	
Mpunowini Lake	$7{\cdot}4$–$7{\cdot}8^{2}$–$8{\cdot}1$ Surf.: $7{\cdot}4$ Bottom: $18{\cdot}3$	$18{\cdot}8$–$19{\cdot}6^{4}$–$20{\cdot}5$ $18{\cdot}8$ $20{\cdot}2$	$8{\cdot}3^{1}$	
Sifungo Lake	Surf.: $6{\cdot}6$ Bottom: $7{\cdot}6$ $7{\cdot}5$	$19{\cdot}3$–$20{\cdot}7^{3}$–$23{\cdot}0$ Surf.: $19{\cdot}3$ Bottom: $23{\cdot}0$ $21{\cdot}7$	$8{\cdot}3$–$8{\cdot}6^{2}$–$8{\cdot}8$ $8{\cdot}3$ $7{\cdot}5$ (H_2S smell)	23 feet
Nhlange Lake	$3{\cdot}3$–$3{\cdot}4^{2}$–$3{\cdot}5$ Surf.: $3{\cdot}3$ Bottom: $3{\cdot}5$	$20{\cdot}2$–$20{\cdot}3^{2}$–$20{\cdot}4$ $20{\cdot}2$ $20{\cdot}0$	$8{\cdot}0$–$8{\cdot}3^{2}$–$8{\cdot}5$	14 feet

Appendix B

Comparative list of the fauna of the Kosi Bay Estuary System.
P = present, C = common, A = abundant.

	Estuary Mouth			Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake	Nhlange Lake
	Sandy shore	Pebble beach	Rocky outcrop					
PORIFERA								
Desmospongia sp. (KOS 6B)								C
Haliclona raphidiophora (Lendenfeld)		P						
Higginsia coralloides Higgin		P						
COELENTERATA: *Actinozoa*								
Small brown species (KOS 21A)			P					
Light coloured sp. (KOS 30A)			P					
Small burrowing anemone (KOS 33D) ..			C					

	Estuary Mouth			Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake	Nhlange Lake
	Sandy shore	Pebble beach	Rocky outcrop					
ANNELIDA: *Polychaeta*								
Ceratonereis keiskama Day				P	P			
Dasybranchus caducus (Gr.)				C				
Dendronereis arborifera Peters				P	C	P	C	
Loimia medusa Sav.				C				
Lycastis indica Southern				P	P			
Nerine cirratulus (D. Ch.)		P						
Notomastus abberans Day..								
Orbinia bioreti Fauvel				P				
Perineries capensis (Kbg.)		P		P				
Pomatoleois kraussii (Baird)		P						
Scolecolepsis indica Fauvel				C	A			
ANNELIDA: *Sipunculoidea*								
Phascolosoma scolops Sel et de Man		P						
,, *stephensoni* Stephen		P						
Siphonostoma australe	P	P		P	P			
CRUSTACEA: *Cirrepedia*								
Balanus amphitrite v. *denticulata* Broch.				C	P			
,, *trigonus* Darwin			P					
Chthamalus sp. (KOS 18A)			P					
Tetraclita squamosa (Brug.) v. *rufotincta* Pilsbry.			P					
CRUSTACEA: *Tanaidacea*								
Tanais philetaerus Stebb.							P	
CRUSTACEA: *Isopoda*								
Cirolana fluviatilis Stebb...					C			P
Dies monodi Brnrd.					C	P		
Pontogeloides latipes Brnrd.	C		P		C		C	
Sphaeroma annandalei Stebb.								C
Synidothea variegata Cllge.					P	A	C	
CRUSTACEA: *Amphipoda*								
Afrochiltonia capensis (Brnrd.)					C	C	P	
Grandidierella sp. (KOS 62D)					P			
Melita zeylanica Stebb.					A	A	C	P
Talorchestia ancheidos Brnrd.				P		C	P	A
Urothoë serrulidactylus Brnrd.							P	
CRUSTACEA: *Macrura*								
Alpheus sp. (KOS 32B)			P					
Athanas sp. (KOS 33)		P						
Caridina nilotica (P. Roux)								A
Metapenaeus (? *monoceros*) (Fabr.)					P			
Palaemon pacificus Stimps.						C	C	
Penaeus indicus M. Edw...							C	
,, *japonicus* Bate				C	P			
,, *monodon* Fabr.							C	

	Estuary Mouth			Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake	Nhlange Lake
	Sandy shore	Pebble beach	Rocky outcrop					
CRUSTACEA: *Anomura*								
Calcinus laevimanus (Randall)	P	P						
Callianassa kraussi Stebb.					C	A	A	
Clibanarius longitarsus (de Haan)			C	C	P			
,, *virescens* (Krss.)		P	C P					
Coenobita cavipes Stimps.			P					
CRUSTACEA: *Brachyura*								
Actaea depressa (White)		P						
Actumnus setifer (de Haan)		P						
Cyclograpsus punctatus M. Edw.		C						
Epixanthus frontalis (M. Edw.)		C						
Eriphia smithii McLeay		C						
Euruppellia annulipes (M. Edw.)		P						
Grapsus strigosus (Herbst)		C						
Hymenosoma orbiculare Desm.					P	P	C	
Liomera bellus (Dana)		P						
Matuta lunaris (Forsk.)	P							
Metapograpsus messor (Forsk.)		C		C	P			
Ocypode ceratophthalmus (Pallas)	C							
Ozius regulosis Stimps.		P						
Pseudograpsus erythraeus Kossman		P						
Pseudozius caystrus (Ad. & White)		C						
Rhyncoplax bovis Brnrd.								C
Sarmatium ? crassum Dana				P	P			
Scylla serrata (Forsk.)					P		P	P
Sesarma catenata Ortm.					P			
,, *eulimene* de Man				P	C			
,, *meinerti* de Man				P	P	C	C	
Uca annulipes (M. Edw.)				A	P			
Uca chlorophthalmus (M. Edw.)				P	P			
Xantho quinquedentatus Kr.		P						
Zozymodes xanthoides (Kr.)		P						
INSECTA								
Chironomid larvae					P			
Hydrometridae								P
MOLLUSCA: *Pelecypoda*								
Barbatia decussata (Sow.)		P						
Crassostrea cuculata (Born)		C	C					
Dosinia hepatica (Lam.)				P				
Isognomon dentifera (Krss.)		C						
Loripes clausus Phil.	C			C				
Modiolus (*Brachydontes*) *variabilis* Krss. ..		C						
Modiolus capensis Krss.					P	C	C	C
Mytilus perna (Linn.)		P						
Psammobia ornata Desh...	P							C
Pteria natalensis Jameson	P	C						
Tellina queketti Sow.	P							

	Estuary Mouth			Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake	Nhlange Lake
	Sandy shore	Pebble beach	Rocky outcrop					
MOLLUSCA: *Gastropoda*								
Assiminea bifasciata (Nevill)					A		P	
Cassidula labrella Desh.				C	P			
Cellana capensis (Gmelin)			P					
Cerithidia decollata (Linn.)				P	P			
Cerithium morus Lam.		C						
Coralliophila sp. (KOS 26U)		P						
Cypraea annulus Linn.	C	C						
Drupa squamosa (Pease)		P						
,, *tuberculata* (Blainv.)		C						
Engina (*Pusiostoma*) *mendicaria* (Linn.)		C						
Littorina obesa Sow.		P						
Littorina scabra Linn.				C	P	C		
Mitra litterata Lam.		P	P					
Natica marochiensis Gmelin				C				
Nerita albicilla Linn.		C						
,, *plicata* Linn.		P						
,, *umlaasiana* Krss.		A						
Planaxis sulcata Q. & G.		C						
Polynices mamilla Lam.	P			P				
Pyramidella mitralis A. Adams				P				
Pyrazus palustris Linn.				C	C			
Siphonaria anneae Tomlin		P	P					
,, *capensis* Q. and G.			P					
,, *oculus* Krss.		P	C					
Tricolia bicarinata (Dunker)		P						
Vermetus sp. (KOS 37A)	P							
ASCIDIA								
Styela aequatorialis Michaelson..		C						

Appendix C

Comparative list of the fishes of the Kosi Bay Estuary System
P = present, C = common, A = abundant.

	Estuary Mouth			Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake	Nhlange Lake
	Sandy shore	Pebble beach	Rocky outcrop					
Abudefduf saxtilis Forsk.	←	—	P	→				
Acanthopagrus berda (Forsk.)			C	C				
Acanthurus fulgiginosus (Lesson)	←P	→						
,, *triostegus* (Linn.)			P					
Alticops oryx (Cuv.)			P					
Ambassis commersoni Cuv. & Val.				C				
,, *safga* (Forsk.)				P	C			
Antennablennius bifilum (Gunth.)	←	—	C	→				
Arothron aerostaticus (Jenyns)			P					
Bothus pantherinus (Rupp.)				P				
Callyodon guttatus (Schneider)			C					
Caranx melampygus Cuv.	←	—	P	→				
,, *sexfasciatus* Q. & G.	←	—	P	→				
Chaetodon lunula (Lacep.)			P					
Coracinus multifasciatus (Pellegr.)			P					
Diplodus sargus Linn.			C					
Dules taeniurus Cuv.			C					
Echidna nebulosa (Ahl.)		L	ocality Unknown					
Eleotris fusca (Bloch)						P		
Ellochelon vaigiensis (Q. & G.)		L	ocality Unknown					
Elops saurus Linn.	←	P	→					
Enneapterygius obtusirostre Klusinger			C					
Epinephelus areolatus (Forsk.)			C					
Epinephelus tauvina (Forsk.)			P					
Fissilabrus dimidiatus (Val.)			P					
Fistularia petimba Lacep.	P							
Gerres acinaces Bleeker		L	ocality Unknown					
,, *oyena* (Forsk.)					C			
,, *rappi* (Brnrd.)	←	—	P	→				
Gilchristella aestuarius (Gilch. & Thomp.) ..		Between Sifungo and Mpunowini						
Gobius giuris Hamil.				C	P	C	C	P
Hepsetia pinguis (Lacep.)		L	ocality Unknown					
Hyporamphus delagoae (Brnrd.)		L	ocality Unknown					
Johnius hololepidotus (Lacep.)	←	—	P	→				
Kuhlia taeniura (C. & V.)			P					
Lethrinus nebulosus (Forsk.)			C					
Lithognathus mormyrus (Linn.)	←	P	→					
Liza macrolepis (Smith)	←	—	A	→				
Lutianus argentimaculatus (Forsk.)			P				C	
,, *fulviflamma* (Forsk.)		L	ocality Unknown					
,, *vaigiensis* (Q. & G.)			C					
Monodactylus argenteus (Linn.)	←	—	A	→				
,, *falciformis* Lacep.	←	—	A	→				
Mugil cephalus Linn.	←	—	A	→				
,, *robustus* Gunth.	←	—	P	→				
,, juv.				C	C		C	

	Estuary Mouth			Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake	Nhlange Lake
	Sandy shore	Pebble beach	Rocky outcrop					
Neoscorpis lithophilus (G. & T.)	←—	A	—→					
Periophthalmus sp.					P			
Platycephalus indicus (Linn.)	←—	P	—→					
Pomacentrus sindensis (Day)			P					
Pomadasys operculare (Playfair)	←—	——	P	——→				
Pterois volitans (Linn.)			P					
Rhabdosargus sarba (Forsk.)			C					
Rhinecanthus aculeatus (Linn.)			P					
Sphyraena jello Cuv.								
Spyraena obtusata Cuv.	Be	twee	n M	punow	ini &	Sifu	ngo	C
Strializa canaliculatas (Smith)	←—	——	A	——→				
Thalassoma lunare (Linn.)			C					
Therapon jarbua (Forsk.)			P	P	P		P	
Tylosurus crocodilus (Lesueur)			C					
Zanclus cornutus (Linn.)			P					

Appendix D

Birds occurring in the near vicinity of the water.

Note.—The figures appearing in the different columns are the maximum number seen at any time in that particular area. Therefore the figures for the same species in different columns may refer to the same birds but appearing in different areas.

	Estuary mouth	Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake	Nhlange Lake
Actitis hypoleucos (Common Sandpiper) ..				1		
Anas undulata (Yellow-billed Duck)				←——	4	——→
Anhinga rufa (Snake Bird)		Locality	Unknown			
Ardea cinerea (Grey Heron)			10	10		
„ *purpurea* (Purple Heron)			1			
Bubulcus ibis (Cattle Egret)				12		
Burhinus vermiculatus (Water Dikkop)			2			
Butorides striatus (Green-backed Heron) ..				←——	1	——→
Ceryle rudis (Pied Kingfisher)	3	2	1	3		
Charadrius hiaticula (Ringed Plover)				1		
„ *marginatus* (White-fronted Sandplover)	36	9	4			
„ *tricollaris* (Three-banded Sandplover)		2	2	2		

	Estuary mouth	Tidal basin between Noisy Pt. and Ugulu River mouth	Shallows between Ugulu River mouth and Mpunowini Lake	Mpunowini Lake	Sifungo Lake	Nhlange Lake
Circus ranivorus (African Marsh Harrier) ..				←———	1 ——→	
Corythornis cristata (Malachite Kingfisher) ..				1		
Egretta garzetta (Littel Egret)	1	2	10			
Gypohierax angolensis (Vulturine Fish Eagle) ..				←———	1 ——→	
Hagedashia hagedash (Hadedah)				5		
Haliaëtus vocifer (Fish Eagle)	1	2				
Himantopus himantopus (Black-winged Stilt) ..		1				
Larus cirrocephalus (Grey-headed Gull)		2		1		
Megaceryle maxima (Giant Kingfisher) ..				←———	2 ——→	
Motacilla capensis (Cape Wagtail)		1	2	←———	3 ——→	
Numenius arquata (Curlew)		1	1	4		
,, *phaeopus* (Whimbrel)	10	11	10	14		
Nycticorax nycticorax (Night Heron)		Locality Unknown				
Pandion haliaëtus (Osprey)				←——1	——→	
Phalacrocorax africanus (Reed Duiker)				5		59
,, *carbo* (White-breasted Duiker) ..	2	15	3			
Phoenicopterus sp. (Flamingo)			101	←——9	1 ——→	
Porhyrio porhyrio (Purple Gallinule)					1	
Psalidoprocne holomelaena (Black Saw-wing Swallow)	2					
Pseudohirundo griseopyga (Grey-rumped Swallow)		3		←——6	——→	
Recurvirostra avosetta (Avocet)		282	300	300+		
Riparia riparia (African Sand Martin)	1					
Sterna bergii (Swift Tern)	1					
Tringa nebularia (Greenshank)		17	4	←——2	6 ——→	

Broekhuysen, G. J. and Taylor, H. 1959. "The Ecology of South African estuaries. Part X. Kosi Bay estuary system." *Annals of the South African Museum. Annale van die Suid-Afrikaanse Museum* 44, 279–296.

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