A Preliminary Investigation

of the

Ecology of the Larger Kleinmond River Estuary,

Bathurst District.

1953

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by

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for the Degree of M.Sc.

"My remarks are, I trust, true in the whole, though I do not pretend to say that they are perfectly devoid of mistake, or that a more nice observer might not make many additions, since subjects of this kind are inexhaustible."

Gilbert White (1773).

The Lagoon in the Afternoon.

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THE ECOLOGY OF THE KLEINMOND RIVER ESTUARY.

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Introduction

On the coast of the Bathurst Division,Eastern Cape Province,some 42 miles south-east of Grahamstown,lie two estuaries opening within a few yards of one another. These are known as the Kleinemonde. This paper embodies the results of an ecological survey of the fauna of the Larger Kleinmond Estuary. The chief concern has been the aquatic fauna but animals living along the banks have also been dealt with as far as possible, as have the birds.

This is the second of South Africa's blind estuaries to be studied, the Klein River, Hermanus, having been investigated in 1947-49 by workers from the University of Cape Town. Though common in South Africa, blind estuaries are rare in parts of the world such as Europe, and present an almost entirely new field of research for the ecologist. It is hoped, therefore, that the investigation of the Kleinmond Estuary and a comparison with the results obtained from the Klein River, Hermanus, will add to our knowledge of this subject and be of service to future investigators.

The history of the Kleinmond River is worthy of mention, for the lagoon was not always blind and shallow. The early maps of the 1820 settlers show the river as a navigable stream; sailing vessels anchored out at sea and sent lighters up what was then known as the Lydendoch River to collect fresh meat. The area at the mouth of the river was called Port Jessie. In these early days the region abounded with game. Hippo and elephant were common, the former inhabiting deep pools in the upper reaches of the river; pools which have since completely silted up.

Constant ploughing of the slopes adjoining the river has caused vast amounts of soil to be washed by rains into the stream, and today what was within living memory a deep, clear stream is a shallow, blind and muddy river, a reflection of man's destructive methods of farming. These changes must have had a far-reaching effect on the fauna of the estuary; an effect about which we can, alas, only speculate. It is perhaps significant that though rich in numbers, the fauna is poor in species, tunicates and echinoderms being apparently entirely absent.

The work involved in this survey was undertaken between September 1952 and November 1953, under the direction of Professor J.Omer-Cooper of Rhodes University, frequent and regular visits being made to the estuary. The entire month of February, 1953, was spent on the shore of the lagoon, so that animals could be observed over a continuous period. The starting date of the survey was particularly fortunate, as on September 28th, 1952, the river came down in flood and broke through the sand-bar separating the lagoon from the sea. The work thus began at a definite point in the estuarine cycle, the importance of which it is hoped to show.

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An Ox-waggon passes Station One.

Acknowledgments

I wish to extend my grateful thanks to Professor J.Omer-Cooper, Head of the Department of Zoology at Rhodes University, without whose help this research could not have been undertaken. In particular I wish to thank him for his advice and encouragement, the use of his cottage and boat, and his active help in designing and making apparatus and in collecting. The use of his motor-van and private collecting apparatus is much appreciated.

Special thanks go also to Mr W.Macnae, of Rhodes University, whose wide knowledge of the subject has enabled him to give me much good advice. I thank him for criticising the first draft of the thesis. Professor J.H.Day, University of Cape Town, has also been kind enough to advise me on many aspects of the work, and this has proved invaluable.

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Dr K.H.Barnard (South African Museum)
Insecta : Dr A.J.Hesse (South African Museum),
Rev. C.Tottenham (Cambridge, England),
Professor J.Omer-Cooper (Rhodes University), and
Dr E.Mc C.Callan (Rhodes University)
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METHODS

Animals were collected by day and by night along both banks and from a boat. The collections were made throughout the estuary and not restricted to the places labelled as stations, as only in this way could a comprehensive survey be made. For convenience the animals were then referred to the nearest station. In choosing collecting methods attention was paid to the remark that "the best method of collecting is collecting." Complicated methods were avoided and simplicity was the key-note. The following catagories were those finally listed:-

(1) Animals collected by hand when walking along the banks. These included insects, crabs and sessile molluscs and crustaceans. Into this catagory fall also those animals found by turning over stones and stranded debris.

(2) Animals collected by digging. The larger burrowing forms were taken by this method.

(3) Animals collected by sifting sand and mud. This method accounted for the majority of the invertebrate species. A set of sieves fitted with mesh gauze of various sizes was specially made for this purpose and in some cases coarse bolting-silk was used with success.

(4) Animals taken with hand-nets. These included the smaller fish, crabs and swimming prawns. A most useful piece

of apparatus was a shrimping net designed and made by Professor J.Omer-Cooper. This consists of an equilateral wooden triangle to which a coarse net is attached; the wooden handle is made as a perpendicular to the bottom edge of the triangle. The net is pushed in front of the collector and the angle at which it is held determines the depth of sand disturbed. The sand enters the frame and passes through the net behind it, large and medium-sized animals being retained. This net was used regularly in the lagoon with great success but had to be abandoned above station three, where the mud became too soft to allow of its manipulation.

(5) Plankton was collected regularly by day and by night in three types of plankton net. These nets are described in the chapter on plankton.

(6) Fish taken on rod and line.

(7) Fauna collected by stamping on the mud. This included Staphylinidae, Heterocerus beetles and some Amphipoda.

(8) Fauna collected by sweeping aquatic weed. This last method accounted for such Amphipods as Melita zeylanica and the crab Hymenosoma orbiculare.

Individual specimens were immediately preserved in alcohol while mud-siftings and plankton samples were preserved by the addition of formalin and later sorted into alcohol. Water samples were taken regularly, in Winchesters, for analysis in the laboratory but as much of the analysis as possible was done in the field. From time to time field analysis was checked in the laboratory by more accurate methods.

Ladell's Flotation Machine was used in an attempt to make a quantitative survey of the mud-fauna. The apparatus was originally intended for quantitative studies on soil fauna, particularly soil insects, and for this purpose it has proved most satisfactory. It is, however, not suitable for a mud fauna, as the soft bodies of these forms are mutilated beyond regognition by the action of the stirrer.

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DESCRIPTION OF THE ESTUARY

(a) Topography.

The Kleinmond Estuary is a small stream, some fifteen miles in length, which drains the central south-eastern part of the Bathurst Division of the Eastern Cape Province; a farming area devoted in recent years to the production of pine-apples and to cattle-farming. The district is characterised by extensive grass-veld, with coastal bush, some forest and low hills. The mouth of the estuary under discussion lies eight miles north-east of Port Alfred and some four miles south-west of Great Fish Point.

The estuarine section of the stream falls into two natural divisions: (1) The River, some four and a half miles in length, and (2) The Lagoon, which extends for just under two miles.

The Lagoon is normally closed to the sea by a sand-bar which increases in height and width as long as the mouth remains closed. This sand-bar appears to be formed by sand from two sources; wind-blown sand from the dunes and sand washed in by the sea. It requires very heavy seas and floods to break the bar and the lagoon is often closed for periods of two years or more.

Seventeen stations were established, the first seven of which lie within the lagoon. Station one was located at the extreme bottom end of the lagoon, station two on the left bank, where rocky ground is first encountered. Station three, on the right bank, comprises a promontåry which juts out into the lagoon and the mud-flat in front of it. Between this mud-flat and the right bank is a shallow bay which was investigated with great thoroughness. Stations four, five, six, and seven were established on alternate banks of the lagoon and station eight in the first bend of the river, defined as the jundtion between lagoon and river. At no point is the lagoon very deep; under normal circumstances it averages only about three feet and the greatest depth read was five feet, six inches, in the channel between stations one and two. On the other hand the lagoon is very wide in proportion, being just over 150 yards across at station two. This type of estuary would seem to be the rule rather than the exception in South Africa. As Krige (1927) points out: "Although not recognisable from the map as such, practically all South African estuaries are true drowned valleys more or less silted up."

The River. Proceeding up-stream from station eight, the river narrows somewhat, until at station nine it measures less than forty yards across. Between stations eight and nine the chaneel is six feet deep. The river grows deeper, and at station ten a depth of just over nine feet is recorded. This is the greatest depth read in the estuary under normal conditions. At station fifteen a rock barrier extends across the stream and above this point the river is extremely shallow, being seldom more than two feet deep.

Half a mile above this rock barrier is a second barrier of even more interest and importance as it marks the boundary of the estuary. As the water passes through this barrier, which extends up-stream for about fifty yards, it drops somewhat, probably only an inch or even less, but sufficiently to make the estuarine boundary clearly defined. Below the barrier the fauna is typically estuarine; above, typically fresh-water. Station seventeen was established at this barrier.

(b) Climate.

Rainfall figures for the area are available and are of some considerable interest. Table 1 gives the average monthly rainfall prior to 1935 at four stations in the vacinity; Rocklands six miles inland with a height of 458 ft above sea-level; The Hope, some ten miles inland; Cuylerville, the nearest station to the mouth; and Great Fish Point, on the coast, to the north-east of the estuary. Table 11 shows the rainfall figures for 1948 and 1949 at Rocklands and at Great Fish Point.

The most striking point about these figures is their lack of consistency. The rainfall in a given month is liable to vary considerably from the mean for that month over a number of years. This inconsistency is shown in a marked manner by the figures for November 1948/49 and for April 1948/49. The rains in November 1949 resulted in a great flooding of the river with a consequent breaking of the sand-bar. The lagoon remained tidal for some weeks.

	Rocklands	The Hope	Cuylerville	Great Fish Point
JAN	1.78	1.42	1.91	1.75
FEB	1.79	1.69	1.36	1.93
MAR	3.08	3.38	1.46	2.91
APR	2.19	1.72	1.28	2.13
MAY	2.38	2.56	1.06	2.36
JUN	1.91	1.70	1.35	1.97
JUL	1.94	2.64	1.17	1.62
AUG	1.92	2.27	1.61	1.33
SEP	3.24	3.52	2.11	2.49
OCT	3.53	3.83	2.13	2.71
NOV	2.08	2.02	1.48	2.62
DEC	2.09	2.32	2.93	1.91
TOTAL	27.93	29.07	19.85	25.73

Table 1

Average Rainfall in inches

	Rocklands		Great Fish Point	
	1948	1949	1948	1949
JAN	1.06	2.29	0.86	2.14
FEB	1.93	1.73	1.79	1.73
MAR	1.80	0.29	2.84	0.57
APR	7.03	1.56	5.42	2.08
MAY	0.25	0.48	0.33	0.63
JUN	0.81	0.00	0.48	0.00
JUL	1.12	0.32	0.91	0.62
AUG	0.82	2.38	0.89	1.50
SEP	2.19	1.88	1.87	1.76
OCT	5.12	1.88	3.67	2.30
NOV	1.11	8.90	1.57	10.26
DEC	0.78	0.56	0.62	0.75
TOTAL	24.02	22.27	21.25	24.34

Table 11

Rainfall in inches

Air temperatures for some years prior to 1940 are available for Port Alfred and for Great Fish Point, and give some indication of the temperatures likely to be encountered at the Kleinemonde. The following temperatures are given in degrees Fahrenheit, as this appears to be the system generally used for air temperatures in South Africa.

At Port Alfred, between the years 1923 and 1936, the highest temperature recorded was 108°F and the lowest 34°F. At Great Fish Point, the highest temperature between 1917 and 1940 was again 108°F, while the lowest temperature recorded was 38°F. The Mean Maximum temperature at Port Alfred was 73.9°F, the Mean Minimum temperature 54.9°F and the daily range average was thus 19.0°F. At Great Fish Point the Mean Maximum temperature was 71.6°F and the Mean Minimum 56.9°F, giving a mean daily range of 14.7°F.

We may assume that conditions at the Kleinemonde are comparable with the conditions which gave rise to these figures.

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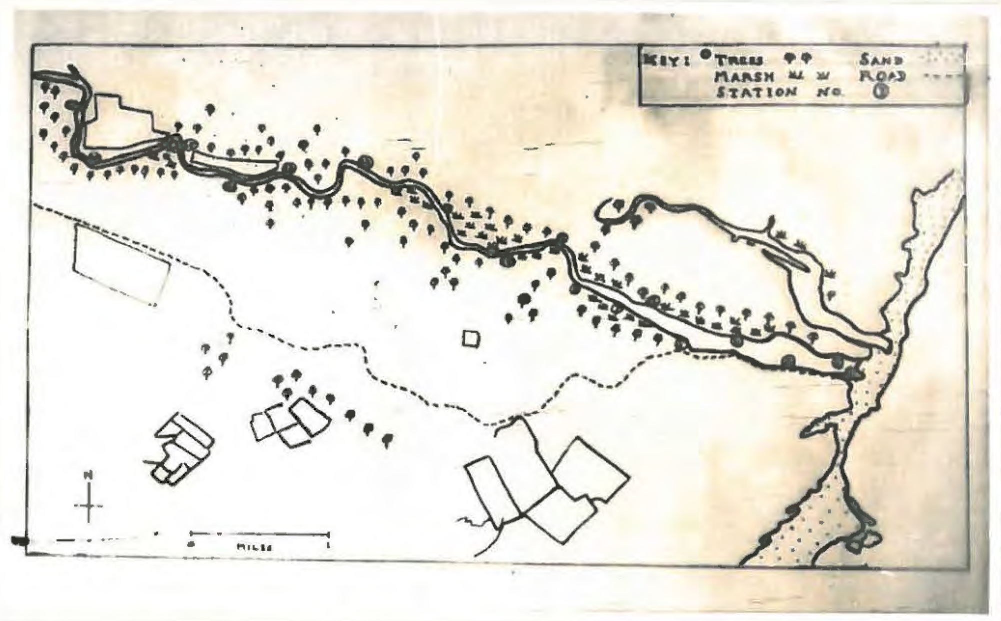

MAP OF THE KLEINMOND ESTUARY

AERIAL PHOTOGRAPH

of

The Lower Part of the Estuary.

PHYSICAL AND CHEMICAL CONDITIONS.

(a) Movements of water and variation in water-level.

As is almost inevitable in a blind estuary, there are no strong currents. Only at station seventeen, the upper rock barrier, is a distinct flow of water noticable and then only after rain. This does not mean, however, that the water lacks mixing. On the contrary, the water is normally very well mixed, as is indicated by the vertical uniformity of chemical conditions and of temperature. The chief factor responsible for this mixing of the water is undoubtedly the wind, assisted by the shallowness of the estuary, for in proportion to the volume a large surface is presented to the action of the wind. Readings of the water-level taken in February and March 1953 also support the view that wind is by far the most important factor influencing the movements of water when the lagoon is closed to the sea. For example, when a strong wind is blowing up-stream, the water-level at station one may drop by as much as four and a half inches, representing the shifting of what is really a very large volume of water.

Normally, tides have little effect on the blind lagoon, for even when high spring tides cross the sand-bar, no rise in water-level is usually apparent. The flow of water through the sand-bar, either from the lagoon into the sea or vica versa, must presumably decrease as the size of the sand-bar increases, but my observations indicate that it is probably never of very great significance. Though the water-level in the lagoon has probably not been lower than the mean water-level of the sea in recent years, it has on occasion been much higher. In July 1953, for instance, floods and high tides caused the water-level to rise by 2 ft 6 in. The water remained at this level for some months. Evidence of a much higher level is provided by the dead tubes of the worm Mercierella enigmatica, which in the upper reaches of the estuary extend to four and a half feet above the water level (28/2/53), showing that the water has in recent years been at that level and remained there for some time. To judge from my experiments on the rate of colonisation of this annelid, it seems likely that this area was covered by water, and saline water at that, for at least two months and probably longer. As the average depth of the estuary cannot be more than about three and a half feet, this rise in water-level represents an increase in the total volume of water of much more than one hundred per cent.

As the surface of the water is large compared with the volume, the weather hot for long periods and the wind often strong, much water must be lost by evaporation, yet between December 1952 and June 1953 the water-level of the lagoon varied about a more or less steady mean; nor did the water show any marked change in salinity. It is therefore assumed that the run-off from the surrounding land roughly balanced the water lost by evaporation. However, with a rainfall as erratic as this area receives, it is impossible to generalise on such a point.

(b) The Substratum.

The substratum of the estuary falls into four divisions, each grading into the next as one proceeds up-stream. They are;

(1) Sand

(2) Muddy Sand

(3) Sandy Mud

(4) Mud

The last three form a natural and slow gradation but the first division, sand, is out of place in the series, for this is wind-blown sand from the dunes and is sharply marked off from the muddy sand higher up the lagoon. Whenever the north-east wind blows, sand is deposited in the lagoon and on its shores up to a limit just below station two, above which the lagoon is sheltered by a hill on the left bank. At this limit, then, the pure sand ends and the muddy sand begins. This is of the utmost significance, for it is here also that a marked change in the fauna occurs; a change which, as will be shown, is greater than that due to any other single factor in the entire length of the estuary. This change in the fauna is not surprising, for whereas muddy sand may be rich in detritus, the dune-sand which is blown into the lagoon must be sadly lacking in organic matter. The substratum of this lower part of the lagoon is constantly being modified; and shifting sand is harsh environment for animal life.

Throughout the estuary, except where wind-blown sand prevails, the more or less brown mud overlies an almost black mud which often smells quite strongly of hydrogen sulphide. These reduced layers are of great importance as they severely limit the depth to which most species may penetrate, conditions being largely anaerobic. The black colour is due to hydrated ferrous sulphide, the overlying brown mud containing ferric oxide. The oxidation of the ferrous ion proceeds unaided under aerobic conditions and the animals which burrow in the mud bring about conditions suitable for this oxidation. Thus not only are the mud-dwelling animals limited by the reduced layers, but these layers are themselves limited by the nature and numbers of the animals living in the mud.

Galliher (1933) has much of interest to say on this subject and it is worth quoting certain passages from his paper which throw light on this discussion.

"A complex community of micro-organisms characterize the black marine muds and a number of biochemical reactions are involved in the formation of these muds. The areas of hydrotroilite (a hydrated Iron Sulphide) accumulation are dominantly alkaline and their development is the normal thing to expect where organic matter and sulphate are available."

There appear to be at least three types of bacteria involved in the sulphur cycle but from our point of view by far the most important are the "heterotrophic bacteria which utilize organic compounds and liberate hydrogen sulphide, among other things, during the decomposition of some of the proteins." It is probably these bacteria which account for the decay of molluscan shells in the reduced layers, for it seems unlikely that the calcium itself is being dissolved in such cases.

(c) Suspended Matter and the Penetration of Light.

Like nearly all the other conditions in the estuary, this must fluctuate greatly with the opening and closing of the mouth. When the estuary was visited in September 1952, the mouth was open and the river running fairly swiftly. At no place could the bottom be seen, even where the water was only a few inches deep, and the whole estuary had a dirty brown colour right down to the mouth. These observations were made when the tide was going out.

In marked contrast to this was the condition in February 1953, after the mouth had been closed for some time. The bottom could be seen clearly at all points below station two. Above this station the bottom was visible at a depth of three feet and at station six was no longer visible at a depth of one foot six inches. A Secchi Disc was used without success, for with one exception it could always be seen on the bottom. The exception was at station ten, where it disappeared at a depth of a little over seven feet.

The Lagoon from Station Three

(d) Temperature.

Records of temperature were made in various parts of the estuary from January to September, 1953. (The majority of these readings are given in Appendix B.) The highest temperature recorded is 33.0°C (26/1/53) and the lowest 11.5°C (30/6/53). It should, however, be noted that the record of 33.0°C was made in the shallow bay behind station three and that the highest temperature recorded in the main body of water was 29.75°C (on the previous afternoon).

It has been suggested that the rate of increase or decrease in temperature is often more important to the fauna than the temperature at any given time. Observations were thus made on the rate of temperature change. For any given period this rate of change is not the same all over the estuary, but varies with the depth of water. Thus at station one, where the water is two feet deep, the temperature was found never to fluctuate more than 0.5°C in an hour, while in the bay behind station three, in about two inches of water, fluctuations of 2°C in an hour were not uncommon.

Horizontal variations in temperature were often found to be quite considerable even over a small area of water. At station one, for instance, the difference in temperature between water 20ft from the shore and water 2ft from the shore was commonly as much as 2.5°C. This again may be related to the depth of the water. Vertical variations were much less marked.

Temperatures were taken in mud at depths of three inches and six inches, both under water and on the shore. The results agree with those of Nicol (1935) in that "the temperature in mud varies little from that of the overlying water but may show a lag of a degree or two with rapidly rising or falling temperature." This was found to be true both in sand (at station one) and in mud (at station nine). The difference in temperature between the three inch depth and the six inch depth is liable to be greater on shore than in mud or sand under water.

(e) Salinity.

Though comparatively few salinity determinations have been made, conditions in the estuary appear to be quite clear and straight forward. When the lagoon is open to the sea the estuary is tidal and the usual salinity gradients exist. When the sand-bar begins to build up, the sea continues to enter the lagoon as the tide rises, but the outflow from the river is to some extent checked. As the bar increases in height the average water-level of the lagoon rises. Eventually there is no flow at all out of the lagoon, except for the seepage through the bar which, as has been stated, is very slight. At last the lagoon is completely cut off from the sea and even high spring-tides fail to cross the bar.

Now at first, as would be expected, the water at the bottom end of the lagoon has approximately the same salinity as that of the sea and the salinity decreases as we proceed up stream. This gradient tends to become less and less marked as the estuary remains closed, mostly due, no doubt, to mixing caused by the wind. The salinity at station one falls while the salinity at station seventeen rises. The salinity at the bottom end of the lagoon is, however, replenished as high-tides cross the sand-bar, but the "flattening" of the gradient becomes more apparent when the estuary finally becomes completely isolated from the sea.

This series of phenomena is modified by rain-fall and by evaporation. For instance a water-sample taken by Professor J.Omer-Cooper in October, 1951, had a salinity of 41.18 ‰ (i.e. very much higher than that of the sea), presumably due to excessive evaporation. It is interesting to note that under such conditions invasion from the sea, should this occur, would decrease the salinity of the lagoon.

After heavy rains, which often occur in this area, the upper reaches become quite fresh and the salinity of the lagoon itself may drop suddenly with the violent rise in water-level.

Table three gives a list of the readings taken. The Knudsen method was used to obtain these. All the samples were taken from the surface water and it is doubtful whether any significant vertical gradient would indeed exist,when the mouth is closed,in so shallow an estuary.

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Station Number	3/2/53	12/2/53	21/2/53	25/2/53	14/3/53	30/5/53	30/6/53	26/8/53	10/9/53	9/10/53
1	28.37	27.65	27.29	35.68			34.87		27.65	
2	28.37	27.56	27.29	34.33	27.65	26.29	34.33	28.37	27.65	27.29
3	28.19		27.20				30.81			
4				30.81				28.01		
5	28.10	27.29		28.19	27.47			27.83		
6		27.20		27.83	27.20			27.47		
7	28.01		27.20		26.83			27.20		
8			26.83	26.92						
9			26.56		26.92			26.92		
10				26.56						
11			25.84					26.29		
12				24.49	26.02					
13				24.04	25.84			25.84		
14					25.66					
15				22.86				24.49		
16					24.04			24.31		
17				21.06	23.86			24.13		
18					3.28					

Table 111

Salinity Readings

(Station 18 refers to the fresh water above the estuary)

Osmotic Pressure

Several readings of the osmotic pressure were taken by measuring the freezing-point lowering due to the dissolved substances. This method, using a Beckmann Thermometer, is very accurate but takes a great deal of time. Therefore, only enough readings were taken to establish that the osmotic pressure was proportional to the salinity.

The following readings are given in the number of degrees centigrade lowering of the freezing-point.

Date	Station No. 1	2	3	5	8	9	17
3/2/53			1.534				
25/2/53	1.968			1.533	1.483		
14/3/53		1.525				1.482	1.315

Table of Osmotic Pressures

These readings, being proportional to the salinity measurements made on the same samples, indicate that by far the greater part of the dissolved substances is derived from the sea.

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(g) The Carbon Dioxide System.

Readings of pH were taken under field conditions and checked in the laboratory by electrical methods. The apparatus used in the field consisted of a Lovibond Comparator fitted with a B.D.H. Thymol Blue Disc. By comparing the colour-disc with solutions of known pH it was found possible to take readings correct to 0.05.

The water in the estuary was at all times quite strongly alkaline, the lowest reading being 8.20 and the highest 8.60. It thus seems unlikely that the fauna of the estuary is much affected by changes in hydrogen ion concentration. Table 1V gives a list of the readings taken.

In March and May, 1953, pH readings were taken at night as well as by day. The Lovibond Comparator showed no variation, which must thus have been less than 0.05 and have had no appreciable affect on the fauna.

Some investigation into the significance of pH readings was done, as Professor Omer-Cooper had suggested to me that the degree of neutrality was perhaps more important from the ecological point of view. It is true that the pH does not give an accurate measure of the degree of neutrality, for pH varies with temperature (pure water at $0^{\circ}C$ has a pH of 7.4 as compared with 7.0 at $25^{\circ}C$). However, this is because the dissociation constants vary with temperature, and the effect on the fauna is a real one.

Readings of Alkaline Reserve were taken, following the Wattenberg Method. "A stream of air, washed free from CO_2 is passed through 200cc of the sample of water to which 10cc of N/20 HCl has been added and the liquid heated to boiling in order to drive off all the CO_2 set free. The hot liquid is then back titrated with N/20 barium hydroxide, using a mixture of three parts of Brom cresol green and two parts of methyl red as indicator."

"The alkali reserve of any natural water is important, as on it largely depends the amount of carbon dioxide available for photosynthesis, thus influencing indirectly the supply of oxygen. ...... It is also closely related to the hydrogen ion concentration." (Nicol, 1935).

The readings of alkali reserve are given in <u>Table V</u>.

Date

Station Number	15/1	3/2	8/2	12/2	21/2	25/2	14/3	17/4	5/5	6/5	21/5	30/6	26/8	10/9	9/10
1	8.60	8.60	8.60	8.55	8.60	8.60	8.45	8.60	8.55	8.55	8.60	8.55	8.50		
2	8.60	8.55		8.50	8.55	8.55	8.50		8.55	8.60				8.55	8.45
3	8.55	8.55		8.50		8.55	8.60	8.55			8.50		8.45		
4	8.55	8.60	8.50			8.55	8.50		8.50					8.50	8.45
5			8.50	8.50	8.50		8.50			8.55			8.45		
6				8.55		8.50		8.50	8.50		8.55				
7					8.50		8.50			8.50					
8						8.55		8.50	8.50		8.45		8.50		
9						8.45	8.40		8.45	8.45			8.45		
10						8.45	8.40	8.45		8.45					
11							8.40	8.40	8.35	8.40			8.35		
12							8.40	8.40	8.40	8.35			8.35		
13							8.30	8.35	8.30	8.30			8.25		
14							8.20	8.30	8.20	8.35			8.20		
15							8.40	8.35	8.30	8.30			8.30		
16							8.40	8.35	8.35	8.30			8.40		
17							8.40		8.35	8.30			8.35		
18							8.20		8.20	8.20			8.20		

Table 1V

pH readings.

(18 refers to the fresh water above the estuary.)

Readings of Alkali Reserve

(Excess Base)

Station No.		14/3/53	6/5/53	30/6/53	26/8/53
	1	.0024	.0022		
	2	.0024	.0023	.0021	.0023
	3	.0022			.0021
	4	.0022			
	5	.	.0018		.0020
	8	.0018		.0019	
	9		.0017		
	12	.0016		.0015	
	15	.0015			
	17	.0012		.0013	

(The readings are expressed in Normalities.)

Table V

(h) Oxygen Content.

In general the oxygen content would appear to be fairly high, despite the paucity of aquatic flora, for nowhere is the estuary very deep and the surface presented to the air is large in proportion to the volume of water. Another, and perhaps more important, effect of the shallowness of the estuary is that the wind mixes the water and thus little variation in oxygen content is to be found at varying depths. The respiratory currents set up by Callianassa undoubtedly help in this respect and it is probable that even the oxygen content of the inhabited mud is quite high (though no actual readings are available), for black reduced mud is uncommon within a foot or two of the surface. This presents a marked contrast with estuaries such as the Zwartkops at Port Elizabeth, where the smell of H_2S is often very strong.

Readings of the oxygen content were taken on three occasions. The sampling-bottle was arranged so that the sample was not contaminated with oxygen from the air, and analysis was carried out according to the Winkler Method. On August 26th the oxygen content at station one, a foot below the surface, was 7.1 p.p.m. and three feet below the surface measured 6.7 p.p.m. On September 10th the oxygen content 1 inch from the bottom at station nine was 5.5 p.p.m. but on October 9th, with a strong wind blowing, measured 6.8 p.p.m. These readings were in about 6 feet of water, where Callianassa is absent.

Station Six

(i) Phosphates

A number of rough phosphate determinations were made by the comparator method, first converting all the phophorus to $-PO_4$. This method, applied to the Lovibond Comparator, gives readingsd correct to five parts per million.

The readings taken are at first sight startling, even though South Africa is notably deficient in phosphates, for out of twenty-five samples taken all over the estuary at differeht times of the year, only one sample showed a phosphate content of more than 5 parts per million. This single exception was a sample taken from the bottom end of the lagoon on July 1st, 1953, when high seas were breaking over the sand-bar into the lagoon. This reading is in the region of 7·3 parts per million.

(j) <u>Nitrates</u>.

A number of Nitrate readings were taken in the field and in the laboratory. The comparator method was adopted, using a Lovibond Comparator fitted with the appropriate Nitrate Disc. The readings indicate that more nitrate is present in winter than in summer in the closed lagoon.

In February water from the lagoon had a nitrate content of 30 p.p.m.,while water taken from station ten showed a reading in the region of 27.5 p.p.m. On April 17th the reading from the lagoon was 25 p.p.m. and at station ten had risen to 32.5 p.p.m. A further set of readings was taken in June when water both from the lagoon and from the river had a nitrate content of 35 p.p.m. In June a reading of 42.5 p.p.m. was taken on water from the lagoon, and 45 p.p.m. is recorded from August. In October,values had fallen to 30 p.p.m.

It is not possible to draw many conclusions from these figures. Even the fluctuations between summer and winter are not very great and it may be just coincidence that this pattern of differences occurred during 1953. It would seem, however, that the phosphate concentration is likely to prove a limiting factor rather than the concentration of nitrates.

The Flora of the Estuary.

Aquatic flora is not abundant in the estuary. Zostera is completely absent and Ruppia, though quite common, occurs only in the shallows, leaving the deeper water colonised only by algae. Ruppia is present throughout the estuary, but is less common at the foot of the lagoon than it is in the middle reaches.

The largest of the algae is Codium tenue, which is very common above station two. Other algae taken at the estuary include two species of Enteromorpha, Ectocarpus, Cladophora Sphacelaria, Dictyota, and Gelidium. These are all usually found as drift, but Ectocarpus and Cladophora have been found epiphytic on Ruppia and on Codium.

The shore flora is dominated by various species of Arthrocnemum, particularly in the middle reaches of the estuary. Arthrocnemum perenne (var. radicans) is the pioneer and tolerates occasional submergance, even for long periods of time. Arthrocnemum australasicum and A. africanum occupy more conservative positions, higher up the bank and in the salt-marshes on both shores, where submergence in neither as common nor for such long duration.

Two species of Salicornia are present but are much less common than Arthrocnemum. Salicornia meyeriana is to be found in the salt-marshes, while a second species, much rarer, tends to occupy the areas immediately behind the Arthrocnemum perenne.

The common grass of the estuary, found from station two to above station seventeen, is Sporobolus virginicus. Stenotaphrum secundatum also occurs in isolated patches in the salt-marshes.

In the upper reaches are to be found the bulrush, Typha, and, nearer the water, and extending down into it, the sedge, Scirpus and Priorium. The Bamboo-like Phragmites also occurs in this area.

At the foot of the lagoon shore flora is rare, the commonest plants being Juncus and Cotula. The wild-fig, Disphyma, and Aster are also present and these extend up into the salt-marshes.

The Water-level rises rapidly
(30/6/53)

VII. List of Fauna with Biological Notes.

Phylum: Cnidaria

Class: Hydrozoa

Hydractinia sp.

A species of *Hydractinia*, shortly to be described by Dr. N.A.H.Millard, is common in the lagoon, growing on the shells of the gastropod *Nassarius kraussianus*. Dr.Millard tells us that this Hydrozoan is common in estuaries all round the east and south coasts of South Africa.

In May, 1953, small hydrozoan medusae were common in the plankton. It is possible that they are the medusae of the above species.

Class: Scyphozoa

Order: Rhizostomeae

Medusae are fairly common in the river in some years and though none were seen during the course of the survey, a specimen taken by Prof. J.Omer-Cooper in 1947 is in the author's possession.

Phylum: Aschelminthes

Class; Nematoda

Small white nematode worms are common in the sand and mud from station two to station eleven and are present in small numbers at station twelve. They are not found below station two.

Phylum: Annelida

Class: Polychaeta

Family: Nereidae

Ceratonereis keiskama Day

This species is abundant in the mud from station two to station seventeen and is even present in the fresh water above this station. It has also been taken from under stones and under bark at stations five, eight, and twelve. It appears to be completely absent from the sand below station two.

Dendronereis arborifera Peters

This nereid is not as common as the species listed above, but has been taken from submerged branches at stations three, six, seven and ten. It was also taken from the mud at station ten and was present in a plankton sample from station thirteen on March 14th, 1953.

Family: Spionidae

Prionospio aucklandica

Common from station eleven to station fifteen in mud. On March 14th it was recorded also from station ten.

Family: Sabellidae

Oridia parvula

This species was very abundant at station fourteen in March, 1953, and was present at station thirteen.

Family: Serpulidae

Mercierella enigmatica Fauvel

This tube-forming worm, undoubtedly the most abundant annelid in the estuary, is apparent on almost every solid object from station two to station seventeen. It's range is remarkably well defined; at the latter station the tubes do not peter out but stop quite suddenly half way up the rock barrier. The point at which they stop, measurable to within an inch or less has been taken as the upper limit of the estuary. The lower limit of their range is no less well-marked, for no tubes occur below the point at which the coarse dune-sand begins, while stones placed only a few feet above this point are readily colonised.

Various objects were placed in the estuary at several stations in order to observe the rate of colonisation of this worm. All that can be said at this stage of the research is that Mercierella enigmatica is capable of colonising both rock and wood with extraordinary rapidity given the right conditions. The following factors appear to influence this rate:

(1) Temperature. The rate of colonisation is definitely slower in winter than in summer. It must, however, be admitted that factors other than temperature may be partly or even wholly responsible for this difference.

(2) Objects nearer the surface are colonised more rapidly than those in deeper water. This may be due to a higher oxygen content of the water, or the fact that such objects are

generally freer from silt. *Mercierella* is certainly unwilling to colonise surfaces on which there is a layer of silt.

(3) Salinity. The extent of it's range would indicate that the worm will colonise between very widely separated limits of salinity. Rapid changes of salinity,however, probably effect the rate of colonisation.

(4) The food supply must effect the rate to a certain extent.

Phylum: Polyzoa

Family: Membraniporidae

Near *Membranipora*. This Ectoproctan has been found encrusting weed at stations five, six, seven, and nine. It is not very common.

Polyzoa are fairly common encrusting solid objects from station four to station eleven, particularly on the tubes of *Mercierella enigmatica*. This genus is also near to *Membranipora* and may be the same species as that listed above.

Tubes of Mercierella enigmatica on stone placed in water at station four for three months.

(6/5/53)

Phylum: Mollusca

Class: Lamellibranchiata

Order: Filibranchiata

Modiolus capensis Krauss.

This small species of mussel is common in the estuary, being most abundant between stations eight and thirteen, but extending from station two to above station sixteen. It's abundance is limited by the number of solid objects available for colonisation, for though it occurs attached to weed and has been found on the mud itself, it does not appear to do well in such situations. It is not averse to colonising objects already colonised by Mercierella enigmatica.

Order: Eulamellibranchiata

Solen capensis Fischer

This "pencil bait" is common between stations two and eleven, in places not heavily colonised by the prawn Callianassa kraussi. It has already been pointed out that "the activities of the prawn make the sand unstable and so unsuited to the type of hole Solen prefers." (Scott, Harrison, Macnae. 1952). One living specimen was taken from the sand near station one (12/2/53).

Psammotellina capensis

This species is common from station one to station nine and a single specimen has been taken from the mud at station eleven (14/3/53). It occurs just under the surface of the mud in shallow water.

Tellina regularis Smith

Stations eight and nine. Uncommon. (10/9/53 and 14/10/53).

Donax sp.

A small species of Donax is present bur rare in the sand near the mouth of the lagoon. A larger species is found on the sea-shore to the left of the lagoon.

C Teredo sp.

The ship-worm is abundant in the laggon and not only bores into submerged branches but also attacks the boats. It is not found below station two and is uncommon in the upper reaches of the estuary.

Class: Gastropoda

Assiminea ?sinensis G.Nev.

This species is common on weed throughout the lagoon and the lower reaches of the river.

Assiminea sp.

A second species of Assiminea is very common in the area in which muddy sand prevails; that is from station two to station five. It occurs on the shore near the water and makes tiny tunnels in the damp sand. There is a photograph of these disturbances on page 51.

Nassarius kraussianus (Dunker)

This Gastropod is a scavenger, filling the same sort of niche occupied by Bullia on the sea-shore. It collects round decaying material in large numbers but has also been observed to ingest living algae.

Disturbances caused by Assiminea sp. (X 1)

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Phylum: ARTHROPODA

Sub-phylum: CRUSTACEA

Class: Ostracoda

Fairly large ostracods were taken in fresh water above station seventeen and small ostracods (Stenocypris ?) are recorded from the estuary just below this station.

Class: Copepoda

As has been found at the Klein River, Hermanus, Cyclopoids and Harpacticoids form the bulk of the plankton throughout the estuary.

Class: Cirripedia

Balanus elizabethae Brnrd.

Despite the variety of shapes and sizes, this appears to be the only species of barnacle present. The differences in shape are due to the degree of crowding and the amount of exposure to which the animals are subjected. The species is common on both rocks and submerged wood from station two to station twelve. Dead specimens but no living individuals have been taken from above this station, right to the top of the estuary.

Class: MAlacostraca

Division: Peracarida

Order: Mysidacea

Gastrosaccus sp.

These mysids are common throughout the estuary and were taken in all the night plankton-samples. During the day they have a tendency to enter the burrows of the prawn Callianassa kraussi.

Monopodopsis sp.

A species of this genus was present but very rare in the lower part of the lagoon in 1953. However, the author has in his possession a plankton sample taken by Professor J.Omer-Cooper in 1951, and in this sample, taken at night in the lagoon, the species is quite common.

Order: Isopoda

Cirolana fluviatilis Stebb.

This isopod is common from station two to station seventeen and has also been found occasionally below station two. It has been taken from the mud as well as from under stones and submerged branches. It occurs in small numbers in plankton samples.

Cyathura carinata (Kroyer)

This elongate isopod is abundant all over the estuary with the exception of the bottom end of the lagoon. It does not appear to swim and has been taken only from the mud. In February 1953, it was so abundant in the bay behind station three that a sieve-full of mud was found to contain fifty-three individuals.

Eurydice longicornis (Studer)

The coarse sand forming the substratum below station two appears to provide an ideal habitat for Eurydice. It is very abundant in this region but is not found elsewhere in the estuary.

Pontogeloides latipes Brnrd

Similar in general appearance to *Eurydice longicornis*, this species occurs in exactly the same area; below station two. It is not as common as the former species.

Exosphaeroma hylecoetes Brnrd

This Sphaeromid appears to be the most abundant isopod in the estuary. It is to be found on submereged objects from station two to station thirteen. It is also common under stones and has been found in large numbers on the banks, feeding on decaying plants. *E. hylecoetes* appears to display a polychromaticism similar to that described for other Sphaeromids.

Tylos capensis

This terrestial isopod is usually found on the sea-shore. It is included here as it is common on the shores of the lagoon at night, where it comes presumably in search of food. It has never been taken above station two and has not been found near the lagoon during the day.

Order: Tanaidacea

Apseudes sp.

This apparently new species, shortly to be described by the author, is common throughout the estuary above station two. It occurs in the top layer of the mud.

Order: Cumacea

Two species of Cumacea have been recorded. One of these is very common in the mud from station two to station fourteen. Both appear to be new species.

Order: Amphipoda

Corophium triaenonyx Stebb.

Living in small,soft tubes, this amphipod occurs from station two to the top of the estuary. It is most abundant from station eight to station fifteen (the first rock barrier), and has colonised almost every solid object between these stations. It makes it's tubes also on water-plants and even on the surface of the mud. It was present in most of the plankton samples.

Melita zeylanica Stebb.

Aquatic weed throughout the estuary, except for the lower part of the lagoon, provides shelter for large numbers of *Melita*. It is most abundant at the top of the lagoon. In February 1953, an algal growth from station nine, which barely filled a one pound jam-jar was found to harbour 1012 individuals of this species.

Parorchestia rectipalma Brnrd.

This is another of those species which occur only below station two. It is fairly common under stones and decaying matter, both in the water and on the shore.

Talorchestia australis Brnrd.

Like *Parorchestia*, this amphipod has been taken only from the bottom end of the lagoon. It, too, is found under rocks and jetsam and it makes shallow burrows in the sand.

Hyale sp.

A marine amphipod, which comes into the lagoon when high tides cross the sand-bar and when the mouth is open. It is unable to establish itself in the blind lagoon and dies off within a few days.

Urothoë pulchella (Costa)

This is yet another species inhabiting only the coarse sand at the lower end of the lagoon, where it is common. It is interesting to note that nearly all the species restricted to the lower end of the estuary are marine forms, and that all are light in colour, being inconspicuous against the white sand. *Urothoe* is no exception to these generalisations.

Grandidierella lutosa Brnrd.

Though previously recorded from the lower part of the Klein River Estuary, Hermanus, at the Kleinmond River this species is most abundant at the top of the estuary and invades the fresh water above it. It is found in tiny burrows in the top layer of mud.

Varuna litterata ($x\frac{1}{2}$)

Division: EUCARIDA

Order: DECAPODA

Sub-order: Macrura

Penaeus japonicus Bate.

Though less common than *Leander pacificus*, this prawn is fairly abundant in the lower part of the lagoon. It has not been seen above station five. Other species of *Penaeus* are said to occur from time to time, but *P. japonicus* was the only one taken during the course of the survey.

Leander pacificus Stimps.

This is the common shrimp in the estuary, being most abundant in the lagoon, where it may be seen in large numbers at night. By day it appears to seek shelter in the weed-beds and under submerged branches. It is also common in the lower reaches of the river and has been taken as high up-stream as station twelve. Colour changes were observed in this species. Specimens taken from the lagoon are transparent and white, but if placed in a glass container among the rocks in the river, they soon take on a brown colour which matches the surroundings admirably.

Sub-order: Brachyura.

Hymenosoma orbiculare Desmarest.

This typically estuarine species is the most abundant crab at the Kleinmond. Most common at the lower end of the lagoon, its range extends at least as far as station thirteen. These lie partially buried in the sand, particularly during the day, and may be found walking over the surface at night, when they may also be observed clinging to weed. Shallow water seems to be preferred. This species walks forwards instead of sideways; rather unusual for a crab.

The Zoeae of Hymenosoma orbiculare were commonly found in plankton samples both from the river and the lagoon, being most abundant in February, between stations eight and nine. On one occasion (14/3/53) they were taken as high upstream as station fifteen.

Cleistostoma edwardsii McLeay

This crab is very uncommon in the estuary, perhaps because of the absence of Zostera; perhaps because the mud is not suitable for colonisation. It has, however, been taken at station three (15/2/53) and at station four (20/2/53 and 28/4/53). Two of these specimens were juveniles taken from Callianassa burrows.

Varuna litterata (Fabr.)

This species of crab, specialised for swimming, is found in the upper reaches of the estuary and extends into fresh water where it is fairly common all the year round. Young crabs have been taken regularly above the rock barrier at station fifteen, but larvae have never been found. It may well be that these crabs do not breed in the river, for they have on several occasions been seen swimming down river towards the sea. Professor Omer-Cooper tells me that in previous years they have been caught in large numbers on their way to the sea, when nets were stretched across the lagoon to trap them. This appears to be the largest crab in the estuary.

Ocypode ceratophthalmus (Pallas)

This is not a truly estuarine species, living as it does in holes in the sand along the sea-shore. However, it is included here as it often occurs along the banks of the lagoon at night, presumably in search of food. It has never been seen near the estuary during the day. Another species of this genus, *O. kuhlii*, is common on the sea-shore, but has never been taken on the banks of the lagoon.

Sub-order: Anomura

Callianassa kraussi Stebb.

A special study was made of this burrowing prawn, as it soon became apparent that this is an animal of the utmost importance in the bionomics of the estuary. Indeed its influence on the ecology can hardly be overstressed ; there can be few aquatic organisms which are not affected by its presence to a greater or lesser degree. By weight it must be almost certainly the most abundant species present and few species are more widely distributed in the estuary, for it occurs from the lower end of the lagoon to above station fourteen. It is not abundant below station one and is absent at the extreme bottom end of the lagoon, probably because sand from the dunes is constantly being blown into this region and the substratum is hence unstable.

Counts were made of Callianassa holes at several stations. This does not give an absolute indication of the number of animals present but is useful in estimating the comparative abundance. In each case ten areas, each of one square foot, were measured off and the number of holes in each area counted. The average for one square foot was then calculated and reduced to the nearest whole number. The following averages were obtained by this method:-

Bottom end of lagoon (July 1953)	------1	per sq. ft.
Station one	---------------- 10	" "
Station two	---------------- 30	" "
Station three	---------------- 58	" "
Station four	---------------- 56	" "
Station five	---------------- 48	" "
Station six	---------------- 56	" "
Station seven	---------------- 56	" "
Station eight	---------------- 60	" "
Station nine	---------------- 59	" "
Station ten	---------------- 54	" "
Station Thirteen	---------------- 23	" "

Callianassa is thus far more abundant here than in the Klein River Estuary, Hermanus, where a maximum of 25 holes per square foot is recorded.

Throughout it's range it's holes occur to a depth of approximately two feet below the surface of the water (14/3/53) and sometimes to two feet six inches in sheltered places. The burrows also extend above the water-level to a height of about six inches and invade the areas dominated by Arthrocnemum where this is not very abundant.

The depth to which the burrows penetrate the mud is by no means constant, but shows a correlation with the depth below the water-table. Large individuals occur at a depth of about three feet six inches where the openings of the burrows are above the water-level, but penetrate less and less deeply into the mud as the water overlying it becomes deeper, burrowing to about a foot where the water is two feet or more in depth. Thus the burrows of the prawn extend to a depth of roughly three feet below the water-table. (These observations were made during the first half of 1953, when the water-level was approximately that of the sea.)

The habits of *Callianassa kraussi* were studied by keeping individuals in "limoria" and observing their activities. Limoria are said to have been invented by Hugh Main some time before 1914, when they were used for the study of soil-burrowing insects. The limoria used by MacGinitie in the study of *C. californiensis*, and copied by the author are "frames holding two plates of glass about three-quarters of an inch apart, filled with mud and submerged in aquaria." The burrows made by the prawn in such limoria incorporate the glass into the sides of of the tubes. The habits of *C.kraussi* appear to be almost identical with those of *C.californiensis* as described by MacGinitie (1934). There is little merit in repeating here what has already been stated by him and there is little to add. One point worth making is that the depth of the first chamber in which the animal turns round below the surface of the mud, varies considerably from individual to individual, being anywhere between two and twelve inches below the opening of the burrow. These figures are from field observation and are not apparent from specimens kept in limoria. On consideration, itseems likely that the variation observed in the field is due to the fact that mud from the surface is either eroded away or added to after the burrow has been excavated.

The burrows are constantly being extended and mud from the ends of the burrows deposited at the surface. As has been pointed out by MacGinitie, "the continual turning over of the soil and the aeration of the subsoil by the burrows of this animal is important to the entire community of mud-dwellers." This is an understatement as far as the Kleinmond Estuary is concerned, for there seems to be little doubt that large volumes of the mud are inhabitable only because Callianassa is present. The sulphur-cycle in muds has already been mentioned and the anaerobic conditions of the reduced layers stressed. The depth at which the black mud begins is largely determined by the nature and numbers of the animals living in the oxidised layers above it. Of all these animals Callianassa has undoubtedly the greatest influence, for where it is most abundant the reduced layers begin below the burrows, leaving up to three and a half feet of oxidised mud above. In the few places where thw prawn is absent the black mud often begins an inch or even less below the surface. Where

Callianassa is present but uncommon the burrows may extend into the black mud but are then surrounded by brown, oxidised mud.

There is a flow of water through the burrows as the animals set up respiratory currents and this is an important factor in mixing the water and establishing uniform conditions both in the water and in the mud.

Many animals take refuge in the burrows of Callianassa, though no actual commensals have been found at the Kleinemonde. Water from the burrows has been found to contain a surprisingly dense population of Protozoa, notably Ciliata but also Flagellata and Rhizopoda. Copepoda are rare in these samples, but Mysidacea are very common during the day. The young of Cleistostoma edwardsii appear to frequent the burrows. Where the openings occur above the water they are made use of by spiders of various species.

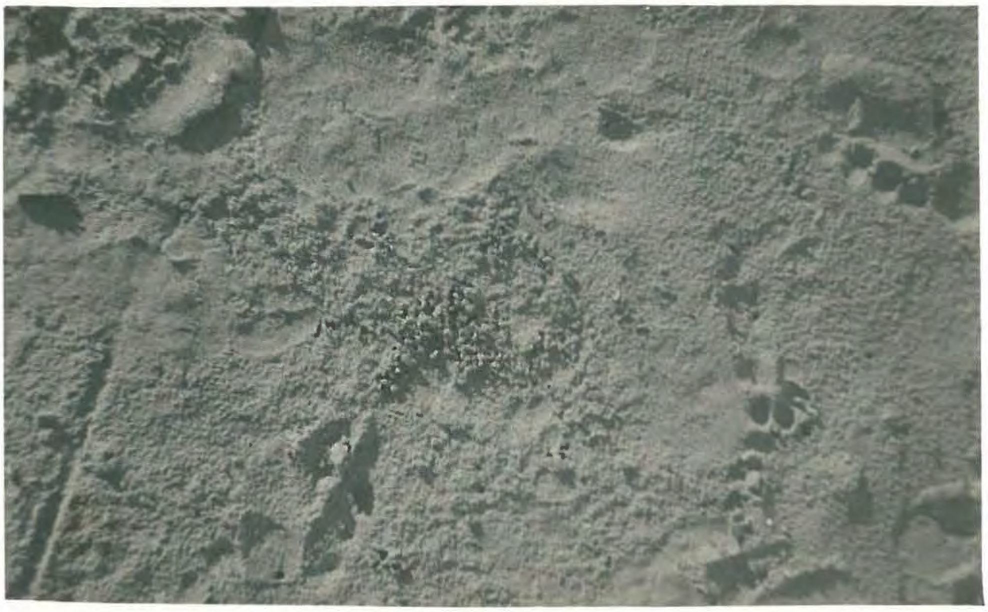
Specimens of Callianassa were collected throughout the year and females carrying egges were found at all seasons. The greatest percentage of ovigerous females, however, occurred in January.

Upogebia africana (Ortmann)

Though there are no burrows of this species of prawn in the Kleinmond Estuary, it is recorded for two reasons. Firstly, live adults have on many occasions been taken from the surface of the mud at various stations and secondly a first-stage *Upogebia* larva was taken in a plankton sample from the lagoon on the 7th of May, 1953. This is accounted for by the fact that fishermen use this prawn as bait, bringing it with them from Port Alfred, where it is common. Unused bait is as a rule thrown into the water. These adult *Upogebia* are apparently unable to colonise the substratum, but in the case of ovigerous females, the eggs may develop. An occasional first-stage larva in the plankton is thus interesting but perhaps not surprising.

Diogenes brevirostris Stimps.

This hermit crab appears to have a very limited range, occuring only at and below station two. In effect, this means that it occurs only on pure sand. At this lower end of the lagoon it is very common.



Holes made in mud by Staphylinids
(Philonthus sp.)

Class: INSECTA

The follwwing list of insects is certainly incomplete. No attempt has been made to collect systematically all the insects occuring in and near the fresh water above station seventeen, but those that have been caught are listed.

Order: Orthoptera

Tridactylus capensis Sauss.

This small gryllid is limited to an area of course sand near station one. Within this area it is remarkably abundant. Over a hundred were taken in five minutes with a small net on 20/2/53. However, outside this area it does not occur at all. Its occurence may be linked with the fact that fresh water seeps up through the sand in exactly the same area as that in which the gryllid occurs. At the Gamtoos River Mouth and at Sea View, Port Elizabeth, the author has found them under identical circumstances, i.e. in coarse sand under the influence of fresh water.

Gryllotalpa africana P.B.

The mole-cricket was very common in February and March, 1953, but since then it has been less abundant. It was most common between stations two and five on the right bank of the estuary, but has been taken also at station nine.

Gryllodes sp.

A cricket belonging to this genus is very common along both banks from station three to the top of the estuary.

Order: Ephemeroptera

May-fly nymphs were common above station seventeen in March, 1953.

Order: Odonata

The following have been recorded from the upper reaches of the estuary.

Ceratogomphus ?pictus Selys.

Orthetrum abbotti Calvert

Trithemis ?artericosa (Burm.)

Trithemis strictica (Burm.)

This blue Anisopteran is very common and has been taken as far down as the mouth of the estuary, as has the red Dragon-fly, Crocothemis erythraca (Brulle)

Pseudagrion ?angolense (Selys)

This Damsel-fly is very common at station seventeen.

Order: Hemiptera

Sub-order: Heteroptera

The following families are represented in the fresh water above station seventeen;

Hydrometridae. Fairly common.

Gerridae. Abundant.

Naucoridae. (14/3/53)

Nepidae. Ranatra sp. (14/3/53)

Notonectidae. Common.

Corixidae. Common.

Order: Trichoptera.

Trichopteran larvae were found in the upper reaches of the estuary in March, 1953.

Order: Coleoptera

Family: Cicindelidae

Cicindela capensis L.

This extremely active beetle is very abundant all the year round, especially on the shores of the lower part of the lagoon.

Family: Carabidae

Pogonus lamprus Wied.

These small beetles are, perhaps, the most abundant animals collected from near the water's edge. They occur throughout the length of the estuary except where wind-blown sand prevails. They may make their own holes in the sand, but prefer to use holes made by other animals. They do not penetrate far below the surface of the soil and are very easily disturbed by stamping.

Omophron sp. (near depressus)

Station six, 22/2/53.

Family: Heteroceridae

Heterocerus sp.

There are two species of Heterocerus beetles at the

Kleinmond, both associated with Staphylinids. One appears to be associated with _Bledius_ _pilicollis_, the other with _Philonthus_ sp. The exact relationship is not clear.

Family: Hydrophylidae

Coelostoma _rufitarse_ Boh.

Fairly common throughout the estuary.

Family: Gyrinidae

Aulonogyrus _alteratus_ Reg.

Common in the fresh water above station seventeen.

Scarabidae;

Phyloctonius sp.

Dyschirius sp.

Family: Staphylinidae

Staphylinids are much in evidence at the estuary, occuring along the muddy shores above station two, as well as in an area of coarse sand near the mouth. They are as follows:

Bledius _pilicollis_ Bernh.

Most common along the left bank, from station two to station eight, this species also occurs in an isolated patch near station three on the right bank.

Bledius sp.

This is a small black species occuring only in the coarse wind-blown sand near the mouth, in that area where fresh water seeps up through the sand. It thus occurs in the same area exactly as that in which the picnomole-cricket, _Tridactylus_ _capensis_ is to be found. Like Tridactylus, this Staphylinid is very abundant in this small area and forty have been taken from an area of sand six inches square (5/2/53). The same species has been taken under exactly similar conditions at the Gamtoos River Mouth and on the beach at Sea View, Port Elizabeth.

Philonthus sp.

This Staphylinid appears to favour the same kind of habitat as does Bledius pilicollis. However, whereas Bledius is to be found mostly on the left bank, Philonthus is limited entirely to the right bank. The reason for this is not at all clear, the soil on both banks being very similar.

Order: Diptera

Family: Culicidae

Culicid larvae are common in the fresh water above the estuary.

Family: Chironomidae.

Chironomid larvae were common all over the estuary, especially in January and February, 1953. Adults were taken in large numbers in May.

Family: Ephydridae

These flies are abundant along the shores of the lagoon.

Class: Arachnida.

Sub-class: Araneida

Several species of spider are common on the banks of the estuary.

Class : Pisces

The variety and abundance of fish in the Kleinmond Estuary is largely dependent on the opening and closing of the mouth, for it would seem that few species breed in the estuary and the majority of adults find their way out to sea when the mouth opens, being replaced by juveniles seeking shelter. Thus the longer the mouth has been closed, the larger are the specimens taken.

No Elasmobranchii have been taken in the estuary during the course of the survey, though they are said to occur from time to time. The list of Teleostei must of necessity also be incomplete, as many species undoubtedly visit the estuary only occasionally.

Elops saurus Linn.

The Cape Salmon is a fairly regular visitor to the lagoon and penetrates quite high up the river. Before the breaking of the sand-bar in September, 1952, there were a fair number of large individuals, some of which were caught by anglers. These had presumably been in the estuary for some years. Since the opening of the mouth none has been taken. They appear to live mostly on dead or disabled fish, but are also fond of prawns and shrimps.

Gilchristella aestuarius (Gil.& Thom.)

The Whitebait is a common resident of the lagoon, where it occurs in shoals of large numbers of individuals. It almost certainly breeds in the estuary and is preyed on by most of the carnivorous fish and birds.

Trachysurus feliceps (Valen.)

This barbel is not very common, but sometimes enters the lagoon when this is open to the sea.

Hyporhamphus knysnaensis (Smith).

The Needlefish is usually quite common but is most often seen at night. It favours the lagoon rather than the river. It is probable that this is one of the few species which breed in the estuary.

Solea bleekeri Boul.

This is the common sole of the estuary and was the only one taken during the investigations. It is most abundant in the lagoon.

Syngnathus acus Linn.

Pipe-fish are often abundant in the estuary, occuring well up into the river. they can be observed in some numbers at night if the weeds in shallow water are disturbed.

Palunolepis brachydactylus (Cuvier)

The Butterfish is an occasional visitor to the estuary. At present it is exceedingly uncommon.

Hypacanthus amia (Linn.)

Though a regular and common inhabitant, the Leervis does not appear to breed in the estuary. It feeds on most of the smaller fish. Large individuals are often caught after the mouth has remained closed for some time, the record being a forty-pound specimen taken by Mr. Wilfred Omer-Cooper.

Pomatomus saltator (Linn.)

The Elf has not been taken for some years but was at one time fairly common according to Professor Omer-Cooper.

Johnius hololepidotus (Lac.)

The Kob does not breed in the river though it is nearly always present and often quite abundant.

Monodactylus falciformis Lac.

The Mooney is a common fish at the Kleinmond. It is a euryhaline species, most abundant near the top of the estuary but extending down to the mouth. It breeds in the estuary.

Coracinus capensis (Cuvier)

The Highwater is a rare visitor to the lagoon, but at least one has been taken in recent years.

Pomadasys operculare (Playfair).

The Spotted Grunter or Tiger is one of the most abundant fish in the estuary, extending far up the river. It is probable that it breeds in the river. The Grunter will take many different kinds of bait, but not fish. Its chief food in the estuary seems to be the burrowing prawn Callianassa kraussi, which it blows from its burrows with much vigour. It hunts predominantly in shallow water and assumes a vertical position when blowing, so that the tails of these fish can often be observed waving above the water. The pits made in the mud through this type of feeding are quite characteristic and it is a common sight to see an area of mud so heavily pitted that the depressions merge into one another.

Acanthopagrus berda (Forskal).

The Mud or River Bream is not a very common fish at the Kleinmond, but occasionally one is taken on rod and line.

Rhabdosargus tricuspidens Smith.

The Flatty is an abundant fish, breeding in the estuary. It's range extends from below station seventeen, where it is most abundant, to the lower end of the lagoon. The Flatty has has been observed sleeping on it's side on the mud.

Diplodus sargus Linn.

This fish, the Blacktail, is often caught after the lagoon has been open to the sea. However, it does not appear to thrive in the blind lagoon and soon disappears.

Diplodus trifasciatus (Raf.)

The remarks on D.sargus apply also to the Zebra. It is if anything less common.

Lithognathus lithognathus (Cuv.)

The White or River Steenbras is resident and may breed in the river. It is fairly common. Like the Spotted Grunter, it's chief food appears to be Callianassa which it feeds on in the same way. The pits left by the Steenbrs are on the whole deeper and more isolated than those of the Grunter.

Sarpa salpa (Linn.)

The Bamboo is sometimes found in the estuary but it is never common.

Tilapia natalensis Weber.

The Muddy is a resident, breeding in the river. It is common in the upper reaches of the estuary and occasionally comes down to the lagoon.

Mugil cephalus Linn.

This Mullet or Springer is resident in the river, where it is very abundant. It is present right down to the mouth but is seldom if ever taken on rod and line. Their jumping ability is well known and large numbers will spring into the boat at night if a light be turned towards the water. Indeed in the upper reaches of the estuary the size and numbers of these fish are such as to present a real hazard to those in the boat. This species breeds in the river.

Heteromugil tricuspidens (Smith).

This species of mullet is not very common, but has been caught near the mouth (15/2/53).

Strializa canaliculatus (Smith).

Unlike the two species listed above, this mullet is not given to leaping. It is fairly common in the lagoon and is caught with rod and line.

Trachystoma euronotus (Smith).

This is the common mullet above station seventeen, where it is very abundant. It is also present below this point, but there is no record of it's occurence below station fourteen. It breeds in fresh water.

<u>Psammogobius</u> <u>knysnaensis</u> Smith.

The Sand Goby is abundant in the lagoon even when this has been closed to the sea for some time. It may be observed in large numbers at night, when it rests near the shore, partly covered with sand. It appears to actually sleep in this position.

<u>Gobius</u> <u>giurus</u> Ham.

This Goby is common in the upper reaches of the estuary and is abundant in fresh water.

<u>Anguilla</u> <u>mossambica</u> Peters.

Eels have been observed on several occasions. They inhabit the fresh water above the estuary and run out to sea, presumably to breed. As this is the first authentic record of their migrating, it is worth while quoting the notes made when this phenomenon was first observed; that is,on February 14th, 1953.

"Eels are in the lagoon and crossing the sand-bar to the sea. It is 11p.m. and tonight is New Moon. High tide was at about 4.30 this afternoon, when the sea entered the lagoon. However, no eels were seen attempting to cross at this time and it seems probable that they wait in the lagoon until dark.

"One eel was taken from the lagoon in a hand-net at 10 o'clock this evening and soon afterwards the sand-bar was visited. Here eels were seen leaving the lagoon and making their way across the bar to the sea. Six of these were collected. All seven specimens are "silvered" with gas-bubbles beneath the skin. The head is very narrow and the eye large, just as in the English eels when migrating. When a light was turned onto the eels crossing the bar they remained motionless until picked up. One eels was taken to the sea from the sand-bar, where it was found in an apparently moribund condition. However, on being placed in the sea it at once recovered and swam off through the breakers."

The three specimens studied later were all males, measuring 42cm, 43.2cm, and 44cm in length respectively. The gonads of all three specimens were well developed. The narrowness of the head and the size of the eye were confirmed, but unfortunately the gas-bubbles had disappeared on preservation. Nothing seems to be known of these bubbles and no reference to gas production can be found in the literature. However, Proffessor Omer-Cooper tells me that he has has known of this phenomenen for a good many years.

P.Jespersen, (Dana Report 22, 1942), records the leptocephali of <u>A.mossambica</u> from the Mozambique Channel and Dr.Edge has large numbers of elvers from Madagascar. Dr.Barnard tells us that the South African Museum has two specimens of the elver from South Africa. Now that specimens of the silver phase have been taken and these specimens compared with "yellow eels" of the same species, our knowledge of the stages in the life-history of Anguilla mossambica is complete.

<u>Ophisurus</u> <u>serpens</u> Linn.

The Sandsnake is fairly common. It is notoriously fierce. A Black-backed Gull was observed to fly off with one, which attacked the bird so vigorously that it dropped the fish and flew away. The member of the party who went to pick up the fish was severely bitten. The Sandsnake has been seen to burrow tail first in the mud, with great rapidity. In this position it lies in wait with only the head above the surface of the mud.

<u>Gastrophysus</u> <u>sceleratus</u> (Forster).

The Blaasop has been found in the lagoon after the opening of the mouth.

<u>Amblyrhynchotes</u> <u>honckenii</u> (Bloch)

This species is usually fairly common and often occurs in some numbers, though it does not appear to breed in the estuary.

<u>Antennarius</u> <u>hispidus</u> Bloch.

A visitor to the lagoon, this fish is caught from time to time when the lagoon is open or shortly after it closes.

Class : Amphibia

As might be expected, the estuary itself is not rich in Amphibia, though specimens of *Xenopus laevis* were taken at station thirteen on February 25th, 1953. Apart from this one record *X. laevis* has only been found above station seventeen, where it abounds. Two specimens of *Bufo angusticeps amatolica* Hwtt. have been taken at the upper limit of the estuary and *Rana natalensis* has been found near the water's edge from station fifteen to above station seventeen, but has never been observed in the water. *Rana fuscigula angolensis* Boc. has also been taken above station seventeen (14/3/53). The list is almost certainly incomplete.

Class : Reptilia

The Kleinemonde area abounds with tortoises, only one of which appears to have any bearing on the region under discussion. This species is probably *Pelomedusa subrufa* Gray, the Water-tortoise, which has been observed both in the water and at the water's edge on several occasions, always above station twelve. No specimen has, however, been caught. On April 17th one was seen basking in the sun on a flat rock at the water's edge, near station thirteen. When the boat was still some hundred yards away the tortoise took fright and plunged into the water. Though a search was undertaken, the specimen was not seen again.

Two lizards are worthy of mention as they both commonly occur on rocks near the water, especially from station three to station nine on the right bank. They are Agama atra rudis Blgr. and Agama atra atra Daud.

Snakes are very well represented in the area, but again few are important in the present discussion. The puff-adder, Bitis arietans Merr. is very abundant in the salt marshes and is also to be encountered along both banks at night, when specimens have been seen swimming in the water. Above station nine the Boomslang, Dipholidus typus Smith, has on several occasions been observed on trees overhanging the water. A water-snake which is almost certainly Chlorophis natalensis Smith has been seen in the river on two occasions.

Class : Mammalia

Man is the only mammal which appears to have any significant affect on the ecology of the estuary and his influence is dealt with in a separate chapter.

Class : Aves

Bird-life in the Kleinemonde area is surprisingly rich and varied and many species play a part in the ecology of the region under discussion.

Kingfishers are very abundant, particularly up river, though the commonest, Ceryle rudis rudis, may be seen all the way from the source to the mouth. This Pied Kingfisher has also been seen on the sea-shore to the right of the estuary. The Giant Kingfisher, Megaceryle maxima maxima, is much less common than the Pied Kingfisher, but a few can nearly always be seen in the upper reaches of the estuary. The Half-collared Kingfisher, Alcedo semitorquata, is not often seen, but has been observed fishing near station seventeen, as has the Malachite Kingfisher, Corythornis cristata cristata. A single specimen of the Mangrove Kingfisher, Halcyonopa senagaloides, was seen near station nine (21/2/1953).

The Osprey, Pandion haliaetus haliaetus, though never very common, is a regular visitor to the estuary, while the Sea-eagle, Cuncuma vocifera, is always present, feeding on dead and stranded fish along the bank.

The Waders constitute the most abundant group at the Kleinemonde. Near the mouth the commonest wader is the White-fronted Sand-plover, Charadrius marginatus, but this is soon replaced by the Three-banded Plover, Charadrius tricollaris, as one proceeds up river. The Caspian Plover, Charadrius asiaticus, is sometimes to be seen during the summer months, as is Charadrius hiaticula, the Ringed Plover. The Greenshank, Tringa nebularia, is very common during the summer and one or two may be seen even in winter. The Wood Sandpiper, Tringa glareola, has been seen on several occasions, while the Common Sandpiper, Actitis hypoleucos, is ofteh present in some numbers during the months of December and January. It favours the area near the mouth. The Curlew, Numenius arquata arquata, may be seen throughout the year; common in summer and uncommon in the winter. The Wimbrel, Numenius phaeopus, was present but rare during the summer of 1953, as was the Little Stint, Erolia minuta.

The only representative of the Rails appears to be the Red-knobbed Coot, Fulica cristata cristata, which is very common above station ten and sometimes comes nearer the mouth.

The Water Dikkop, Burhinus vermiculatus, is present all the year round but is usually encountered only at night. Small parties of the Hadada, Hagedashia hagedash hagedash, are common above station four.

Four representatives of the family Anatidae are present and two of these are fairly common. They are the Egyptian Goose, Alopochen aegyptiacus, and the Yellowbill Duck, Anas undulata undulata. The latter often occurs in quite large flocks. Less common are the Shelduck, Casarca cana, and the

White-backed Duck, Thalassornis leuconotus.

The Ardeidae have more species at the estuary than other family of birds, being represented by nine species. The most common is undoubtedly the Grey Heron, Ardea cinerea cinerea, present everywhere except near the mouth. Almost as common is the Black-headed Heron, Ardea melanocephala. A single specimen of the Goliath Heron, Ardeomega goliath was present at the estuary in 1952. At the beginning of 1953 he disappeared for a short while, but returned in February with a mate. The pair of birds have stayed on at the estuary since then. The Purple Heron, Pyrrherodia purpurea purpurea, occurs in the upper reaches of the river. The White Heron, Casmerodius albus melanorhyncus is uncommon but has been seen on several occasions. The Little Egret, Egretta garzetta garzetta, is fairly common and is made conspicuous by it's extraordinary waltzing movements when in the water. The Yellow-billed Egret, Mesophoyx intermedia brachyrhyncha, has been observed from time to time. The Cattle Egret, Bulbulcus ibis, is abundant along the banks of the river, though it seldom enters the water. The White-backed Night-heron, Nycticorax leuconotus, was seen on February 13th, 1953. This bird is "a rarity,recorded from Hankey, Grahamstown, Kleinmond, Middle Drift, East London, Pondoland and other coastal localities. Flushed from thick branches overhanging the water." (Hewitt).

The Hammerhead, Scopus umbretta bannermani, is a familiar bird in the upper reaches of the estuary and is quite often seen towards the mouth.

Storks include the Wood Ibis, Ibis ibis, which has become quite common in recent years, and the White Stork, Ciconia ciconia ciconia, which is also fairly common. A pair of Black Storks, Melanopelargus niger, are a common sight in the vacinity of station three.

The Southern Black-backed Gull, Largus dominicanus, is always fairly common near the mouth but seldom goes above the lagoon. At least three species of Terns have been seen at the estuary, the commonest being the Caspian Tern, Hydroprogne caspia, of which there are always a few present. Two other Terns, ?Sterna hirundo and ?Sterna macrura, visit the lagoon during summer, but never stay for very long.

The common Cormorant of the estuary is the Reed Cormorant, Microcarbo africana africanoides, but two other species may be seen from time to time. They are the Cape Cormorant, Psuedocarbo capensis, and the White-breasted Cormorant, Phalacrocorax lucidus.

The Darter, Anhinga rufa levaillantii, is fairly common. The Avocet, Recurvirosta avosetta, is recorded by Professor J. Omer-Cooper, though the auther has not seen the species at the Kleinmond.

The Cape Dabchick, Poliocephalus ruficollis, is quite common above the lagoon.

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Notes on Plankton

Plankton samples were taken by day and by night, using three types of plankton net.

(1) A fine white net attached directly to round hoop. This would seem to be the type of net in general use.

(2) A fine white net with a square mouth, attached by four tapes to a square, metal frame of slightly larger dimensions. The advantage of this net is that it's depth below the surface of the water is easily controlled and, should the frame touch the bottom, the sand passes over the bottom edge of the frame without entering the net itself.

(3) A black net similar in other respects to (1). This net was used at night on several occasions to find out whether some of the larger forms were evading the conspicuous white nets. This proved to be the case, for on all occasions mysids of the genus Gastrosaccus were taken in far greater quantities than with either of the white nets.

It was hoped that an accurate quantitative survey of the zooplankton in the estuary might be undertaken, but this proved to be impracticable for a number of reasons. Firstly, a plankton net begins to lose it's effeciency as it fills with plankton. It is true that this error can be greatly reduced by towing for a very short distance at a time, but this undoubtedly increases other errors. Secondly, the efficiency of the net is related to the speed at which it is towed, and this connot always be constant. Thirdly, as has been pointed out, certain species tend to avoid the net and it is probable that even the use of a black net at night does not completely counteract this error. Lastly, the plankton has a tendency to occur in patches and has never been found to occur uniformly, even over a small area of the estuary.

However, even though a quantitative survey could not be undertaken with the desired degree of accuracy, samples were taken with care, always over a previously measued distance, wind, temperature and other conditions being noted. Each sample was at once preserved by the addition of formalin and later measured. Plankton counts were attempted on each sample. The following facts emerge concerning the zooplankton in general:-

(1) There is a great variation in the quantity of plankton between night and day. Between sunrise and sunset there is hardly any plankton at all in the water. For example, on February 25th, 1953, a tow-netting between stations one and two at 4p.m. caught only two copepods and a mysid; a tow-netting between the same two points at 10p.m. the same evening took 26cc of plankton. It is a well-known fact that marine plankton occurs generally at a lower level during the day than during the night, but there is nothing in the literature to suggest the position in an estuary of the Kleinmond type, where the

plankton actually descends into the mud during the day.

(2) The amount of plankton taken depends on the intensity of the light, the greatest volume being taken on the darkest nights. Observations do not support the suggestion that the quantity of plankton shows a variation with the phases of the moon, regardless of the actual intensity of the light on any given occasion.

(3) There appears to be no vertical zonation of the plankton in the water, probably because of the shallow nature of the estuary.

(4) As has already been pointed out, the plankton tends to occur in patches, it's horizontal distribution being by no means uniform. It is often more abundant along one bank than along the other, and a correlation has been found between this phenomenon and the direction of the wind. Indeed the wind seems to be the chief extrinsic factor influencing the horizontal distribution.

(5) There appears to be less plankton in the water in winter than in summer, but the differences are not very great.

From time to time plankton-samples were taken at hourly intervals during the night. To check the results of this experiment, plankton was kept in an aquarium tank provided with a natural substratum. Combined hourly collecting and continuous observations of the tank led to the following conclusions:-

(1) The amount of plankton varies during the night, reaching a maximum between 10p.m. and 11p.m. This is, of course modified by the intensity of light during the given period but was always true of the plankton in the aquarium tank, which was shaded from the moonlight.

(2) The various species comprising the plankton do not all rise at the same time, some forms (notably the larvae of Callianassa kraussi) appearing only for a short period when the plankton is at it's peak. First in evidence are the Copepods, which begin to appear as soon as it grows dark and remain in the water practically all night, reaching maximum numbers usually before midnight. The Mysids rise soon after dark but have nearly always returned to the mud (or the holes in the mud) by 1a.m. Cumaceans remain in the water for a very short time, being most in evidence between 10p.m. and 11p.m. Larvae of the prawn, Callianassa kraussi were most often taken between 10 and 10.30p.m.

Amphipods and Isopods of various species were almost invariably present in the samples, but never in large numbers. The medusae of Hydractinia were very common in May, 1953, both by day and night. Chironomid larvae were common in February, March and April. The larvae of Ephemeroptera were present in plankton from station seventeen in March. Zoeae of the crab Hymenosoma orbiculare were taken regularly.

The Influence of Man on the Ecology of the Estuary.

The effect of Man on the Ecology is greater than might at first be supposed. His influence is expressed in the following activities:-

(1) Farming in the area,

(2) The artificial breaking of the sand-bar.

(3) Fishing.

(4) The introduction of new species.

(5) The introduction of alien material into the water.

Of these activities, farming is by far the most important, though it is difficult to say just how much the ecology is and has been affected by this factor. It is certain that the estuary is muddier and shallower than it was and that this is largely due to soil erosion from the surrounding areas under cultivation.

The artificial breaking of the sand-bar is a more definite and measurable factor. The effect is much the same as when the bar is broken by the sea and floods. The lagoon is repopulated by marine species, most of which disappear after the reclosing of the mouth, young fish enter the lagoon and most of the larger fish leave it. The lagoon becomes tidal temporarily and the substratum of the lower part of the lagoon may be modified due to wave action. The inhabitants of the cottages along the shore of the lagoon generally open the lagoon when the water-level rises to an inconvenient height.

Fishing does not seem to affect the ecology to any great extent, most of the species caught being always quite abundant. Only the populations of Steenbras and Kobeljou are likely to be seriously depleted by fishing. The netting of fish is far more destructive than rod and line fishing, for many young fish are destroyed, being left stranded on the bank or used as bait. Luckily, most of the anglers who fish in the estuary are conscious of this fact and the netting of fish for bait is seldom practised.

The introduction of new species is probably a rare occurence, but is mentioned due to the persistant, if unconscious introduction of the prawn _Upogebia africana_ which has been discussed earlier.

Many of the abundant smaller fish eat the scraps of food which are thrown into the water, This provides a larger food-supply than might be imagined, for it is a common practise to wash dirty plates and cooking utensils in the lagoon.

Apart from the effects of farming, the chief result of man's activities would thus seem to be to decrease the numbers of large fish in the estuary, while increasing the numbers of the smaller fish.

The Little Kleinmond Estuary

Although the Kleinemonde Estuaries are so close together and open within a few yards of one another, the Little Kleinmond Estuary presents several points of contrast with the Larger Estuary.

Firstly, despite the fact that the river is only about a third of the length of the Larger Kleinmond, the lagoon is almost twice as deep. The sand-bar is more often broken, and the lagoon was open to the sea in July 1953, when the level of the water in the Larger Kleinmond Estuary rose several feet, without breaking it's sand-bar.

The substratum, too, presents a contrast, for coarse sand forms the bottom throughout the lagoon, pure mud being encountered only at the very top of the estuary. This fact, as well as those mentioned above may well be due to the absence of man's activity as expressed in farming, for until a year or two ago the Little Kleinmond, unlike the Larger Kleinmond, did not drain an area under cultivation. However, within the last few years pineapples have been cultivated on the slopes adjoining the Little Kleinmond River, and it is thus no rash prophecy to contend that this estuary will soom be as muddy and shallow as the larger estuary near it

On the whole the fauna is very similar, though if anything the Little Kleinmond is richer in animal life. The forms which, in the larger estuary occur only below station two are here to be found throughout the lagoon. These forms include such species as Pontogeloides latipes and Eurydice longicornis among the Isopods and Amphipods such as Talorchestia australis and Urothoë pulchella. This difference in distribution would seem to be linked with the difference in substratum, even when one bears in mind the danger of attributing differences in distribution to a unit factor.

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Discussion and Conclusions

In considering the fauna of the Larger Kleinmond Estuary as a whole, of primary importance would seem to be the absence of surf-action. There are actually two factors involved here; the action of the surf as a purely physical factor and the continual surge of water of high oxygen content as a chemical factor. To many marine animals either one or both of these factors is essential, and the absence of these forms in the estuary may be therefore largely atributed to the absence of surf-action there. On the other hand, animals which find the surf-action a prohibitive factor may find conditions in the estuary ideal and so seek shelter in the lagoon. The absence of forms such as Mytilus, all Tunicates and Echinoderms, and the abundance of small sand-dwelling animals and young fish may all be associated to a greater or lesser extent with this fundamental problem.

The very essence of the estuarine environment and hence of the whole ecology, would seem to lie in the fact that the estuary is a "drowned valley" which has silted up. The blind and shallow nature of the lagoon and the great comparative length of the estuary, all factors related to this phenomenon and exaggerated by erosion from lands under cultivation, are obviously of no small significance.

The fact that the estuary is blind is of the utmost importance. There are no strong currents and normally no tidal influence. There is thus no intertidal zone, nor does the salinity change regularly at any given point as is the case with a tidal estuary. However, the salinity at any station may decrease suddenly and violently after rains or slowly increase through evaporation. Extremes are greater and changes more dramatic than is usually the case in a typical tidal estuary and extreme conditions are likely to exist for a longer period. The fauna is thus a hardy one, capable of a high degree of adaptability to changing conditions.

The fauna of the Kleinmond River may be divided into three sections. Firstly, there is the change which occurs at station seventeen and which is to be expected with the change from brackish water to fresh water. Another equally well-marked change in the fauna occurs at station two and there can be no doubt that this is largely, if not entirely, due to the sudden change in the substratum at this point. Below station two the substratum consists of coarse, wind-blown sand with almost no organic content, while above station two there exists a muddy sand. Among the forms which live in the substratum there is almost no overlapping, species being restricted to either one side or the other of this line of limitation. Forms such as Mercierella enigmatica and Balanus elizabethae are also limited to the area above station two, and it is difficult to correlate the occurence of such animals with the change in substratum. Their absence below station two may be partly due to the wind-blown sand constantly falling through the water. Wave-action when the mouth is open may also be a contributing factor.

Apart from these two changes, the fauna is strikingly uniform. We come to the conclusion that the two chief factors influencing distribution in the river as a whole are the Salinity and the condition of the substratum. It is unlikely that the concentrations of Phosphates, Nitrates and Oxygen influence the distribution and changes in the Hydrogen-ion concentration probably have very little effect on the fauna, the water being always alkaline.

It is doubtful whether fluctuations in temperature are ever as great as those which most littorine animals have to withstand. Marine forms with a narrow temperature tolerance, living in deep water, may be prevented from colonisation by such a barrier, but it seems unlikely that other species would be excluded on this account. During the course of the survey, temperature fluctuations did not appear to affect the fauna to any great extent, though in previous years particularly severe cold-spells have led to the death of hundreds of fish, and it is hardly likely that the rest of the fauna would be unaffected under such extreme conditions.

It would not be wise at this stage to draw many conclusions concerning the bionomics of the estuary; one or two points, however, appear to be fairly clear. Phytoplankton being relatively scarce, perhaps because of the low phosphate content of the water, it's place in the food-chains is to a great extent taken over by the attached plants. Some animals eat the living plant, but it is as detritus that these plants assume an all-important role as a basic food. Such essential animals as Callianassa kraussi, nearly all young Amphipods and some adult Amphipods, Annelids and some molluscs are detritus feeders and these form the basis for longer or shorter food chains.

The fauna of the estuary is poor in species, though rich in numbers. The blind nature of the estuary is quite obviously one of the important factors involved here, for "the initial fauna depends on which larval or juvenile forms are introduced at the time of closure. Those with short lives will disappear unless they can breed in the estuary. Others will die because the salinity and other physical factors are modified by rain or evaporation. Blind estuaries usually have poor faunas." (Day. 1951.)

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Summary

This is an ecological survey of the fauna of the Larger Kleinmond Estuary, Bathurst District, Eastern Cape Province. The estuary is normally closed to the sea. Physical and Chemical conditions are described; the estuary is always more or less saline; both the water supply and the estuarine water itself are alkaline; the phosphate content is extremely low.

The flora of the estuary is dealt with briefly.

The distribution of the fauna is discussed and biological notes are given on the various species. A short comparison is made with the Little Kleinmond Estuary, which opens nearby. The plankton of the estuary is discussed in an attempt to discover some of the laws governing it's behaviour. Some mention is made of Man's influence on the ecology.

The discussion deals mainly with the distribution of the fauna and attempts to correlate this distribution with the physical and chemical conditions.

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APPENDIX

Distribution Chart of Invertebrate Species.

The comparative abundance of species is indicated on the system used by Stephenson. P; present, F; fairly common, C; common, A;abundant, V; very abundant. Only the species found during the course of the actual survey are listed. The station numbered 18 refers to the fresh water above the estuary.

Station No.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
COELENTERATA:																		
Hydractinia sp,	C	A	A	A	C	C		P										
POLYZOA:																		
Membranipora sp. (1)					P	P	F	F		P								
Membranipora sp. (2)				F	P	P		F	F	P	P							
NEMATODA:		C	C	C	C	C	C	C	C	C	C	P						
ANNELIDA:																		
Ceratonereis keiskama		C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	P
Dendronereis arborifera			F			F	P			F			P					
Prionospio aucklandica										P	C	C	C	C	C			
ORIDIA parvula													P	V				
Mercierella enigmatica		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
MOLLUSCA:																		
Modiolus capensis		P	F	F	F	F	P	A	A	C	A	A	C	F	F	P		
Solen capensis	P	C	C	C	C	C	C	C	C	C	C							
Psammotellina capensis	F	C	C	C	C	C	C	C	C		P							
Tellina regularis								F	P									
Donax sp.	P																	
Teredo sp.		C	A	A	A	A	A	A	A	A	C	C	P	P				
Assiminea ?sinensis	C	C	C	C	C	C	C	C	C	C	C	P						
Assiminea sp.		A	C	C	F													
Nassarius kraussianus	C	A	A	A	C	C												
CRUSTACEA:																		
Ostracoda (1)																		F
Ostracoda (2) (Stenocypris?)																P	F	
Copepoda (several species)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Balanus elizabethae		C	C	C	C	C	C	C	C	C	C	C						
Gastrosaccus sp.	C	C	C	C	C	C	C	C	C	C	C	C	F		F			

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CRUSTACEA (continued):																		
Monopodopsis sp.	P	P	P															
Cirolana fluviatilis	P	C	C	C	C	C	C	C	C	C	C	C	F	F	F	F	F	
Cyathura carinata		C	V	V	V	V	V	V	V	V	V	V	V	A	A	A	A	
Eurydice longicornus	V	P																
Pontogeloides latipes	C	P																
Exosphaeroma hylecoetes		V	V	V	V	V	V	V	V	V	V	V	C					
Tylos capensis	C	P																
Apseudes sp.n.		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	F	
Cumacea spp.n.		C	A	A	A	A	C	C	C	C	C	C	C	P				
Corophium triaenonyx		P		P	F	F		C	A	A	A	A	A	A	A	C	P	
Melita zeylanica		P	F	F	C	C		V	V	V	V	A	C	F		F		
Parorchestia rectipalma	F	F																
Talorchestia australis	F																	
Hyale sp.	P																	
Urothoe pulchella	C																	
Grandidierella lutosa													P	P		A	V	C
Penaeus japonicus	F	F		P	P													
Leander pacificus	A	A	A	A	C	C	C	F	F			P						
Hymenosoma orbiculare	C	C	C	C	C	C	C	C	C	C	C		P					
Cleistostoma edwardsii			F	P														
Varuna litterata	Sometimes present ————————————																F	C
Ocypode ceratophthalmus	F																	
Callianassa kraussi	F	A	V	V	V	V	V	V	V	V	V	V	A	P				
Diogenes brevirostris	C	P																
INSECTA:																		
Tridactylus capensis	V																	
Gryllotalpa africana		A	A		A	P			P									
Gryllodes sp.				C	C	C	C	C	C		P	C		A			P	
Ephemeroptera																		C
Odonata																	P	C
Hydrometridae																	P	F
Gerridae																		A
Naucoridae																		P

INSECTA (continued):	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Nepidae: Ranatra sp.																		P
Notonectidae																		C
Corixidae																		C
Trichoptera (larvae)																	P	P
Cicindela capensis	A	C	F	P														
Pogonus lamprus		P	A	A	A	A	A	C	V	P		F	A		P			
Omophron sp.						P												
Heterocerus sp. (1)		F	F	F		F		F										
Heterocerus sp. (2)			F		F		F		F									
Coelostoma rufitarse	P	F		F	F	F	P			P	P				P			
Aulonogyrus alternatus																		C
Phyloctonius sp.		P		P														
Dyschirius sp.			F															
Bledius pilicollis		A	F	C		A		A										
Bledius sp.	V																	
Philonthus sp.			A		A		C		A									
Culicidae																		C
Chironomidae	F	C	C			C		C	C	P	F		P		P			
Ephydridae	A	F	F	P														

Appendix B.

Temperature Records

1953

(a) The following readings were taken in water 20 ft from the shore at the stations indicated:-

Date	Station	Time	Temperature in ^{o}C.
Jan. 25th	2	11.00 a.m.	26.5
	2	3.30 p.m.	29.75
	3	4.30 p.m.	28.0
Jan. 26th	2	11.00 a.m.	27.5
	3	12.15 p.m.	29.0
	4	2.00 p.m.	29.5
	5	2.15 p.m.	29.5
Jan. 27th	2	8.00 a.m.	24.0
	2	10.15 a.m.	25.25
	2	12.30 p.m.	26.0
	2	3.30 p.m.	27.75
Feb. 2nd	1	11.00 a.m.	24.0
	2	11.15 a.m.	24.25
Feb. 3rd	1	9.30 a.m.	24.0
	1	3.30 p.m.	27.0
	1	8.00 p.m.	26.0
	2	10.00 a.m.	25.25
	2	12.15 p.m.	28.5
	3	10.15 a.m.	25.0
	3	11.45 a.m.	28.25
	4	11.00 a.m.	28.0
Feb. 4th	1	9.30 a.m.	24.5
	1	11.00 a.m.	25.0
	1	1.30 p.m.	26.5
	1	4.00 p.m.	27.5
	1	5.30 p.m.	27.25
	1	8.00 p.m.	26.25
Feb. 5th	1	9.30 a.m.	25.0
	1	12.00 p.m.	26.25
	1	1.30 p.m.	27.25

Date	Station	Time	Temperature in °C.
Feb. 5th	1	3.00. p.m.	27.75
	1	6..00p.m.	28.0
	1	8.00p.m.	27.0
Feb. 7th	2	9.00 a.m.	25.75
	2	11.00 a.m.	2 6.75
	2	1.00 p.m.	27.75
	2	2.00 p.m.	27.75
	2	3.00 p.m.	27.50
Feb. 11th	1	11.00 a.m.	26.0
	3	11.15 a.m.	26.5
	5	12.00 p.m.	27.0
Feb. 12th	1	9.00 a.m.	25.5
	2	10.00 a.m.	27.0
	3	10.15 a.m.	27.0
	4	10.30 a.m.	28.0
	5	10.40 a.m.	26.0
	6	11.00 a.m.	29.5
Feb. 21st	4	11.30 a.m.	26.5
	5	11.40 a.m.	25.5
	7	11.55 a.m.	26.0
March 14th	2	11.30 a.m.	24.5
	3	11.45 a.m.	26.0
	1	2.30 p.m.	25.0
April 17th	1	10.00 a.m.	21.25
	1	12.30 p.m.	21.5
	2	2.30 p.m.	22.0
May 4th	3	12.30 p.m.	18.5
May 5th	2	8.00 a.m.	15.0
May 6th	2	10.00 a.m.	15.5
	2	2.00 p.m.	19.0
June 29th	2	3.00 p.m.	14.5
	2	6.00 p.m.	13.0
June 30th	2	8.00 a.m.	11.5
	2	10.00 a.m.	12.75
	2	3.00 p.m.	13.0

Date	Station	Time	Temperature in °C.
July 1st	1	8.00 a.m.	12.5
	2	9.00 a.m.	12.5
Aug 26th	3	11.00 a.m.	15.25
	1	2.30 p.m.	19.0
	1	4.00 p.m.	18.5
Sept. 10th	2	1.00 p.m.	21.5
October 9th	2	2.30 p.m.	23.0

(b) The following readings were taken in the shallow bay behind station three, in about two inches of water:-

Date	Time	Temperature in °C.
Jan. 26th	12.30 p.m.	33.0
Jan. 27th	8.00 a.m.	21.5
	10.00 a.m.	25.0
	11.00 a.m.	26.5
	12.15 p.m.	29.0
	2.00 p.m.	30.25
	3.30 p.m.	30.5
	6.00 p.m.	28.75
Feb. 11th	11.15 a.m.	28.5
May 5th	8.15 a.m.	12.0
	10.00 a.m.	15.75
	12.30 p.m.	17.0

(c) The following readings were taken in mud and in the overlying water. Four sets of readings have been chosen at random.

Feb. 24th , 11.30 a.m. , station one. (sand)

Water, 20ft from shore	24.5°C
Sand, 20ft from shore, depth 3 inches	23.5°C
Water, 2ft from shore	27.25°C
Sand, 2 ft from shore, depth 3 inches	26.25°C

Sand, 2 ft from shore, depth 6 inches	26.00°C
Sand, on shore, depth 3 inches	25.0°C
Sand, on shore, depth 6 inches	23.5°C

Feb. 24th , 1.00 p.m. , station one.

Water, 20ft from shore,	25.5°C
Sand, 20ft from shore, depth 3 inches	24.75°C
Water, 2ft from shore	28.0°C
Sand, 2ft from shore, depth 3 inches	27.25°C
Sand, 2ft from shore, depth 6 inches	26.25°C
Sand, on shore, depth 3 inches	27.0°C
Sand, on shore, depth 6 inches	25.0°C

Feb. 25th , 10.45 a.m. , station nine (mud).

Water, 2ft from shore	25.0°C
Mud, 2ft from shore, depth 3 inches	25.0°C
Mud, 2 ft from shore, depth 6 inches	24.5°C
Mud, on shore, depth 3 inches	25.0°C
Mud, on shore, depth 6 inches	24.0°C

Feb. 27th , 1.30 p.m. , station nine.

Water, 2ft from shore	26.5°C
Mud, 2ft from shore, depth 3 inches	26.25°C
Mud, 2ft from shore, depth 6 inches	26.0°C
Mud, on shore, depth 3 inches	26.25°C
Mud, on shore, depth 6 inches	25.5 °C

(c) Water-level readings for February and March 1953, Station One.

(Wind velocities are given on the Beaufort Scale.)

February

Date	Time	Reading	Wind Velocity	Remarks
6th	7.45pm.	5.5"	Up stream (1)	Low Tide 2.01 pm.
	9.30pm.	5.0"	Up stream (1)	
7th	9.00am.	5.5"	None	Low Tide 3.04 pm.
	10.00am.	5.8"	Down stream(1)	
	11.00am.	5.8"	Down stream(1)	
	12.00	5.4"	Up stream (1)	
	1.00pm.	5.4"	Up stream (1)	
	3.10pm.	5.2"	Up stream (2)	
	5.30pm.	5.0"	Up stream (2)	
	8.00pm.	5.0"	Up stream (2)	
8th	12.15pm.	7.0"	None	Heavy rains during the night.
	2.00pm.	7.0"	Down stream(1)	
	4.00pm.	7.2"	Down stream(1)	Low Tide 4.46 pm.
9th	10.00am.	6.0"	None	Low Tide 6.25 pm.
	12.00	6.0"	Up stream (1)	
	2.00pm.	5.9"	Up stream (1)	
	4.00pm.	5.8"	Up stream (1)	
	8.00pm.	6.3"	None	
10th	9.00am.	6.0"	Up stream (2)	
	11.00am.	5.6"	Up stream (5)	
	1.00pm.	5.1"	Up stream (5)	
	3.00pm.	4.8"	Up stream (6)	
11th	11.00am.	6.0"	Up stream (1)	
	1.00pm.	6.0"	Up stream (1)	
14th	10.00am.	5.8"	Down stream(1)	
	11.00am.	6.0"	Down stream(2)	
	12.00	6.2"	Down stream(3)	
18th	1.00pm.	6.2"	None	
	2.00pm.	6.2"	None	
	3.00pm.	6.2"	Up stream (1)	
	4.00pm.	6.0"	Up stream (1)	
	5.00pm.	5.9"	Up stream (2)	
	6.00pm.	5.8"	Up stream (2)	

Date	Time	Reading	Wind Velocity	Remarks
20th	9.00am.	6.0"	None	
	10.00am.	6.3"	Down stream(2)	High Tide 8.02 am.
	11.15am.	6.4"	Down stream(2)	
	12.15pm.	6.4"	Down stream(2)	
	2.00pm.	6.6"	Down stream(3)	
	4.00pm.	6.3"	Down stream(1)	
	5.15pm.	6.0"	Down stream(1)	
22nd	1.00pm.	6.1"	Up stream (2)	Rain.
	2.15pm.	6.2"	Up stream (1)	
	3.00pm.	6.2"	None	
	4.30pm.	6.3"	None	
24th	8.00am.	6.0"	Up stream (3)	
	9.00am.	6.0"	Up stream (3)	
	10.00am.	5.9"	Up stream (3-4)	
	12.15pm.	5.9"	Up stream (3)	
	4.30pm.	6.0"	Up stream (3)	
28th	1.15pm.	6.2"	Down stream(1)	
	3.00pm.	6.3"	Down stream(3)	
	5.15pm.	6.4"	Down stream(3)	
			March 1953	
15th	9.00am.	7.0"	Down stream(1)	High Tide 3.56 pm.
	10.15am.	7.2"	Down stream(1)	
	11.30am.	7.2"	Down stream(1)	
	1.00pm.	7.0"	Up stream (1)	
	2.00pm.	6.8"	Up stream (1)	
	3.00pm.	6.8"	Up stream (3)	
	4.00pm.	6.6"	Up stream (3)	
	5.00pm.	6.6"	Up stream (3)	
	6.30pm.	6.6"	Up stream (2)	
22nd	1.30pm.	7.0"	Up stream (1)	High Tide 8.34 am.
	3.00pm.	7.0"	Up stream (1)	
	5.15pm.	7.0"	Up stream (1)	

A Quantitative Study of Plankton Samples

These figures have not been dealt with in the main body of the thesis, as their degree of significance is not clear. The samples studied were all taken over the same distance, i.e. from station two (on the left bank) to the right of the bottom end of the lagoon, and return, an overall distance of 785 yards. On each occasion the following conditions were noted:-

(1) Date
(2) Time
(3) Intensity of the moonlight
(4) Temperature
(5) Wind

Each sample was preserved in formalin and stored in the laboratory. The counts were made in the following manner. The sample was made up to exactly 150 ccs and kept agitated so that a uniform distribution of plankton was obtained. Part of this diluted sample was then poured into a Petri Dish to a depth of 1cm. The dish was marked in squares of 1 sq.cm. and when the plankton settled the number in one of these squares was counted. Ten such counts were made, the sample in the dish returned to the main sample, and the whole process repeated ten times.

The following is an example of such a count. The final averages have been reduced to whole numbers.

Plankton sample 1. 3/2/53 9.30 p.m.
Temp. 24.5°C. Sky overcast. No moon.
Wind upstream, slight (1-2).
Species occurring: Cumacea 1 (Round body)
Cumacea 2 (Laterally compressed)

Sample 1 (continued) - 3/2/53

<u>Gastrosaccus</u> sp.
<u>Monopodopsis</u> sp.
<u>Cirolana fluviatilis</u>
Copepoda 1
Copepoda 2
Zoeae of <u>Hymenosoma orbiculare</u>
Chironomid larvae
Medusae (<u>Hydractinia</u> ?)

	Cumacea 1	Cumacea 2	Gastrosaccus	Copepoda 1	Copepoda 2	Zoeae	Others
	2.1	0.1	8.0	90.4	17.3	1.0	1 Medusa 1 Chironomid larva
	0.8	0.0	10.7	80.3	14.0	0.2	1 Cirolana fluviatilis
	2.1	0.2	9.1	85.2	8.1	1.8	-
	3.0	0.5	6.8	92.0	12.2	1.3	1 Monopodopsis sp. 3 Medusae
	0.2	0.0	6.4	86.9	10.0	1.2	2 Medusae
	1.0	0.2	8.7	89.0	14.5	2.0	1 Chironomid larva
	1.9	1.8	10.2	82.1	9.0	0.9	1 Medusa 1 Cirolana fluviatilis 2 Chironomid larvae
	0.2	0.0	4.8	88.2	11.1	0.2	-
	0.3	1.0	11.7	87.9	9.8	0.0	2 Medusae
	2.0	0.5	11.3	80.0	6.8	2.7	1 Chironomid larva 1 Medusa
Av.:	1	0.5	9	86	11	1	

The following table gives a list of the final averages obtained on some of the samples for the more common species.

Date	Time	Cumacea 1	Cumacea 2	Gastro-saccus	Copepoda 1	Copepoda 2	Hymenosoma zoeae	Other species found
3/2	9.30	1	0.5	9	86	11	1	Medusae. Monopodopsis. Chironomids. Cirolana fluv.
7/2	9.00	0.3	0	8	78	9	1	Medusae. Cirolana. Apseudes.
	10.00	1	0.4	10	84	9	2	Medusae. Cirolana. Callianassa larvae. Exosphaeroma.
	11.00	5	1	10	91	12	2	As above plus Melita zeylanica
	12.00	1	0	7	80	8	1	Medusae. Cirolana.
	1.00	0	0	2	77	6	1	Medusae. Exosphaer.
11/2	8.00	0	0	1	71	5	0	Medusae. Apseudes. Corophium.
	10.00	3	1	9	82	8	0.5	Medusae. Chironomid Cirolana. Melita. Grandidierella.
	11.00	4	1	10	90	8	1	Callianassa larvae. Medusae. Cirolana.
7/5	8.00	0	0	1	67	4	0	Corophium. Exosphaeroma.
	9.00	0.2	0	4	69	7	0.3	Cirolana.
	10.00	6	1	8	71	10	0.5	Upogebia larva Corophium. Medusa. Exosphaeroma
	11.00	3	1	7	67	9	0.2	Melita zeylanica Grandidierella.
	1.00	0	0	1	60	3	0	-

Plankton Counts

APPENDIX 11

Appendix 11

Since the completion of the main body of the thesis a number of further points have arisen which justify a second appendix.

Definition. Some controversy has arisen as to the exact definition of the word "estuary". (Lat. aestuarium, a place reached by aestus, the tide). If we then take the origin of the term as a criterion, the word "estuary" applies only to a river which is open to the sea and is of necessity tidal. When the Kleinmond lagoon is open to the sea it must undoubtedly be considered an estuary, but when it is closed the phrase "blind estuary" is a contradiction in terms. The correct term for the blind lagoon would be "marine salina."

To avoid confusion, however, the term "estuary" has been used throughout the thesis to denote the lower reaches of the river, regardless of whether this is open or closed to the sea. In fact Professor J.H.Day (1951) considers this use of the term to be altogether legitimate when he defines an estuary as being that part of a river which is salt, this salinity being derived from the sea. From the point of view of ecology this is probably the most convenient definition.

Phosphates. It is known that phosphates, among other substances, are released from the reduced layers of the mud. It may be that the lack of phosphates in the water of the Kleinmond is partly due to the large amount of oxidised mud present and that a great deal of phosphate is held in this mud. If so,this is yet another function of that all important animal Callianassa kraussi.

Additions to the faunistic list.

Phylum: Arthropoda

Sub-phylum: Crustacea

Class: Malacostraca

Order: Mysidacea

A marine mysid, not yet identified, is extremely common in the sand in the inter-tidal region of the sea-shore near the estuary. When the mouth of the lagoon is open this species colonises the area below station two and becomes very abundant. Also, when the mouth is closed and heavy seas break over the bar, the mysid is swept into the lagoon where it manages to establish itself for a short while. It does not appear to breed in the blind lagoon.

Class: Insecta

Order: Diptera

Family: Ephydridae

Lamproscatella dichaeta (L.w.)

Family: Canaceidae

Xanthcanaca n.sp.

Both of these species are common on the shores of the lagoon, particularly near the mouth.

Phylum: Chordata

Class: Aves

Phoenicopterus ruber

The Greater Flamingo is recorded by Professor J. Omer-Cooper in 1952 and was seen by the author on October 9th, 1953.

A further note on the Substratum.

It has been pointed out that the condition of the substratum at the Kleinmond is not one that we would normally expect to find in an estuary. The series at the Kleinmond goes from sand at the mouth, through muddy sand and sandy mud to pure mud beyond the top of the lagoon. When silt is carried by a river the coarser particles (sand) would be deposited first and the finest particles last, thus reversing the position found in the Kleinmond Estuary except for the wind-blown sand at the extreme bottom end of the lagoon. We must conclude that all the sand in the estuary is derived from the sea and that only mud-particles are carried down by the river.

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