The ecology of South African estuaries. Part XII: The Bot River, a closed estuary in the south-western Cape

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Although a considerable amount of work has been done on open estuaries in southern Africa very few studies have been on estuaries that are normally closed. The Bot River vlei is an estuary of this type, and the information presented here is the result of initial surveys carried out in 1980. The vlei, situated on the south-west coast of South Africa, has recently been opened to the sea. The salinity at the time of survey ranged from 7 – 12‰, although this is subject to seasonal fluctuations and artificial opening of the estuary. The major primary producers are the reeds *Phragmites* and *Scirpus* which may reach a biomass of 1,794 and 0,961 kg dry mass m^{-2} and the aquatic macrophytes *Potamogeton* (0,071 kg m^{-2}), *Ruppia* (0,371 kg m^{-2}), *Chara* (0,071 kg m^{-2}) and *Cladophora* (0,140 kg m^{-2}) growing down to water depths of 2,9 m. The invertebrate fauna is poor both in terms of biomass and diversity, but large numbers of birds, particularly herbivorous coots, and fish are found. The Bot River estuary appears to be in an intermediate stage of the evolution of coastal lakes from open estuaries.

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Alhoewel daar heelwat werk reeds in Suid-Afrika verrig is op oop getymondings het slegs enkele studies aandag gegee aan getymondings wat normaalweg afgesluit is. Die Botriviervlei is 'n getymonding van lg. tipe, en die gegewens hier aangebied is afkomstig vanaf voorlopige opnames wat in 1980 onderneem is. Die vlei, geleë aan die suidwestelike kus van Suid-Afrika, het onlangs deurgebreek na die see. Die soutgehalte ten tye van die opname het gewissel van 7 – 12‰, alhoewel dit onderhewig is aan seisoenskommelinge en die kunsmatige oopmaak van die getymond. Die hoof primêre produseerders is die riete *Phragmites* en *Scirpus* wat 'n biomassa van 1,794 en 0,961 kg droë massa m^{-2} kan bereik, sowel as die akwatiese makrofiete *Potamogeton* (0,071 kg m^{-2}), *Ruppia* (0,371 kg m^{-2}), *Chara* (0,071 kg m^{-2} en *Cladophora* (0,140 kg m^{-2}) wat groei tot op 'n diepte van 2,9 m onder die watervlak. Die invertebraat-fauna is skraal, in terme van biomassa sowel as diversiteit, maar groot getalle voëls, veral plantvretende waterhoenders, en visse kom voor. Die Botrivier-getymond is skynbaar in 'n tussenin-stadium in die evolusie van kusmere vanuit oop getymonde.

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The Bot River vlei is a large, closed estuary situated between the towns of Kleinmond and Hawston (34°21′S, 19°07′E) on the south-west coast of South Africa, between the Cape of Good Hope and Cape Agulhas (Figure 1). It is approximately 6 km long and 2 km at its widest, with an area of 12,2 km^2 at the time of the survey. The estuary lies at the end of a comparatively small catchment area within which there is considerable agricultural activity.

Although considerable research has been carried out on South African estuaries (see Day, 1981 for review), little has been done on closed estuaries and virtually none on the Bot River. The Swedish Africa Expedition visited the area in 1950 and described it as 'Dry heath with dwarf bushes and flowering plants. In a shallow depression a trickle shaded by dense vegetation. On the shores of the lagoon strings of debris' (Brinck & Rudebeck 1955 p.77). More recently, Summers, Pringle & Cooper (1976) have given results of bird counts undertaken at the estuary, although only the lower reaches were covered. De Decker (1981) has compared the physiological condition of the mullet *Liza richardsoni* from the Bot River estuary with that from the open sea. Finally, Heydorn & Tinley (1980) suggest that the Bot River and Kleinmond estuaries be declared a category B reserve (i.e. one in which no exploitation is allowed), although according to Summers *et al.* (1976) the vlei is already partially protected.

Detailed studies on the Bot River estuary were started at the beginning of 1980 within the framework of a larger project funded by the South African National Committee for Oceanographic Research aimed at assessing the status of estuaries in South Africa. Willis (1981) has recently provided preliminary results of substratum analyses from the Bot estuary and Coetzee (1982) has reported on zooplankton as well as temperature and oxygen fluctuations in the system. The increasing demand on South African estuaries to provide areas for recreational activities, residential developments and waste disposal has made these systems particularly vulnerable. This paper presents results of a descriptive survey of the Bot River estuary designed to provide baseline information for further research into specific aspects of the ecology of the system.

Materials and Methods

A preliminary survey of the estuary early in 1980 showed

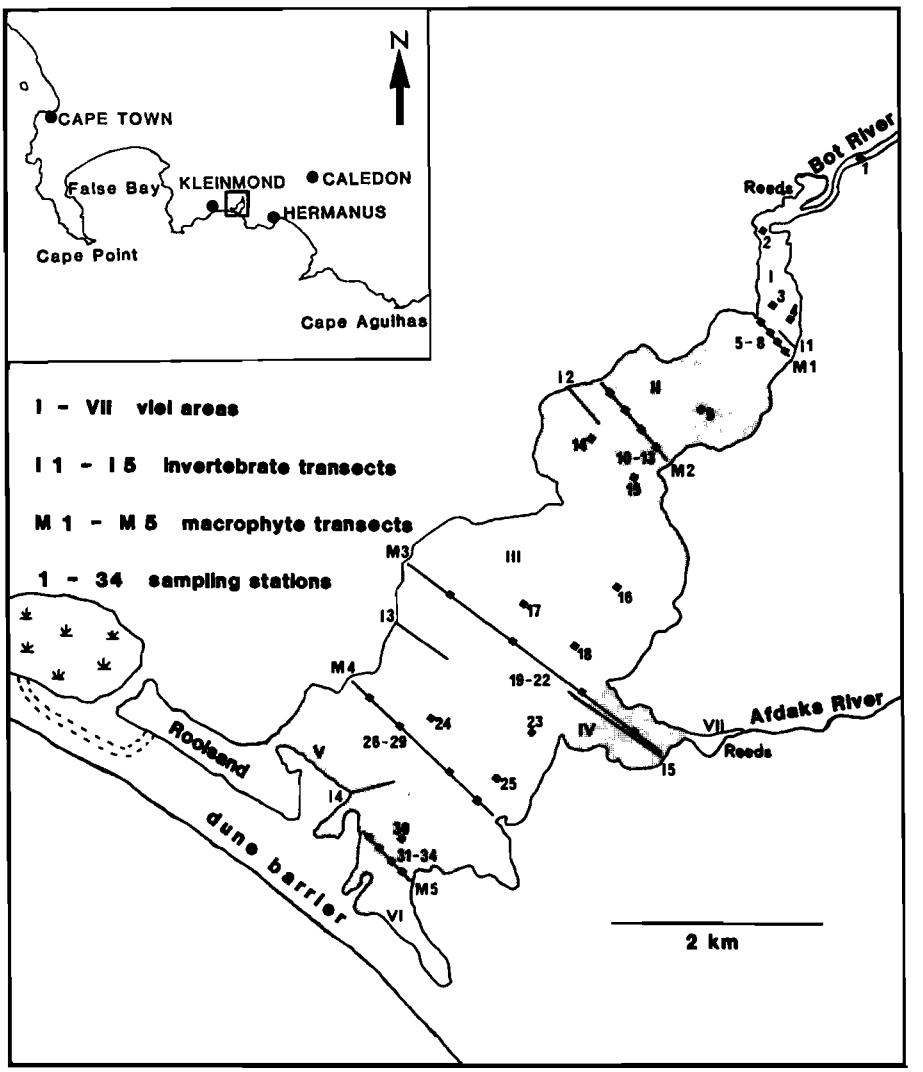

Figure 1 The Bot River estuary in the south-western Cape showing transects and sampling stations. Alternating shading is used to separate the vlei areas from one another.

that the Bot River vlei could be divided into several zones (Figure 1) characterized by the composition of the macrophyte communities.

Zone I: shallow water up to 1 m; dense *Ruppia maritima* and *Chara* sp.; isolated, small stands of *Potamogeton pectinatus;* large amounts of epiphytic *Cladophora* sp.

Zone II: dense *Ruppia* and very dense *Chara;* larger stands of *Potamogeton* than Zone I.

Zone III: main vlei characterized by a large area deeper than 2,9 m where no macrophytes grew; around this a *Ruppia* zone with very little *Chara;* at the southern end dense patches of epiphytic *Cladophora.*

Zone IV: very similar to III but slightly more *Chara.*

Zone V: at the south-western end of the vlei and characterized by pure stands of *Ruppia* less than 50 cm tall.

Zone VI: *Ruppia* less than 20 cm tall; very little *Chara.*

Zone VII: at the mouth of the Afdaks River; *Ruppia* interspersed with small plants of *Chara.*

Submerged plants were sampled at several stations along one transect in each zone except in the largest (Zone III) where two transects were used. The distances between sampling stations varied from 50 to 200 m and a minimum of 5 stations were sampled on any one transect. All the above-ground vegetation was removed from a known area either by a diver using a quadrat and garden shears or by using the weed cutter described by Howard-Williams & Longman (1976) which was operated from a boat. The collected material was sorted to determine species composition, oven dried to constant weight at 60°C and weighed to measure the biomass. The results from stations within each zone were converted to biomass per m^2. The reed beds at the head of the estuary and around the mouth of the Afdaks River were sampled using randomly placed quadrats and harvesting all above-ground vegetation.

To give an indication of the benthic diatom biomass, sediment samples were collected from each station of every transect by a diver using a plastic corer with a diameter of 35 mm. A 5-mm slice of sediment was cut from the surface of each core, as well as from 5- and 15-cm depths. The sediment was extracted in 10 mℓ Analar acetone and analysed for chlorophyll *a* (Strickland & Parsons 1972). The values were expressed as μg chlorophyll per gram of sediment.

Benthic invertebrates were sampled from a series of five transects running from the shoreline towards the centre of the vlei (Figure 1). Duplicate samples were collected at each

station of every transect using a plastic corer (25-cm diameter) to a depth of 30 cm. The corers were easily pushed into the sediment, mostly soft mud, and removed. Animals retained after passing the mud through a 1-mm mesh sieve, as well as those removed from vegetation, were sorted, identified, and oven dried to constant weight at 60°C.

Surface-and bottom-water samples were taken from each of a series of stations covering the whole vlei (Figure 1). Salinity was tested immediately using an optical refractometer. The samples for analyses of nutrients were frozen in liquid nitrogen and returned to the laboratory within a few hours. Analyses for ammonia, nitrate, silicate and phosphate as well as for chlorophyll *a* were carried out using the standard methods described by Strickland & Parsons (1972).

Results and Discussion

Description of the estuary

The Bot River estuary lies at the head of a relatively small catchment area of 813 km^2 (Heydorn & Tinley 1980) and is fed by the Bot River itself, which provides most of the water, and the small Afdaks River which feeds into the estuary halfway along the south-eastern shore. The annual run-off is estimated at 116 × 10^6 m^3 (from Heydorn & Tinley 1980). The Bot drains an area consisting mainly of shales of the Bokkeveld series, although a considerable amount of Table Mountain Sandstone (TMS) is also present, particularly in the Afdaks catchment. A substantial amount of agriculture takes place in the catchment basin, resulting in fairly high inputs of silt and other erosion products (Willis 1981).

The geology of the drainage basin of the Bot River produces waters unstained by humic acids resulting in good light penetration in the estuary. In contrast, the waters of the neighbouring estuaries which are fed by TMS-dominated catchments, are all deeply stained with humic acids to the colour of strong tea.

Extensive reed beds of *Phragmites* and *Scirpus* occur at the north-eastern end, where the Bot River enters, while smaller communities are found at the mouth of the Afdaks River. The estuary is closed off from the sea by a narrow band of dunes of varying height that runs parallel to the sandy coastline. A western extension (Rooisand) runs behind the coastal dunes and is flooded during winter or periods of exceptional rainfall. Halfway along this extension an old mouth is visible, but during the first half of 1981, when water levels were extremely high, the estuary overflowed into the neighbouring Kleinmond swamps through a flat, marshy area and through a deflation channel between the primary and secondary dunes.

Figure 2 shows the bathymetric chart of the lagoon. The maximum recorded depth is some 2,5 m below mean sea level or 3,9 m below the surface of the water at the time of the survey. The deepest area of the estuary lies in its widest part, while an erosion channel, developed from the artificial opening of the vlei in 1977, is visible in the southern part. Since the water level is usually substantially above sea level, and there is no direct contact with the sea, no tidal effects occur. This has substantial implications for the fauna and flora of the estuary. There is, however, a limited input of seawater across a number of wash-over fans clearly visible in aerial photographs of the coastline.

Figure 2 Bathymetric chart of the Bot River estuary (April 1980). Depth contours are in metres relative to mean sea level.

Physical and Chemical Data

Salinity

Salinity values recorded in surface and bottom water during the survey are shown in Table 1. Values were uniformly low with slightly higher readings at the head of the estuary than near the coast. It should be noted that at the time of survey there was no fresh water input from either the Bot or Afdaks rivers. The Bot River had, in fact, been effectively dammed up for some months due to construction of a road bridge at the head of the vlei.

Nutrients

Results of nutrient analyses are shown in Table 1. Values from the Bot River estuary were rather lower than those recorded by Branch & Day (1981) for the nearby Palmiet, or by Harrison & Elsworth (1958) for the Berg River. No clear evidence for stratification was found although at the head of the estuary ammonia values were higher in bottom-water samples, indicating reducing conditions in the

Table 1 Salinity (‰) and nutrient values (μg-at l^{-1}) recorded in surface (s) and bottom (b) water samples from the Bot River estuary, south-western Cape (26.3.1980)

Station No.	Salinity (‰)	Nutrients (μg-at l^{-1})			
		NH_4	NO_3	PO_4	SiO_3
2 s	12	1,29	0,28	0,58	26,19
b	12	5,14	0,83	0,35	22,62
6 s	10	2,14	0,51	0,54	20,24
b	11	8,05	0,55	0,62	17,26
8 s	10	9,71	0,37	0,85	15,48
b	10	8,48	0,78	0,58	17,26
14 s	8	1,90	0,97	0,54	25,00
b	9	5,19	1,52	0,66	16,67
16 s	10	6,24	0,37	0,73	14,29
b	8	6,67	0,37	0,35	11,31
19 s	8	3,56	1,15	0,33	16,27
b	11	1,20	0,51	0,37	18,67
21 s	7	5,77	1,06	0,57	16,27
b	10	1,97	5,54	0,41	15,66
22 s	7	10,67	0,32	0,33	12,65
b	9	2,16	0,32	0,57	19,28
27 s	8	7,93	0,74	0,49	21,08
b	8	6,54	0,69	0,33	12,65
29 s	8	5,91	0,51	0,78	17,47
b	8	1,49	0,51	0,94	19,28
33 s	7	2,60	4,06	0,36	7,06
b	8	6,87	0,46	2,62	9,04

sediments. Silicates appear to be of riverine origin with much higher values encountered at the head of the estuary than near the coastal dunes.

Turbidity

The turbidity of the water was found to fluctuate markedly throughout the day, a pattern that was consistent over a whole year. In the early morning before the onset of winds, secchi-disc readings in excess of 3 m were obtained. By the afternoon, however, turbulence caused by winds frequently reduced these to the order of 10 – 20 cm. This shows that there is considerable wind-induced circulation in the vlei, leading to the suspension of fine sediments, particularly in the more exposed lower reaches.

Additional data

Since the Bot River study is one in which a number of organizations are involved, a good deal of additional data have been collected. Surface water temperatures were found to range from 25°C in mid-summer to 10,5°C in winter (Coetzee 1982), with greater seasonal variations in the upper than the lower reaches.

Oxygen concentrations reported by Coetzee (1982) ranged from 11,0 mg ℓ^{-1} to 6,2 mg ℓ^{-1} in summer, moderately high values with no evidence of oxygen depletion anywhere. The lower reaches tended to show higher concentrations than the upper reaches, probably owing to the more exposed conditions there, resulting in increased turbulence and oxygenation of the water.

Substratum analyses of sediments from the Bot River vlei have been carried out by Willis (1981). These have shown that the shallow areas consist mostly of medium to fine sand. The area with water deeper than 1,5 m consists of over 95% mud in the top 10 cm of sediment. The area near the yacht club where the Afdaks River enters, has outcrops of Bokkeveld rocks which weather to very clay-rich sediments with high mud content.

Continuous records of vlei water levels have been obtained since April 1978 by the Department of Water Affairs using a recording depth gauge. The results show the gradual filling of the vlei following the artificial opening in 1977. In October 1978 a maximum level was reached followed by a decline. Other maxima were recorded in June and July 1979, September 1980, February 1981 (as a result of a brief and unusual flood), and August 1981. Interestingly, both the maximum and minimum levels recorded since 1978 are very similar: approximately 2,3 m and 1,4 m respectively. It would appear that high water levels are usually reached at least once a year. The level decreases gradually after a period of flooding, then rises rapidly with the onset of fresh floods. Records prior to 1977 are few, although an aerial photograph taken in 1976 also shows high levels.

Biological Data

Macrophyte communities

The upper reaches of the estuary were dominated by two reed species, *Phragmites australis* and *Scirpus littoralis*. *Phragmites* was the more abundant of the two, *Scirpus* occurring in small, homogeneous stands among the former. The two species also occurred at the mouth of the Afdaks River and in the marshland between the Bot River vlei and the Kleinmond estuary.

The grass *Sporobulus virginicus* covered parts of the large Rooisand area that is only subjected to periodic flooding, as well as the gently sloping areas along the edges of the vlei. This species was also present in the overflow channel between Rooisand and the Kleinmond estuary, except in those areas subject to high salinities due to seawater overtopping the dune barrier. Above the level occupied by *Sporobulus,* there was a narrow band of tussocks and restionaceous grasses.

The remaining macrophytes consisted of permanently submerged species found wherever conditions were favourable. The most important species in terms of biomass was *Ruppia maritima,* which was found throughout the main body of the vlei in water shallower than 2,9 m. *Potamogeton pectinatus* occurred in the upper reaches in isolated, very dense beds. The stonewort *Chara* sp., an alga, was widely distributed but particularly dense in Zones I and II. Another alga, *Cladophora* sp., was found growing epiphytically mainly in Zones I, III and IV. This is an opportunistic species and appears to be able to colonize submerged grasses very rapidly and smother them, forming dense algal mats which may break loose and float on the water.

Interestingly, the distribution of the macrophytes, when superimposed on the bathymetric chart shown in Figure 2, showed a clear cutoff point at the – 1,5-m level throughout the estuary. Since bathymetry was referenced to mean sea

level and the surface of the vlei was 1,4 m above this level, the submerged vegetation was limited to water depths less than 2,9 m. Deeper water was found only in Zones III and IV and here the bottom was always very turbid owing to large amounts of fine suspended material. Clearly this drastically reduces light penetration and thus plants are restricted to the shallower, less turbid water.

Biomass estimates from transects and quadrats for the two reed species and the four submerged macrophytes are listed in Table 2. It can be seen that in all but Zone I where the other macrophytes were relatively more dense, *Ruppia* made up the bulk of the standing stock, averaging about 70% of the submerged biomass in Zones II, III, and IV and over 98% in Zones V, VI and VII. The reed species occurred only around the two rivers but their biomass per unit area far exceeded that of the submerged plants.

Table 2 Biomass of macrophytes (kg dry wt m^{-2}) from seven areas of the Bot River estuary in the south western Cape

Plant Species	Zone I	II	III	IV	V	VI	VII
Ruppia	0,052	0,239	0,118	0,371	0,071	0,009	0,195
Potamogeton	0,028	0,035	0,000	0,000	0,000	0,000	0,000
Chara	0,032	0,071	0,001	0,007	0,000	0,001	0,004
Cladophora	0,035	0,008	0,069	0,140	0,000	0,000	0,000
Total submerged macrophytes	0,147	0,353	0,188	0,518	0,071	0,010	0,199
Phragmites	0,955	0,000	0,000	0,000	0,000	0,000	1,794
Scirpus	0,654	0,000	0,000	0,000	0,000	0,000	0,961
Total reeds	1,609	0,000	0,000	0,000	0,000	0,000	2,755

Benthic diatoms

The standing stock of benthic diatoms was estimated using chlorophyll *a* levels measured in the sediment. Table 3 shows readings for the top 0,5 cm of sediment only. Values from 5 and 15 cm below the surface were extremely low to undetectable and have been omitted. Surface chlorophyll levels were uniformly low and no recognizable trends were detected throughout the estuary, except that the lowest values were recorded in the coarsest sediments near the bottom of the estuary (Zone V, Figure 1). The values were similar to those reported by Branch & Day (1981) for the nearby Palmiet estuary but were about three orders of magnitude lower than those measured in sediments at Langebaan lagoon (Branch, unpubl. data). It is likely that shading by macrophytes plays a major role in limiting diatom biomass in the Bot River estuary, reducing light levels at the sediment surface to a minimum. The open sandbanks at Langebaan have no such macrophytes and diatom biomass is consequently much higher.

Phytoplankton

Microscopic examination of water samples indicated that the bulk of the phytoplankton from the Bot River vlei consisted of flagellates. Chlorophyll *a* levels measured at several stations on three occasions are given in Table 4. The values are uniformly low, ranging from 0,35 to 4,55 $\mu g\ \ell^{-1}$, even lower than those reported from the Palmiet estuary (Branch & Day 1981). It seems likely that the high degree of wind-induced mixing of the water in the main body of the vlei with the resulting turbidity leads to greatly reduced light penetration which in turn would depress phytoplankton growth.

Table 3 Concentrations of chlorophyll *a* in the upper 0,5 cm of sediment from the Bot River estuary, south-western Cape

Station No.	Chlorophyll *a* ($\mu g\ g^{-1}$ substratum)
5	3,824
6	0,752
7	0,695
8	1,301
10	1,204
11	1,446
12	2,805
13	2,880
19	0,314
20	1,192
21	1,214
22	0,290
26	0,688
27	3,904
28	2,563
29	0,571
31	0,241
32	0,142
33	0,163
34	0,264

Table 4 Phytoplankton chlorophyll *a* values ($\mu g\ l^{-1}$) measured on three occasions at the Bot River estuary, south-western Cape. Surface water was used for analyses

Station No.	Date 27.2.80	24.3.80	26.3.80
1	5,90	3,24	1,80
2	–	2,28	2,20
3	0,92	3,55	2,47
4	–	0,59	0,39
9	–	0,35	0,96
14	1,30	–	0,59
15	2,40	–	1,45
16	–	–	1,95
17	1,30	–	2,87
18	2,20	–	2,45
23	–	–	2,58
24	–	–	2,68
25	1,90	–	2,99
30	0,50	–	1,20

Table 5 Maximum densities (per m^2) and, in parentheses, maximum biomass (mg dry wt m^{-2}) of invertebrates from five transects from the Bot River estuary, south western Cape.

Species	Transect No. 1	2	3	4	5
Polychaeta					
Nephtys zeylanica	60 (96,00)	0 (0,00)	200 (320,00)	160 (256,00)	0 (0,00)
Ceratonereis erythraeensis	860 (494,50)	1140 (655,50)	100 (57,50)	720 (414,00)	780 (448,50)
Isopoda					
Exosphaeroma hylecoetes	260 (796,80)	760 (2523,20)	300 (996,00)	1980 (6572,60)	20 (66,40)
Cyathura carinata	80 (155,20)	280 (543,20)	240 (465,60)	220 (426,80)	160 (310,40)
Amphipoda					
Melita zeylanica	140 (126,40)	1320 (1193,28)	440 (397,76)	580, (524,32)	240 (216,96)
Corophium triaenonix	180 (810,00)	60 (270,00)	0 (0,00)	0 (0,00)	0 (0,00)
Orchestia ancheidos	0 (0,00)	40 (936,00)	20 (234,00)	240 (2808,00)	80 (936,00)
Tanaidacea					
Apseudes digitalis	0 (0,00)	20 (24,00)	0 (0,00)	0 (0,00)	0 (0,00)
Macrura					
Palaemon pacificus	0 (0,00)	0 (0,00)	0 (0,00)	60 (580,00)	0 (0,00)
Anomura					
Callianassa kraussi	0 (0,00)	0 (0,00)	200 (5600,00)	20 (560,00)	0 (0,00)
Insecta					
Ephemeropteran larvae	0 (0,00)	80 (720,00)	0 (0,00)	0 (0,00)	0 (0,00)
Chironomid larvae	0 (0,00)	0 (0,00)	0 (0,00)	0 (0,00)	160 (83,20)
Dipteran pupae	0 (0,00)	0 (0,00)	60 (31,20)	20 (10,40)	0 (0,00)
Staphylinid beetle	0 (0,00)	0 (0,00)	0 (0,00)	40 (16,00)	0 (0,00)
Bivalvia					
Lamya capensis	40 (280,00)	40 (280,00)	360 (2520,00)	180 (1260,00)	140 (980,00)
Gastropoda					
Hydrobia sp.	400 (80,00)	0 (0,00)	3840 (768,00)	4000 (800,00)	1960 (392,00)
Assiminea sp.	0 (0,00)	980 (196,00)	0 (0,00)	980 (196,00)	0 (0,00)

Invertebrate fauna

Five transects were used to sample invertebrates in the estuary. The most striking feature of the results is the paucity of the fauna. A total of only 18 species of invertebrates was recorded. Because of the discontinuous distribution of the species along each transect only maximum densities and biomass are shown in Table 5. Clearly some species may reach rather high densities, up to 4000 individuals of *Hydrobia* per m^2 being recorded on transect 4, although this is nowhere near figures of up to 100 000 individuals per m^2 found in the nearby Palmiet, an open estuary (Branch & Day 1981). No marked differences in the species composition of the five transects were recorded, with the major species occurring at all locations. The nature of the estuary with no tidal exchanges and relatively uniform physical and chemical conditions throughout, would tend to lead to this fairly even distribution of invertebrates.

Figure 3 shows the distribution of species recorded from transect 4, the transect yielding the most species. This is given as representative of the distribution of invertebrates although on other transects some of the species were not present. There is a clear driftline fauna consisting of a staphylinid beetle, the amphipod *Orchestia ancheidos*, the isopod *Exosphaeroma hylecoetes* and the polychaetes *Nephtys* and *Ceratonereis* as well as a few individuals of *Hydrobia*. The remaining species are fairly evenly distributed with

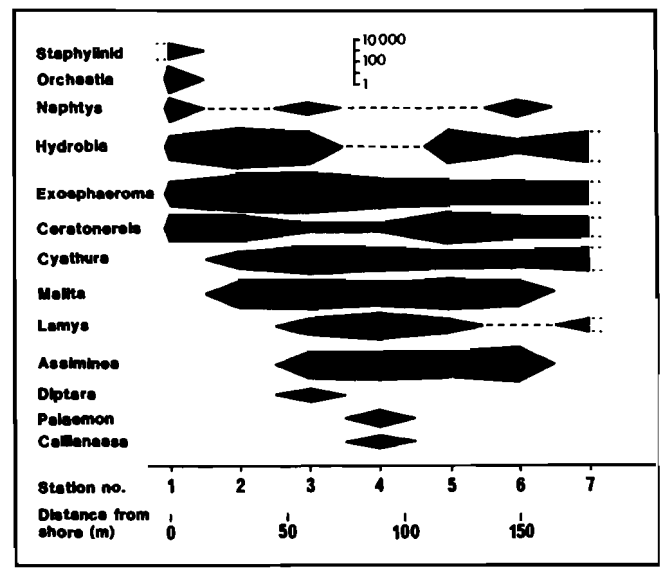

Figure 3 Densities of invertebrates per m^2 from transect No. 4 at the Bot River estuary, south-western Cape.

Callianassa, Assiminea and *Palaemon* showing a more patchy distribution.

The biomass distribution of invertebrates in the top 30 cm of sediment and in the weeds along five transects is given in Figure 4. A feature of the data is that the biomass is

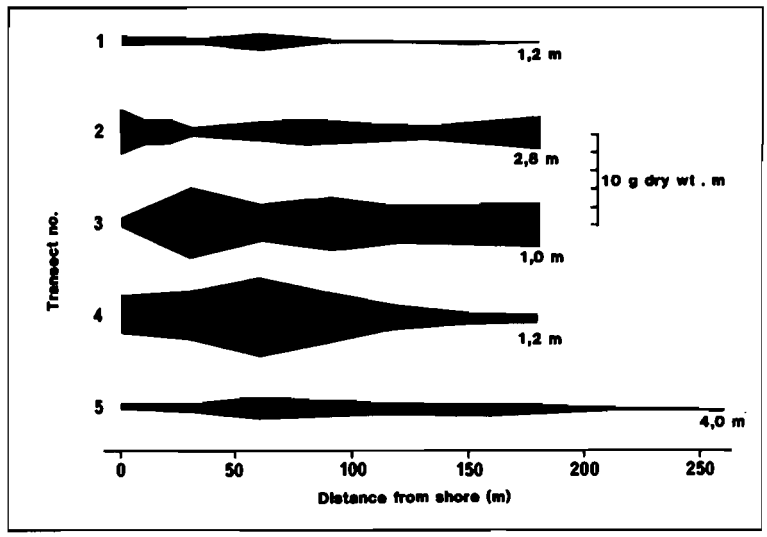

Figure 4 Invertebrate biomass distribution along five transects at the Bot River estuary, south-western Cape. The first sampling station was at the driftline and the water depth of the final station is given. For transect profiles see Figure 2 and Appendix for full data.

relatively low, ranging from 0,02 to 8,13 g dry weight m^{-2}, much lower values than those recorded from most other estuaries (Day 1981). Table 5 has shown that numerically *Hydrobia* is dominant on several transects. Because of its small size, however, it contributes relatively little to the biomass and several less abundant but larger species (e.g. *Callianassa, Orchestia, Exosphaeroma)* have a greater impact in terms of biomass.

Additional data

The avifauna of the Bot River estuary has been studied by C. Heyl, Department of Nature Conservation, who has carried out monthly counts of the red-knobbed coot (*Fulica cristata)*. The Western Cape Wader Study Group conducted a census of all birds on the Bot estuary in January 1981.

A very extensive survey of fish has been carried out by B. Bennett (Zoology Department, University of Cape Town, in prep.), and Coetzee (1982) has reported on the zooplankton in the Bot River estuary.

Conclusions

The Bot River vlei appears to be a coastal lake in the making. This much is clear from a number of factors, the foremost of which are that it does not appear to have opened to the sea naturally for a long time, that the level of the water is nearly always above sea level and that, except when opened artificially, it is completely atidal. In addition, there is a well-defined overflow channel that carries flood waters from the Bot River vlei into the Kleinmond estuary. It would appear, therefore, that if the vlei were left undisturbed, it would remain in approximately the state described in this paper, although during periods of exceptionally heavy rains or floods the waters could breach the dunes leading to a natural opening of the estuary. According to Heydorn & Tinley (1980), however, the dune coast at the mouth of the Bot River is aggrading, implying that the dune barrier is in the process of widening. This is confirmed by Landsat scenes taken in 1973 and 1978 (Figure 5). The shaded area in the 1978 scene shows the amount of additional sand deposited during this six-year period.

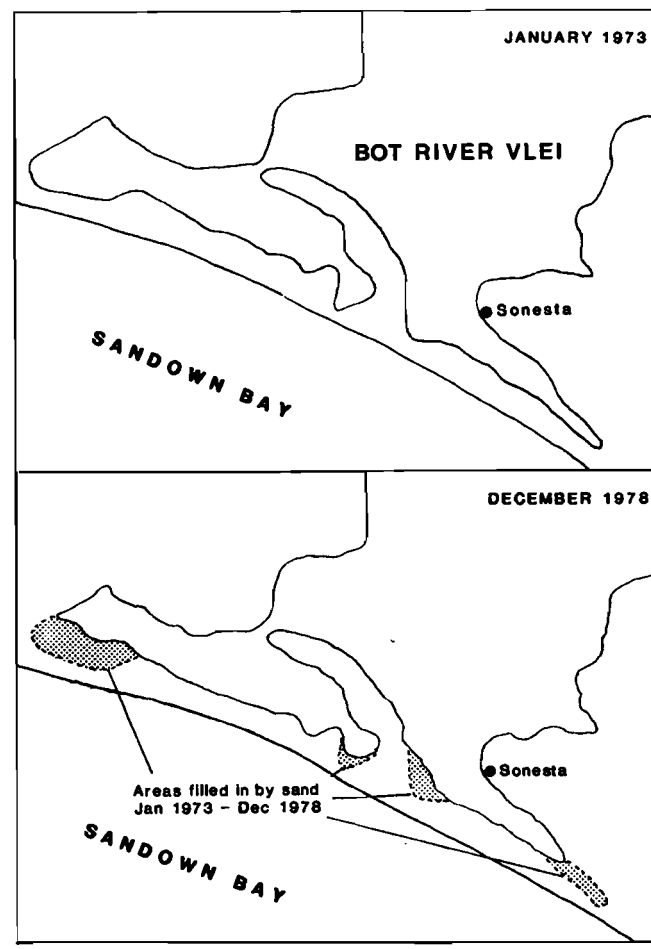

Figure 5 Landsat scenes of the lower section of the Bot River estuary and the coastal dunes. The shaded areas in the 1978 scene represent areas filled in by sand in the six-year interim period.

While the estuary is closed, input of seawater is confined to occasional overtopping of the dune barrier via wash-over fans. Apart from that, there is no direct contact with the sea. If the dune barrier is in the process of widening, however, this type of input can be expected to decrease resulting in a probable reduction in salinity in the estuary.

Marine species as well as estuarine species with little tolerance for low salinities would be adversely affected. Thus mass mortalities of the fish *Lithognathus lithognathus, Rhabdosargus globiceps, Arius feliceps* and *Ophisurus serpens* occurred in October 1981, when salinities dropped to below 3‰. It should be noted, however, that salinities as high as 10‰ have been recorded in the Bot River and its tributaries (Heydorn, pers. comm.) and thus the salinity may never drop to extremely low levels even if the estuary were permanently closed.

The Bot River vlei is an important wetland for avifauna. It supports 8% of the resident wader population between the Olifants River and Cape Agulhas, and 2,4% of the resident plus migrant waders (Summers *et al.*, 1976). As shown earlier the estuary also carries a very large coot population, which plays a major role in the ecology of the vlei. A study carried out recently by the Western Cape Wader Study Group (unpubl. data) showed that approximately 50% of all coots in the area between the Olifants and Great Brak River mouths were on the Bot River vlei. The Bot counts obtained by the Group also make up 27,7% of the total number of coots that have been estimated to occur on all South African coastal wetlands in a separate study by the Percy FitzPatrick Institute of African Ornithology (J. Cooper, pers. comm.). While no estimates exist for inland populations of these birds, the coots on the Bot River vlei must represent a substantial proportion of the total South African population.

Fairall (1981) has calculated the food consumption of both juvenile and adult coots at Swartvlei and his figures suggest that a population of 20 000 coots consume about 500 kg dry weight of *Potamogeton* and *Ruppia* per day. Thus these birds may consume as much as 10% of the annual production of the macrophytes in the Bot River estuary when the system is undisturbed. Artificial opening of the vlei, however, has been a regular feature and this means that the submerged areas change continually. This results in unpredictable and transient areas which are able to sustain primary production, owing to changes in the euphotic layer. Regular manipulation of the water level of the estuary must, therefore, inevitably result in reduced annual production of macrophytes making it a highly unstable refuge for the waterfowl of the area.

The effects of opening the vlei are known to be dramatic. The entire body of water down to sea level is drained within a few hours. When the initial water level is so high that the euphotic zone lies above mean sea level, the effect of draining the vlei is to leave all the submerged macrophytes stranded. The plants die within a few days. This effectively removes all the food for the coots but also leads to the extermination of a large proportion of the invertebrate fauna in the vlei (*cf.* Davies 1982) and thus the food source of wader populations. Thus it would appear that there is an urgent and immediate need to formulate a consistent management strategy for the Bot River estuary, an important and unique system in the western Cape.

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Appendix on opposite page

Appendix Biomass (mg dry wt m^{-2}) of invertebrates recorded from five transects (see Figure 1) at the Bot River estuary, south-western Cape.

Species	Station No. 1	2	3	4	5	6	7
Transect 1							
Nephtys zeylanica	–	–	96,00	–	–	–	–
Ceratonereis erythraeensis	494,50	34,50	–	–	–	–	–
Exosphaeroma hylecoetes	132,80	398,40	796,80	–	–	–	–
Cyathura carinata	77,60	116,40	77,60	155,20	77,60	155,20	38,80
Melita zeylanica	126,40	18,00	18,00	54,20	–	54,20	–
Corophium triaenonix	–	–	810,00	–	–	–	–
Lamya capensis	–	–	–	–	–	280,00	–
Hydrobia sp.	80,00	–	4,00	8,00	–	–	–
Total biomass	911,30	567,30	1802,40	217,40	77,60	489,40	38,80
Transect 2							
Ceratonereis erythraeensis	655,50	149,50	46,00	11,50	46,00	–	–
Exosphaeroma hylecoetes	2257,60	730,40	597,60	265,60	1261,60	531,20	2523,20
Cyathura carinata	116,40	349,20	232,80	194,00	543,20	155,20	232,80
Melita zeylanica	1193,28	325,44	777,44	144,64	542,40	361,60	144,64
Corophium triaenonix	–	–	–	270,00	–	–	–
Orchestia ancheidos	468,00	936,00	–	–	–	–	–
Apseudes digitalis '	–	–	–	24,00	–	–	–
Ephemeropteran larvae	–	–	720,00	–	–	–	–
Lamya capensis	–	140,00	280,00	–	280,00	280,00	280,00
Assiminea sp.	16,00	4,00	–	–	136,00	64,00	196,00
Total biomass	4706,78	2634,54	2653,84	909,74	2809,20	1392,00	3376,64
Transect 3							
Nephtys zeylanica	–	–	–	64,00	320,00	320,00	32,00
Ceratonereis erythraeensis	–	57,50	–	–	–	–	–
Exosphaeroma hylecoetes	–	597,60	398,40	996,00	531,20	265,60	199,20
Cyathura carinata	–	271,60	232,80	426,80	465,60	271,60	349,20
Melita zeylanica	18,08	361,60	361,60	397,76	72,32	144,64	90,40
Orchestia ancheidos	234,00	–	–	–	–	–	–
Callianassa kraussi	–	5600,00	560,00	1120,00	560,00	2240,00	2240,00
Dipteran pupae	31,20	–	–	–	–	–	–
Lamya capensis	420,00	560,00	1680,00	2520,00	1120,00	980,00	1400,00
Hydrobia sp.	4,00	136,00	640,00	252,00	768,00	180,00	376,00
Total biomass	707,28	7584,30	3938,30	5776,56	3837,12	4401,84	4686,80
Transect 4							
Nephtys zeylanica	256,00	–	32,00	–	–	128,00	–
Ceratonereis erythraeensis	126,50	149,50	34,50	34,50	414,00	–	–
Exosphaeroma hylecoetes	464,80	3452,80	6573,60	1460,80	730,40	332,00	265,60
Cyathura carinata	–	155,20	426,80	232,80	155,20	155,20	232,80
Melita zeylanica	–	343,52	524,32	162,72	452,00	235,04	–
Orchestia ancheidos	2808,00	–	–	–	–	–	–
Palaemon pacificus	–	–	–	580,00	–	–	–
Callianassa kraussi	–	–	–	560,00	–	–	–
Dipteran pupae	–	–	10,40	–	–	–	–
Staphylinid beetle	16,00	–	–	–	–	–	–
Lamya capensis	–	–	280,00	1260,00	140,00	–	140,00
Hydrobia sp.	32,00	800,00	200,00	–	204,00	4,00	124,00
Assiminea sp.	–	–	48,00	100,00	36,00	192,00	–
Total biomass	3703,30	4901,02	8129,62	4390,82	2131,60	1046,24	762,40

Appendix (continued)

Species	Station No. 1	2	3	4	5	6	7
Transect 5							
Ceratonereis erythraeensis	–	–	448,50	11,50	115,00	11,50	–
Exosphaeroma hylecoetes	–	–	66,40	–	–	–	–
Cyathura carinata	–	–	310,40	77,60	116,40	–	–
Melita zeylanica	216,96	54,24	90,40	54,24	–	–	–
Orchestia ancheidos	–	–	468,00	–	936,00	–	–
Chironomid larvae	–	72,80	10,40	83,20	–	–	–
Lamya capensis	–	–	980,00	980,00	280,00	280,00	–
Hydrobia sp.	200,00	392,00	32,00	136,00	–	16,00	16,00
Total biomass	416,96	863,20	2406,10	1259,34	1447,40	307,50	16,00