The ecology of two degraded estuaries on the north coast of Natal, South Africa

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The biota of the Tongati and Mdloti estuaries were studied in relation to the environment and human interference. Results are compared with those obtained from a relatively undamaged estuary. The Tongati receives treated sewage effluent, is rarely closed from the sea, has low salinities and low oxygen tensions, but is rich in phosphorus and nitrogen. Energy values of benthic floc from Tongati were high and large quantities of water hyacinth (*Eichomia crassipes*) occurred. The zooplankton and zoobenthos were impoverished and dominated by freshwater species. The roots of *Eichomia* provided a habitat for many invertebrates, chiefly insect larvae and the crab *Varuna litterata*. The fish fauna was poor and most species were confined to the lagoon near the mouth. Iliophagous species, mainly Mugilidae, were dominant. The Mdloti, frequently closed from the sea but often artificially opened, exhibited typical estuarine salinity patterns, was well oxygenated but relatively poor in phosphorus and nitrogen. Primary production and energy values of benthic floc were low. Zooplankton and zoobenthos were impoverished. The fish fauna, similar to that of Tongati, was dominated by Mugilidae.

The food chain from benthic floc to iliophagous fish remains viable in these degraded estuaries.

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Die biotas in die Tongati en Mdloti, twee klein gedegradeerde estuaria in Natal, is bestudeer met betrekking tot die omgewing en steùrings deur mense. Resultate word vergelyk met dié van vorige studies op 'n aangrensende ongeskonde estuarium. Tongati ontvang behandelde riooluitloop, is selde van die see afgesny, het 'n lae soutgehalte en lae suurstofspanning maar bevat hoë konsentrasies stikstof en fosfor. Energie-inhoud van die bentiese vlok uit Tongati is hoog en groot hoeveelhede waterhiasinte (*Eichomia crassipes*) kom ook voor. Die soöplankton en soöbentos is verarm en varswaterspesies is dominant. Die wortels van *Eichomia* verskaf 'n habitat vir verskeie ongewerwelde diere, hoofsaaklik inseklarwes en die krap *Varuna litterata*. Die visbevolking was klein en meeste soorte (hoofsaaklik Mugilidae) was slegs naby die monding teenwoordig. Mdloti was dikwels van die see afgesny, maar is ook baie keer ontydig oopgemaak. Dit het 'n soutgehalte tipies van estuaria en suurstofspanning was deurgaans hoog, maar konsentrasies van stikstof en fosfor was laag. Primêre produksie asook energie-inhoud van die bentiese vlok was laag. Soöplankton en soöbentos was verarm. Die visbevolking is gelyksoortig met dié van Tongati en word oorheers deur Mugilidae.

Die voedselketting vanaf bentiese vlok na iliofagiese vissoorte bly lewensvatbaar in hierdie gedegradeerde estuaria.

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Many of the smaller estuaries of the Natal coast have been adversely affected by various human activities (Begg 1978), but no detailed studies have been undertaken to show how such degradation has altered their ecology in terms of trophic relationships, diversity and the response of organisms to different forms of human interference. The Mhlanga estuary is unusual as it is conserved in a relatively natural state and the studies by Whitfield (1980a,b,c) provide base-line data with which other estuaries can be compared. During 1980 the World Wildlife Fund, through the South African Nature Foundation, commissioned a project on degraded estuaries in Natal as part of their 'Seas Must Live' campaign. The estuaries chosen for study were the Tongati and Mdloti which are adjacent to Mhlanga estuary. Begg (1978) described the environmental condition of Mhlanga as good, Mdloti as fair and Tongati as poor. The object of this study was to determine the composition, interrelationships and fluctuations of the biota in relation to the physical environment over a one-year period. In this way an attempt has been made to demonstrate how various types of interference affect the estuary as a whole and to pinpoint key factors responsible for ecosystem degradation.

Study areas

The location of the Tongati, Mdloti and Mhlanga estuaries is shown in Figure 1. Detailed descriptions are given in Begg (1978) and for Mhlanga in Whitfield (1980a). The sampling stations hereafter referred to as lower, middle and upper reaches are shown in Figure 1. Mhlanga estuary is subject to a minimum of human interference and remains closed to the sea for most of the year owing to a low outflow and longshore drift of sand, only opening after heavy rain, usually in summer. Tongati and Mdloti estuaries are frequently opened artificially by the digging of a channel through the sandbar when water levels rise significantly to cause flooding of sugar cane on the adjacent floodplains. Tongati receives a discharge from a sewage works and industrial effluent from sugar and textile mills (Begg 1978). Mdloti is occasionally subject to industrial pollution from the upper catchment but the surrounding area is mainly one of intensive agriculture.

Materials and methods

Physical data

The salinity, temperature, oxygen concentration and turbidity were measured monthly at the stations shown in Figure 1. Bottom-water samples were collected using a Hydrobios 2 ℓ sampling bottle. Salinity was measured with a Goldberg optical salinometer, temperature with a mercury thermometer cor-

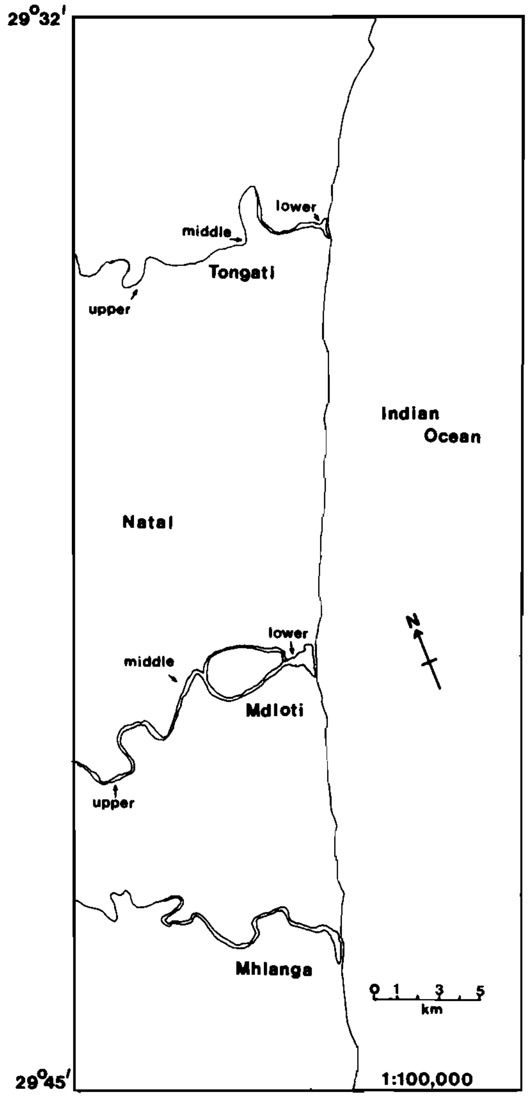

Figure 1 The location of Tongati, Mdloti and Mhlanga estuaries showing positions of sampling stations.

rected to 0,1 °C, oxygen with a Yellow Springs oxygen meter and turbidity with a Hach 16800 nephelometer.

The state of the mouth of each estuary was monitored approximately weekly. It was described as closed if little or no water crossed the sandbar from the sea at high tide.

During November 1981, water samples were collected from all sampling stations for analyses of nitrogen and phosphorus levels. In addition Mugilidae (grey mullet) were collected at Mdloti for heavy metal and pesticide assays. These analyses were performed by the National Institute for Water Research in Durban. Samples were also collected to check for the presence of coliform bacteria, particularly *Escherichia coli*. The bacteriological methods used were those of Mackie & McCartney (1950).

Substrata

The upper 5 cm of substratum from three sampling stations in each estuary was removed using the benthic floc sampling apparatus of Whitfield (1980a). The particle size distribution of each substratum was obtained by washing the sample through a series of Endecott sieves with mesh sizes of 4; 2; 1; 0,5; 0,25; 0,125 and 0,063 mm. The contents of each sieve were measured by volume and expressed as proportions of the whole sample.

Zooplankton

Samples at the surface were collected monthly from the lower reaches of both estuaries using a Clarke-Bumpus plankton sampler fitted with a flow-meter and a 70 μm mesh net. Samples on or near the bottom were collected with a D-net (Crossbar 360 mm, arch 190 mm) fitted with a 70 μm net. All plankton samples were collected after sunset and preserved immediately in 10% formalin. Counting and calorific determinations of zooplankton were performed as described by Blaber (1979).

Zoobenthos

Zoobenthos was collected monthly using a Zabolocki-type Ekman grab at three stations in each estuary. The sorting and counting procedures followed those of Whitfield (1980a).

Benthic floc

Benthic floc is the term used to describe the mixture of detritus and micro-organisms found on benthic substrata. This was collected monthly at all stations using the apparatus described by Whitfield (1980a).

Epiphytic flora and fauna

Tongati and Mdloti estuaries are bounded by extensive *Phragmites* reed swamps but extensive sampling indicated a total absence of the epiphytic organisms characteristic of such swamps at Mhlanga estuary.

Epipsammic flora

This was collected by scraping the top 0,5 cm of substratum into the benthic floc apparatus.

Fauna from *Eichornia crassipes*

The roots of the floating water hyacinth growing in Tongati were the habitat for numerous invertebrates. Two plants were collected from each station each month. Mobile animals were dislodged from the roots by washing the plant in 10% formalin. Sessile animals, of which there were very few, were removed from the roots with forceps.

Fish

The lower reaches of both estuaries were sampled monthly using a large seine-net (70 m × 2 m × 12 mm bar mesh) and a small seine-net (10 m × 1,5 m × 4 mm bar mesh). In the middle and upper reaches a cast-net was used. A minimum of 20 casts were performed at each station each month. All fish were measured to standard length and a subsample of the catch preserved in 10% formalin. The stomach contents of the preserved specimens were analysed and the results expressed in terms of the percentage frequency of occurrence of the various food items.

Birds

Monthly counts were made of all water-associated species.

Energy determinations

Calorific values were obtained from published information (Blaber 1979; Blaber, Cyrus & Whitfield 1981; Cyrus 1980; Whitfield 1980a) or were determined using a Philipson microbomb calorimeter or a Gallenkamp ballistic bomb calorimeter. The latter was used to obtain values for each sample of benthic floc to which known amounts of mineral oil were added to obtain complete combustion.

Results

The percentage of oxygen saturation, salinity and temperature of the surface waters of Tongati and Mdloti during 1980/81 are shown in Figures 2 and 3. The same parameters for bottom waters are shown in Figures 4 and 5. Figures 2 to 5 also indicate when the estuary mouths were open or closed.

The Tongati estuary was open for most of the year which, together with a continuous outflow and periods of high rainfall (e.g. March 1981), served to maintain low but fluctuating salinities. However, temperature and oxygen levels showed little response to the state of the mouth. Oxygen concentrations in Tongati were generally low although marked fluctuations occurred, particularly in bottom waters. For four months of the year the bottom waters of the upper reaches had oxygen saturations of less than 25% and during July and August 1981 values of less than 5% were recorded.

The Mdloti estuary was open intermittently throughout the year but completely closed from late May until late August. Bottom salinities fluctuated according to the state of the mouth, tide and inflow of fresh water but the upper reaches only exceeded 5‰ during December and January. Surface-water salinity was generally very low except when the mouth was open in March, April and October. Oxygen levels in Mdloti rarely fell below 50% saturation and surface concentrations

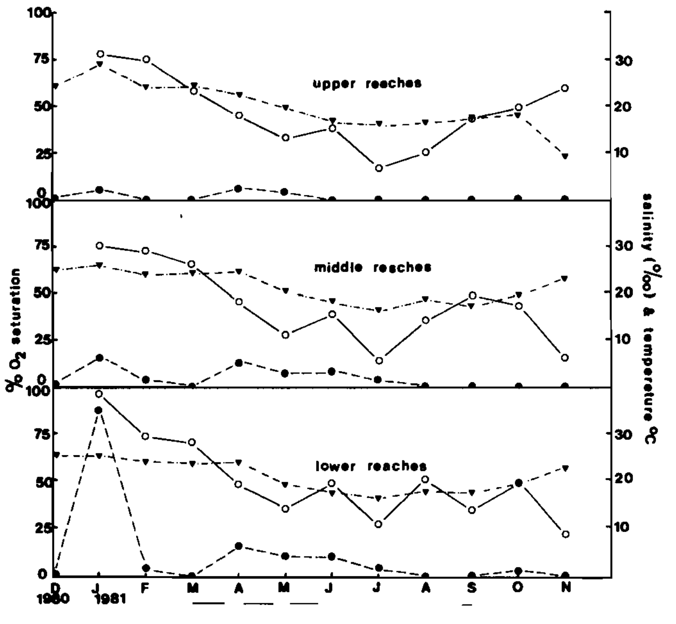

Figure 2 Physical conditions in the surface waters of Tongati estuary from December 1980 to November 1981. (○—○ = % oxygen saturation, ▼–.–▼ = temperature, ● – – ● = salinity, — = periods of closure).

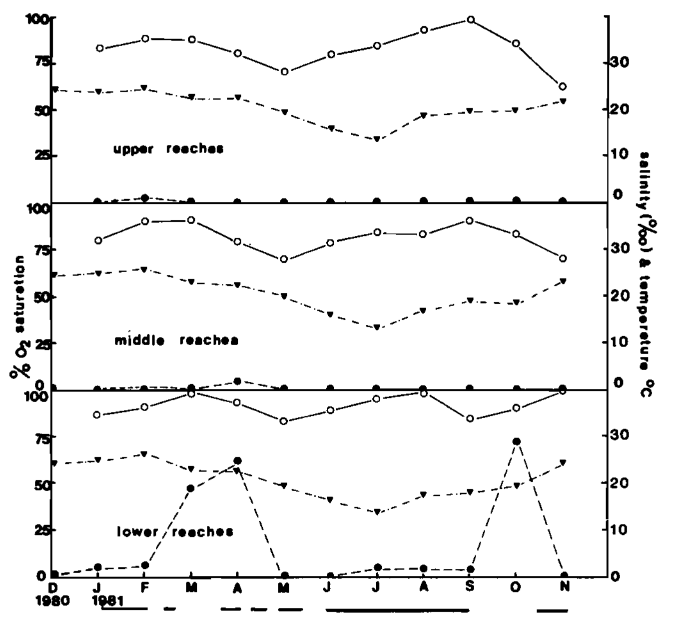

Figure 3 Physical conditions in the surface waters of Mdloti estuary from December 1980 to November 1981. (○—○ = % oxygen saturation, ▼–.–▼ = temperature, ● – – ● = salinity, — = periods of closure).

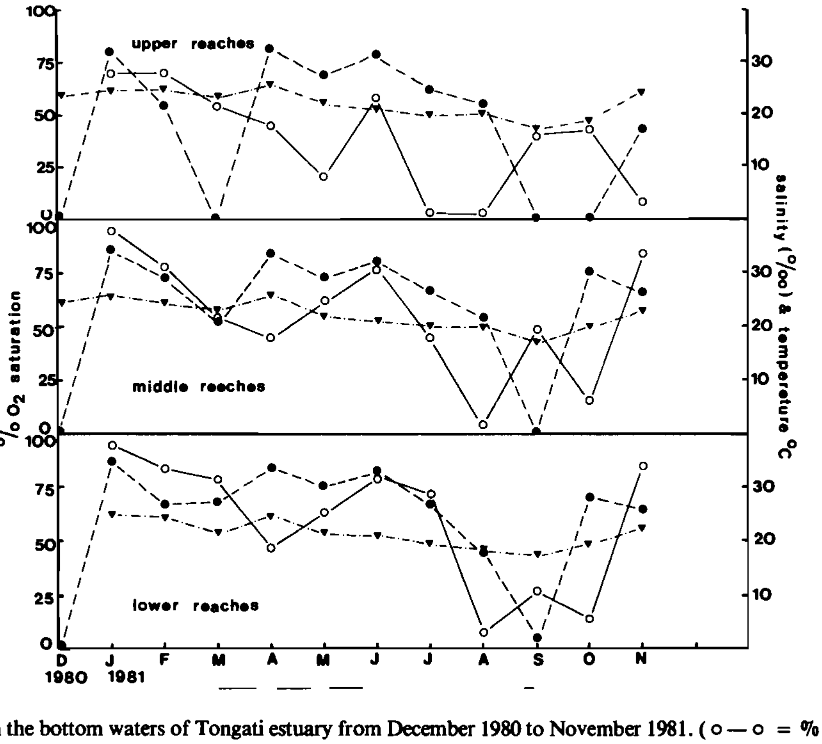

Figure 4 Physical conditions in the bottom waters of Tongati estuary from December 1980 to November 1981. (○—○ = % oxygen saturation, ▼–.–▼ = temperature, ● – – ● = salinity, — = periods of closure).

did not fall below 75% saturation for most of the year. Temperatures in winter dropped to 13 °C and in summer rose to 27 °C.

Surface and bottom turbidities are shown in Figures 6 and 7. High turbidities in both estuaries coincided with high rainfall from December to April and September to November. Turbidities in all areas even at periods of low flow were relatively high (>10 NTU) compared with the sea (usually <2 NTU).

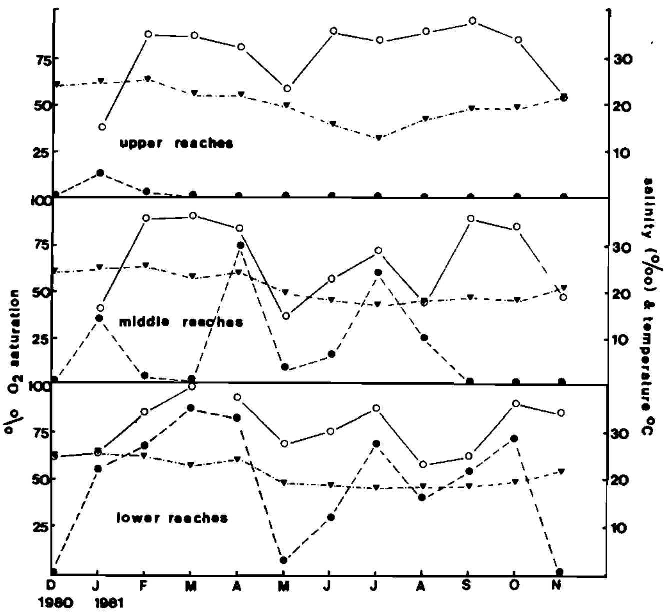

Figure 5 Physical conditions in the bottom waters of Mdloti estuary from December 1980 to November 1981. (o — o = % oxygen saturation, ▼-.-▼ = temperature, ● — — ● = salinity, — = periods of closure).

The values for total phosphorus, soluble reactive phosphorus (SRP), total nitrogen, nitrates and ammonia are shown in Table 1. Phosphorus values in Mdloti may be sufficiently low to limit primary production. Most of the nitrogen in Tongati was in the form of ammonia possibly derived from treated sewage. The high nitrate values for Mdloti may be a result of the use of agricultural fertilizer on adjacent land.

Samples from nine stations in Tongati and six in Mdloti

Table 1 Levels (mg/ℓ) of total phosphorus, soluble reactive phosphate (SRP), total nitrogen, nitrates and ammonia from the water of Mdloti and Tongati estuaries

Estuary & Station	Total P	SRP	Total N	Nitrate	Ammonia
Tongati Lagoon	233	172	1681	6	922
Mdloti Lagoon	44	34	340	2	29
Tongati L/Middle reaches	208	132	2000	3	1245
Mdloti L/Middle reaches	35	20	368	37	26
Tongati Middle reaches	187	75	2653	1	2406
Mdloti Middle reaches	47	34	417	291	27
Tongati Upper reaches	179	124	3653	17	1865
Mdloti Upper reaches	67	48	382	376	31
Tongati River	162	106	4472	2	2662
Mdloti River	43	32	347	468	22

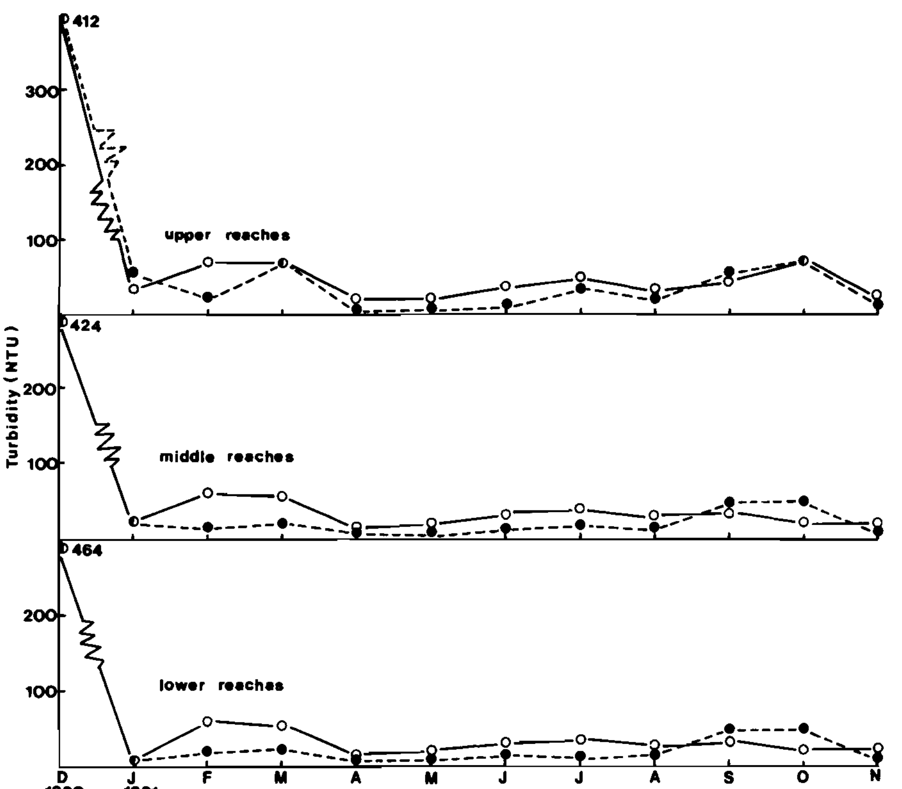

Figure 6 Turbidity (Nephelometric turbidity units = NTU) of surface (o — o) and bottom (● — — ●) waters of Tongati estuary from December 1980 to November 1981.

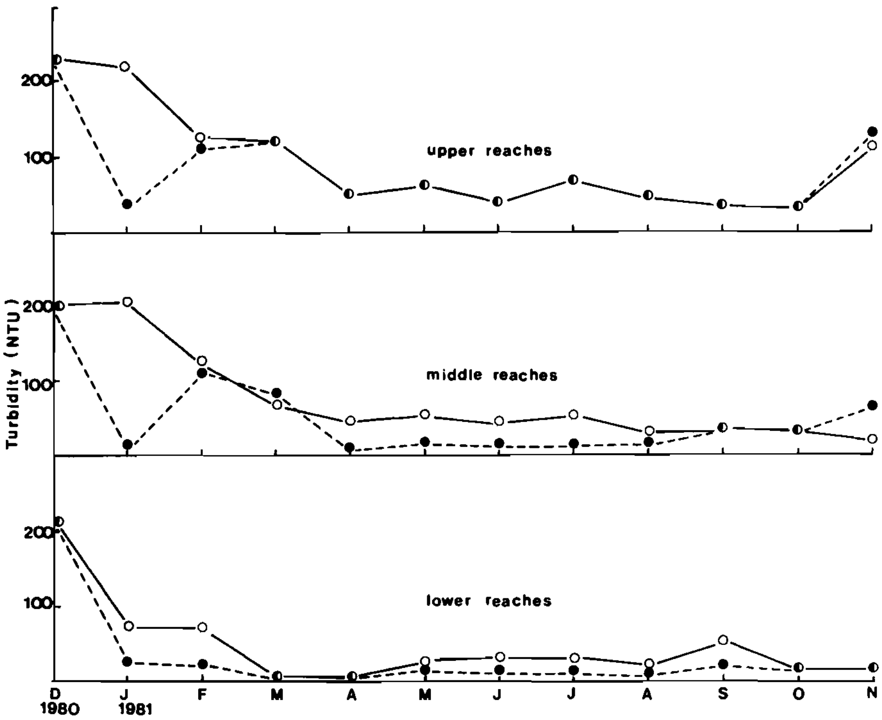

Figure 7 Turbidity (Nephelometric turbidity units = NTU) of surface (o — o) and bottom (● – – ●) waters of Mdloti estuary from December 1980 to November 1981.

showed negative responses to tests for the bacterial pathogen *E. coli* although high levels of other gas-forming bacteria were indicated.

The results of assays for heavy metals on Mugilidae from Mdloti are shown in Table 2. None of the levels recorded were significantly high and give no cause for concern.

Assays on Mugilidae from Mdloti for the pesticides DDE, TDE, DDT, PCB's and Lindane were negative but significant quantities of dieldrin were present. The mean for dieldrin was 49,2 μg/kg of fish with a maximum value of 187 μg/kg (*n*: 10). Chlorinated hydrocarbons such as dieldrin are fat soluble and thus accumulate in fat tissue (Turk, Turk & Wittes 1972). Mugilidae are ideal fish for monitoring for such compounds as they have a relatively high fat content and feed on detritus and micro-organisms which are at the base of the food chain (Blaber 1977). It is not likely that the fish captured in Mdloti had been feeding elsewhere, as they were one year old or less, and were caught after a period of estuary closure.

Substratum

Tongati

The particle size composition of the substratum in the different regions is shown in Figure 8. The lower reaches may be classified as medium/coarse sand (Mdϕ: 2; $\bar{x}$dϕ: 0,76), the middle reaches as medium/fine sand (Mdϕ: 3; $\bar{x}$dϕ: 1,3) and the upper reaches as fine sand (Mdϕ: 3; $\bar{x}$dϕ: 1,9). There is a slight increase in the amount of silt and a decrease in coarse sand towards the upper reaches but otherwise the substratum is relatively uniform.

Mdloti

The particle size composition in four areas is shown in Figure 8. The lower reaches in the channel are medium/coarse sand (Mdϕ: 2; $\bar{x}$dϕ: 0,71) and on the 'mudflats' medium sand (Mdϕ: 2; $\bar{x}$dϕ: 1,2), while the middle and upper reaches may also be classified as medium sand (Mdϕ: 2; $\bar{x}$dϕ: 1,4 and Mdϕ: 2; $\bar{x}$dϕ: 1,1 respectively). Somewhat more silt occurred in the middle and upper reaches but the substratum is relatively uniform.

The striking feature of the substrata at Tongati and Mdloti when compared with that of Mhlanga (Whitfield 1980b) is the virtual absence of silt in the upper reaches. This suggests an increased flow and more flushing, perhaps as a result of relatively frequent openings of the mouths.

Table 2 Levels (μg/g dry weight) of heavy metals from *Mugil cephalus* from Mdloti estuary

Sample No.	Length (mm)	Hg	Cu	Cd	Pb	Zn	Fe	Cr	Co	Ni	Mn
1	230	0,145	1,86	0,345	<0,05	35	14,3	1,65	<0,7	<0,7	1,93
2	240	0,065	1,39	0,343	<0,05	45	13,4	1,92	<0,7	<0,7	1,74
3	230	0,071	1,08	0,401	<0,05	39	13,7	1,15	<0,7	<0,7	0,94
4	245	0,042	1,52	0,308	<0,05	11	18,3	0,98	<0,7	<0,7	0,84
5	290	0,114	1,70	0,223	<0,05	35	26,9	0,71	<0,7	<0,7	2,78
6	235	0,026	1,34	0,399	<0,05	44	17,5	1,91	<0,7	<0,7	9,65
7	210	0,029	2,76	0,410	<0,05	59	27,9	2,29	<0,7	<0,7	5,59
8	160	0,029	2,21	0,379	<0,05	30	21,6	3,02	<0,7	<0,7	15,5
9	170	0,025	1,92	0,454	<0,05	33	19,0	2,17	<0,7	<0,7	4,85

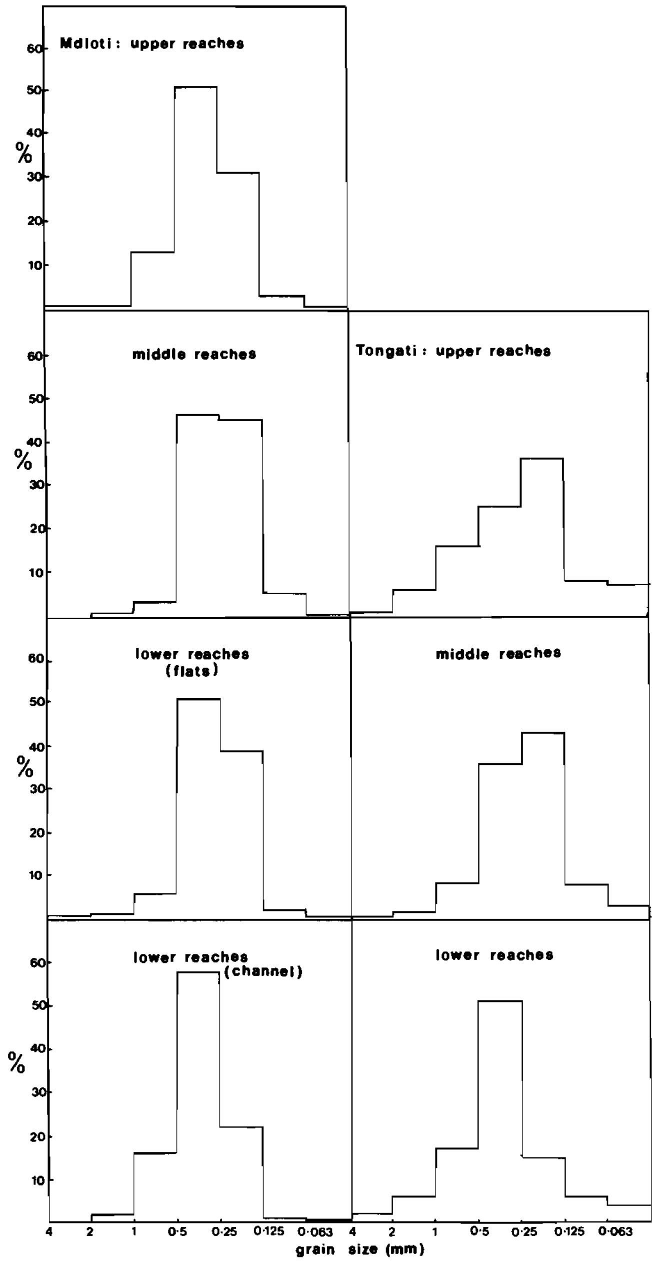

Figure 8 Particle size distribution of substrata in Tongati and Mdloti estuaries.

Epipsammic flora

The intertidal areas of the lower reaches were very rich in algae with the following species recorded: *Navicula* spp. (very common), *Synedra* sp. (present), *Melosira granulata* (present), *Nitzchia* sp. (common), *Spirulina* sp. (common), *Ocillatoria* sp. (very common), and *Euglena* spp. (common). In addition the following species were recorded from intertidal banks of the middle reaches on the Tongati: *Navicula* sp., *Nitzchia* sp., *Synedra* sp., *Microcoleus* sp., *Spirulina* sp., *Ocillatoria* sp. and euglenoid flagellates.

Zooplankton

Results from the D-net and Clarke-Bumpus sampling are shown in Tables 3 and 4 in terms of the percentage contributions of each zooplankter to the total energy value each month (J m^{-3}). In Tongati during summer (January to March) according to D-net samples chironomid larvae were dominant, followed during a period of intermittent mouth closure in April and May by the polychaete *Prionospio* sp., in June by the calanoid *Pseudodiaptomus hessei,* in July by Ostracoda, in August by *Prionospio* sp. again, in September and October by *Musculus virgiliae* and in November *Prionospio* sp. were once more dominant. Thus no one species dominated the zooplankton of Tongati throughout the year. The Clarke-Bumpus results from Tongati agree to some extent with those from D-netting but a higher proportion of copepods, fish larvae and Ostracoda were recorded. *P. hessei* was the dominant zooplankter in surface waters in May, June and September. D-net results indicate a total zooplankton peak during July whereas Clarke-Bumpus results indicate an August peak in total zooplankton from surface waters.

D-net results from Mdloti showed that summer months were dominated by chironomid larvae and macruran zoeae while *Musculus virgiliae* were most important from June to August when the estuary was closed, and in October. The drastic fall in most species in September corresponded with a sudden opening of the estuary. *Pseudodiaptomus hessei* were dominant in May, September and November. Clarke-Bumpus results from Mdloti were similar to D-netting results but *P. hessei* were dominant for five months. The fluctuations in numbers of *P. hessei* in Mdloti are shown in Figure 9. High densities of *P. hessei* coincided with periods when the estuary was closed. Total zooplankton energy on and near the bottom was highest during August and October when the estuary was closed whereas that from the surface peaked in June (estuary also closed).

Total standing-crop values for benthic and bottom-water zooplankton from Mdloti ($\bar{x}$: 2897 J m^{-3}) were greater than from Tongati ($\bar{x}$: 693 J m^{-3}) but the reverse was true for surface values (Mdloti $\bar{x}$: 77 J m^{-3}; Tongati $\bar{x}$: 190 J m^{-3}). In Mdloti high energy values were recorded during winter when the mouth was closed but in Tongati high winter values corresponded with an open mouth.

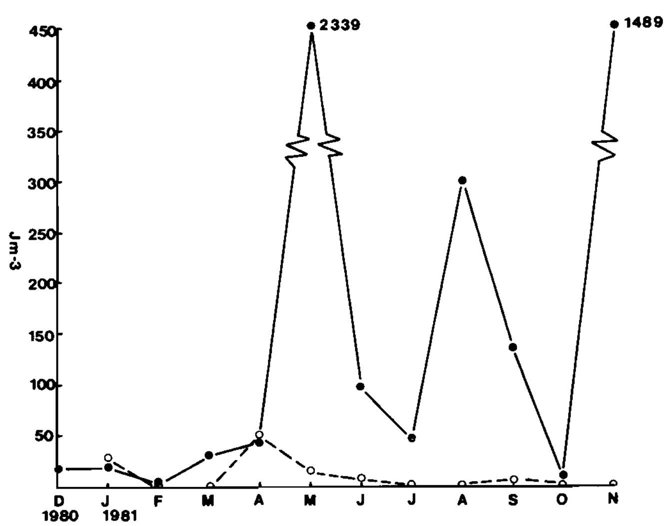

Figure 9 The energy value (J m^{-3}) of *Pseudodiaptomus hessei* from December 1980 to November 1981 in Tongati (o — — o) and Mdloti (● — ●) estuaries.

Benthic floc

The results of monthly floc energy determinations (J m^{-2}) are shown in Figures 10 and 11. With the exception of the lower reaches the energy values of floc from Tongati were more than 10 times greater than those from Mdloti. Relatively large quantities of floc occurred throughout the year in the upper and middle reaches of Tongati but values from the lower reaches

Table 3 Percentage contributions of each zooplankter to the total energy value of Tongati zooplankton (C/B = Clarke-Bumpus net, D = D-net)

Month	Estuary mouth	Net	*Owenia* sp.	*Prionospio* sp.	Amphipoda	Cyclopoid copepods	Harpacticoid copepods	*Pseudodiaptomus hessei* (Calanoida)	Marine Calanoida	Brachyuran zoeae	Macruran zoeae	Cladocera	Ostracoda	Chironomidae larvae	*Musculus virgiliae*	Fish larvae	Total J m^{-3}
Dec 1980	Open	C/B	–	–	–	67	11	21	–	–	–	–	–	–	–	–	15,7
		D	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Jan 1981	Open	C/B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		D	–	–	–	<1	<1	<1	–	–	–	–	–	99	–	–	372,1
February	Open	C/B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		D	–	–	–	<1	–	<1	–	–	11	5	–	80	–	3	167,0
March	Closed	C/B	–	–	–	<1	<1	2	–	–	13	13	–	71	–	–	17,8
		D	–	–	–	<1	<1	2	–	–	26	5	–	60	–	6	49,0
April	Closed	C/B	–	–	–	<1	<1	3	–	16	29	–	–	–	–	51	7,5
		D	–	82	<1	–	<1	13	–	2	<1	<1	–	–	–	<1	381,4
May	Closed	C/B	–	–	–	–	<1	91	–	<1	2	4	–	–	–	2	12,6
		D	–	54	–	–	<1	19	20	–	2	4	–	–	–	–	79,9
June	Open	C/B	–	–	–	<1	–	99	–	–	–	–	–	–	–	–	0,6
		D	–	–	–	–	1	76	18	–	–	–	–	–	–	5	8,8
July	Open	C/B	–	–	–	1	–	–	–	–	–	–	97	2	–	–	99,2
		D	–	10	–	<1	<1	<1	<1	–	–	–	89	–	–	–	5224,0
August	Open	C/B	–	36	–	<1	–	–	–	–	–	–	63	<1	–	–	1573,2
		D	–	99	–	–	1	–	–	–	–	–	–	–	–	–	309,5
September	Open	C/B	–	–	–	<1	–	45	17	–	–	–	–	37	–	–	124,0
		D	–	–	–	–	<1	<1	6	–	–	–	–	42	51	–	919,3
October	Open	C/B	–	–	–	<1	<1	–	–	–	–	4	–	40	55	–	53,2
		D	–	<1	–	–	<1	<1	–	–	–	3	–	–	96	–	96,9
November	Open	C/B	13	–	–	<1	<1	–	–	–	–	3	–	83	–	–	11,2
		D	–	99	–	–	<1	–	–	–	–	–	–	–	–	–	84,5

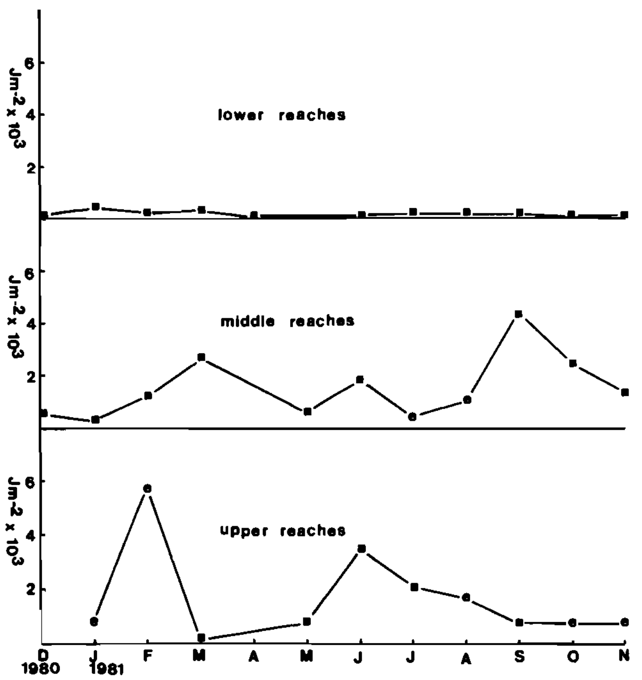

Figure 10 The energy value (J m^{-2}) of benthic floc from three regions of Tongati estuary from December 1980 to November 1981.

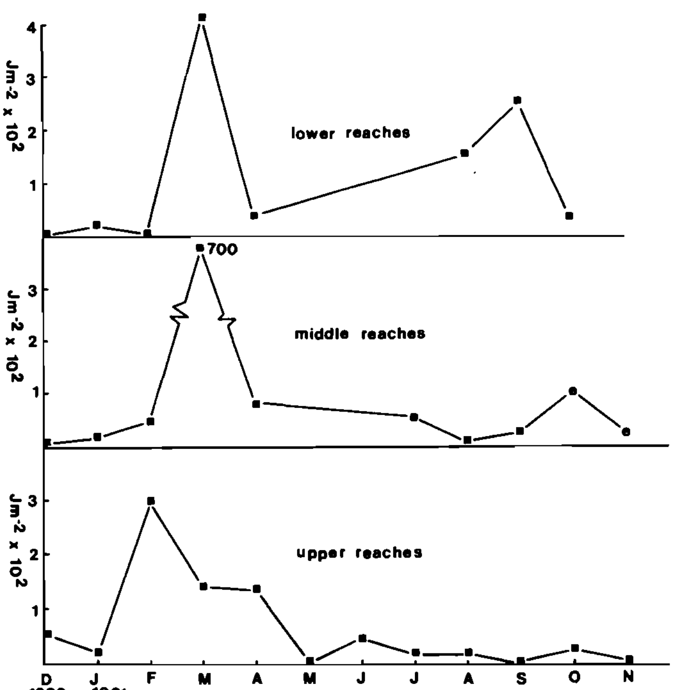

Figure 11 The energy value (J m^{-2}) of benthic floc from three regions of Mdloti estuary from December 1980 to November 1981.

were poor, reflecting perhaps the usually open nature of the mouth. The highest floc values occurred in the upper reaches of Tongati in February and June and in the middle reaches in March and September. The energy content of the floc from Mdloti was more uniform throughout the estuary with peaks in February and March, after the summer rains, and again in September and October. Other than the low floc values from

Table 4 Percentage contributions of each zooplankter to the total energy value of Mdloti zooplankton (C/B = Clarke-Bumpus net, D = D-net)

Month	Estuary mouth	Net	Oligochaeta	Cyclopoid copepods	Harpacticoid copepods	*Pseudodiaptomus hessei* (Calanoida)	*Acartia natalensis* (Calanoida)	Marine Calanoida	Brachyuran zoeae	Macruran zoeae	Cladocera	Ostracoda	Chironomidae larvae	*Musculus virgiliae*	Bivalve spat	Fish larvae	Total J m^{-3}
Dec 1980	Open	C/B	Not sampled														
		D	–	<1	<1	1	–	–	–	–	–	–	98	–	–	<1	1299,1
Jan 1981	Closed	C/B	Not sampled														
		D	–	<1	<1	17	–	–	–	67	–	<1	–	–	–	6	111,6
February	Open/Closed	C/B	Not sampled														
		D	–	<1	4	11	<1	–	–	72	1	–	–	–	–	10	12,3
March	Open	C/B	–	<1	1	82	–	–	<1	–	8	–	–	–	–	8	3,9
		D	–	–	2	40	–	–	–	–	–	–	49	–	–	9	71,7
April	Closed	C/B	–	–	1	44	–	47	<1	–	6	–	–	–	–	–	3,2
		D	–	–	<1	30	–	34	–	–	–	–	29	–	–	6	242,0
May	Closed/Open	C/B	–	–	–	99	–	–	–	–	–	–	–	–	–	1	81,0
		D	–	–	–	98	–	–	<1	1	–	–	–	–	–	<1	2379,1
June	Closed	C/B	–	–	<1	99	–	–	<1	–	–	–	–	–	–	<1	334,1
		D	–	–	<1	3	–	–	<1	–	–	–	–	96	–	<1	4560,7
July	Closed	C/B	–	–	–	5	–	–	–	–	–	–	–	–	95	–	77,0
		D	<1	–	–	<1	–	–	–	–	–	–	<1	99	–	<1	6445,1
August	Closed	C/B	–	–	<1	95	–	–	–	–	–	–	–	–	–	4	14,2
		D	<1	–	–	2	–	–	–	–	–	–	–	97	–	–	10401,2
September	Open	C/B	–	–	1	–	–	–	–	–	–	–	99	–	–	–	14,9
		D	–	–	1	99	–	–	–	–	–	–	–	–	–	–	134,7
October	Open/Closed	C/B	–	–	78	14	–	–	–	–	–	–	–	–	–	8	1,0
		D	–	–	<1	<1	–	–	–	–	<1	–	–	99	–	–	7564,3
November	Open	C/B	–	–	<1	99	–	–	–	<1	–	–	–	–	–	–	161,0
		D	–	–	–	97	–	–	–	2	–	–	–	–	–	1	1535,8

near Tongati mouth the monthly energy content did not show any definite correlation with the state of the mouth. The mean energy values of floc (J m^{-2}) for each estuary were: Tongati: upper 1832 (S.E.588); middle 1548 (S.E.363); lower 121 (S.E.45) and Mdloti: upper 66 (S.E.27); middle 108 (S.E.67); lower 131 (S.E.58).

Zoobenthos

Tongati

The monthly standing crops (J m^{-2}) for the total benthos for the three stations are shown in Figure 12. In the upper reaches a peak occurred in April and May due entirely to the polychaete *Prionospio* sp. but otherwise the energy content of the benthos of this region was low. The high values between May and August in the middle reaches and from May to October in the lower reaches were also due almost entirely to *Prionospio* sp. The times of estuary closure did not correspond with fluctuations in the benthos. The percentage contribution of each species to the total energy content of the benthos is shown for each station each month in Table 5. Periods of high energy content were due to *Prionospio* sp. but at other times the important members of the benthos were oligochaetes, chironomid larvae and the polychaete *Owenia* sp. There were few differences in species diversity between the regions of the estuary and the fauna was dominated by animals of freshwater and estuarine groups with relatively little marine influence.

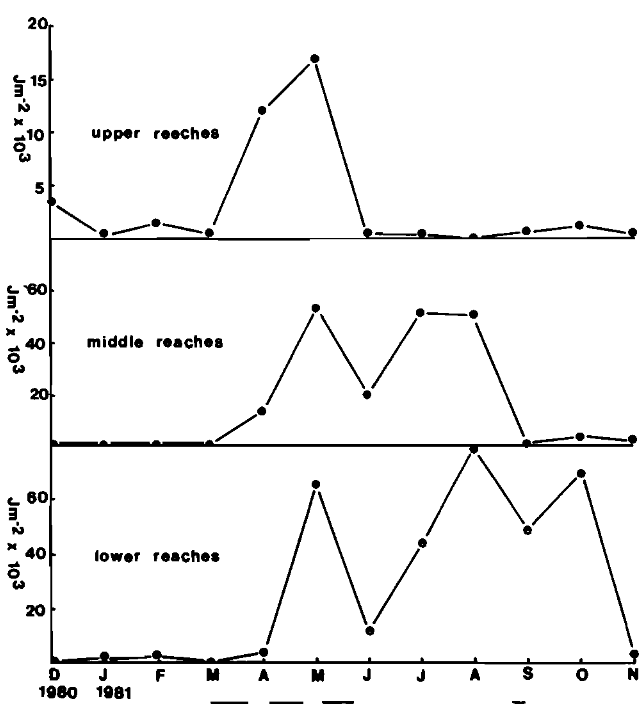

Figure 12 The energy value (J m^{-2}) of total biomass of benthic fauna from three regions of Tongati estuary from December 1980 to November 1981. (— = period of closure).

Mdloti

The species diversity of the benthos was markedly higher than at Tongati but the energy content was significantly less. The monthly fluctuations in total energy content of the benthos

Table 5 Percentage contributions of each benthic taxon to the total energy value (J m^{-2}) of the benthos each month in Tongati estuary (U = upper reaches; M = middle reaches; L = lower reaches; FW = freshwater; Est = estuarine; Mar = marine)

	Dec. 1980			Jan. 1981			February			March			April			May			June			July			August			September			October			November			
Benthos	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	Origin
Oligochaeta	12	100	77	32	–	–	88	88	–	71	83	46	–	–	0,2	–	–	–	–	0,1	0,27	–	–	8,5	–	–	–	8	–	–	4	–	–	57	0,6	1	FW/Est
Hirudinea	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	FW
Ceratonereis erythraeensis	–	–	–	–	–	–	–	–	–	8	–	–	0,5	–	–	–	–	0,4	–	–	–	–	0,1	–	–	–	–	–	–	–	–	–	–	–	–	–	Est
Dendronereis arborifera	–	–	1	–	–	–	–	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Est
Desdemona ornata	–	–	8	–	–	–	–	–	–	–	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Est
Owenia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	76	43	0,05	63	0,1	0,1	43	91	0,5	Est
Prionospio sp.	–	–	–	68	100	100	–	6	99,7	–	–	–	99	100	99,8	99,5	99,9	99,6	–	99,7	72	93	99,9	91	100	100	100	11	21	99,9	–	98,9	99,9	–	0,5	98,5	Est
Brachyuran megalopae	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Est/Mar
Macruran megalopae	–	–	–	–	–	–	0,5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Est/Mar
Chironomid larvae	88	–	13	–	–	–	0,5	2	0,3	14	–	2	0,5	–	–	0,5	0,001	–	81	0,1	1	7	–	0,5	–	–	–	2	30	–	30	1	–	–	2	–	FW/Est
Chironomid pupae	–	–	–	–	–	–	–	–	–	7	–	–	–	–	–	–	–	–	19	–	–	–	–	–	–	–	–	2	6	–	3	–	–	–	6	–	FW/Est
Ephemeroptera larvae	–	–	–	–	–	–	10	–	–	–	–	52	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,05	–	–	–	–	–	–	FW
Total energy (J m^{-2})	3541,1	255,8	767,5	318,6	730,3	872,0	1561,1	269,3	1508,1	431,2	109,8	62,7	12337,0	14104,5	3990,7	16857,0	55378,2	65093,0	321,9	21097,6	12389,6	163,6	51257,8	42005,4	8,0	50278,0	82595,8	468,5	786,0	48886,2	1171,7	3040,1	68556,7	279,5	560,1	3607,0	

Table 6 Percentage contributions of each benthic taxon to the total energy value (J m^{-2}) of the benthos each month in Mdloti estuary (U = upper reaches; M = middle reaches; L = lower reaches; FW = freshwater; Est = estuarine; Mar = marine)

	Dec. 1980			Jan. 1981			February			March			April			May			June			July			August			September			October			November			
Benthos	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	Origin
Hirudinea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	FW
Oligochaeta	68	44	7	23	10	36	68	1	13	1	8	±	–	–	0,5	10	–	10	1	–	20	5	0,5	–	–	2	–	–	0,5	–	<0,5	<0,5	–	9	1	–	FW/Est
Ceratonereis erythraeensis	–	–	–	–	–	34	–	–	74	–	–	86	–	–	29	7	–	24	–	–	51	87	–	27	53	–	29	5	–	19	82	–	46	61	–	30	Est
Dendronereis arborifera	–	19	55	–	1,5	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	1	13	–	–	16	1	1	<0,5	–	–	7	–	–	–	Est
Desdemona ornata	–	6	38	–	–	22	–	–	10	–	–	9	–	68	69	8	71	40	9	22	18	2	62	28	17	51	15	10	63	27	13	52	38	3	25	49	Est
Owenia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,5	–	–	<0,5	–	1	–	–	Est
Prionospio sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–			–	1	–	–	0,5	–	–	–	7	–	–	<0,5	–	–	–	–	–	–	Est
Africhiltonia capensis	–	–	–	–	–	–	3	–	–	–	–	–	1	–	–	–	–	–	–	13	–	–	–	–	22	–	1	–	–	<0,5	–	–	–	–	–	8	Est/Mar
Apseudes sp.	–	–	–	–	–	–	–	–	–	–	–	5	–	17	0,5	–	1	–	–	3	6	–	2	26	–	–	31	–	–	50	–	<0,5	6	–	–	10	Est/Mar
Brachyuran zoeae	–	–	–	–	–	–	–	–	–	–	1	–	87	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	<0,5	Est/Mar
Caradina nilotica	–	–	–	27	–	–	–	28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	FW
Macruran zoeae	–	–	–	9	4	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Est/Mar
Varuna litterata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	Est/Mar
Ancylus sp.	–	–	–	–	–	–	–	–	–	–	–	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14	–	–	–	–	–	–	1	–	FW
Biomphalaria pfeifferi	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0,5	–	–	–	–	FW
Bivalve spat	–	–	–	19	0,5	1	28	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Est/Mar
Anisoptera	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	FW
Chironomid larvae	32	30	–	7	–	–	1	4	3	85	12	–	6	–	1	62	–	10	90	2	1	6	–	–	7	2	–	69	15	<0,5	4	<0,5	–	25	12	1	FW/Est
Chironomid pupae	–	–	–	–	–	–	–	–	–	14	–	–	–	–	–	13	–	1	–	–	–	–	–	–	–	–	–	1	0,5	–	<0,5	–	–	–	–	–	FW/Est
Ephemeroptera larvae	–	–	–	15	26	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	FW
Total energy (J m^{-2})	43,2	28,7	154,1	1536,3	1219,0	167,6	638,8	477,6	241,7	492,0	187,5	334,2	1577,0	188,2	456,7	186,3	969,4	810,6	278,9	1971,9	1646,4	971,6	4611,0	3582,4	717,4	4633,1	2635,5	923,9	3572,5	16786,7	2151,6	5735,4	1337,1	1381,4	2147,2	4539,0	

at each station are shown in Figure 13. Values in the lower and middle reaches peaked during winter when the estuary was closed for about three months. The upper reaches showed no definite pattern with relatively low densities throughout the year. The percentage contributions of each species to the standing crop each month are shown in Table 6. Diversity and numbers of benthic animals were less in the upper reaches than in the middle and lower reaches. The high energy values in the middle and lower reaches in winter were due to the polychaetes *Ceratonereis erythraeensis* and *Desdemona ornata*. The peaks in the summer in the upper reaches were caused by oligochaetes (chiefly tubificids) and chironomid larvae, while those in October and November were due to *C. erythraeensis*.

Fauna associated with *Eichornia crassipes*

This aquatic macrophyte only occurred at Tongati where it was most numerous in the upper and middle reaches. In contrast to the uncolonized stems of *Phragmites* a diverse fauna consisting largely of insects and their larvae was found among the roots of *E. crassipes*. The species which contributed most to the energy content of the *Eichornia* fauna are indicated in the list of fauna (Table 7). Among the insects Bellostomatidae and chironomid larvae were most important while the euryhaline crab *Varuna litterata* was extremely significant. From March to September *V. litterata* contributed more than 50% of the energy content of the *Eichornia* fauna. During November the most important species was the polychaete *Owenia* sp. The standing crop of the *Eichornia* each month in terms of J m^{-2} is shown in Table 8 together with the energy value per plant for the upper, middle and lower reaches. The energy peak from March to May coincided with a period when the estuary was mainly closed.

Table 7 Fauna associated with *Eichornia crassipes* roots in Tongati estuary. (FW = freshwater; Est = estuarine; Mar = marine)

Fauna	Origin
Amphipoda	
Afrochiltonia capensis	Est/Mar
Acarina	FW
Brachyura	
Unidentified zoeae	Est/Mar
Unidentified megalopae	Est/Mar
Varuna litterata	Est/Mar
Cnidaria	
Hydra sp.	FW
Gastropoda	
Ancylus sp.	FW
Biomphalaria pfeifferi	FW
Bulinus sp.	FW
Hirudinea	
Insecta	
Anisoptera	FW
Bellostomatidae	FW
Chironomidae (larvae and pupae)	
Coleoptera (terrestrial) larvae and adults	FW
Collembola	FW
Culicidae (larvae)	FW
Diptera (larvae)	FW
Dytiscidae	FW
Ephemeroptera (larvae)	FW
Gerridae (nymph)	FW
Gyrinidae	FW
Plecoptera (larvae)	FW
Rhynchota	FW
Trichoptera (larvae)	FW
Zygoptera (larvae)	FW
Macrura	
Caridina nilotica	FW
Nematoda	Est/Mar/FW
Oligochaeta	
Tubificida	FW
Ostracoda	Est/Mar/FW
Polychaeta	
Ceratonereis erythraeensis	Est/Mar
Owenia sp.	Est/Mar
Prionospio sp.	Est/Mar
Tanaeidae	
Apseudes sp.	Est/Mar

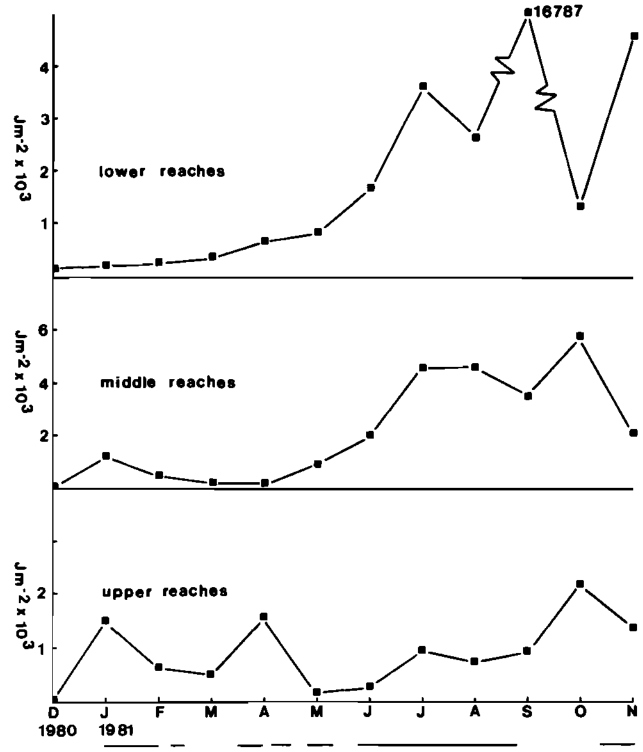

Figure 13 The energy value (J m^{-2}) of total biomass of benthic fauna from three regions of Mdloti estuary from December 1980 to November 1981. (— = periods of closure).

Table 8 Energy values of total fauna associated with *Eichornia crassipes* in three regions (J/plant) of Tongati estuary and the total energy content (J m^{-2}) for the estuary as a whole

	J/plant			
	Upper reaches	Middle reaches	Lower reaches	Whole estuary (J m^{-2})
Dec	Not collected	Not collected	367,1	7354
Jan	127,1	283,3	492,2	6016
Feb	322,2	209,4	825,1	9046
Mar	6912,2	369,7	237,7	50130
Apr	8074,8	307,8	93,2	56504
May	494,9	506,1	7031,0	53546
June	1940,5	Plants absent	1462,5	34030
July	35,7	1200,5	1553,1	18596
Aug	274,1	512,5	741,7	10188
Sept	432,2	Plants absent	Plants absent	8644
Oct	234,6	117,5	Plants absent	3520
Nov	224,5	3732,7	1398,9	35706
$\bar{x}$				24440

Fish

Tongati

The adults and juveniles of 32 species recorded in Tongati are shown in Table 9 together with their origin, trophic position and areas of occurrence in the estuary. Six freshwater species were recorded, one truly estuarine species and the remainder euryhaline marine species. In terms of numbers and biomass Tongati was dominated by Mugilidae with *Mugil cephalus, Myxus capensis* and *Valamugil cunnesius* most abundant while *Liza alata, L. macrolepis* and *Valamugil robustus* were less common. The freshwater catfish *Clarias gariepinus* and the freshwater cichlids *Sarotherodon mossambicus* and *Tilapia rendalli* were relatively abundant and present throughout the year. Low numbers of a variety of euryhaline marine species other than Mugilidae, mainly juveniles, were recorded from the lower reaches. Relatively few species occurred in the middle and upper reaches. The catch per unit effort from cast netting of the 13 species recorded from the middle and upper reaches is shown in Table 10. Mugilidae and *S. mossambicus* were the most common and of most regular occurrence. No fish were captured in these areas in July and November when oxygen levels were very low. A fish kill of mainly *S. mossambicus* was noted in November.

The diet of Mugilidae and *S. mossambicus* which are iliophagous was not investigated as data on the differences be-

Table 9 Species of fish recorded each month (X) in Tongati estuary, together with areas of occurrence, food and origin. (A = adult; J = juvenile; FW = freshwater; Est = estuarine; Eur/Mar = Euryhaline marine; Ilio = iliophagous; Pisciv = piscivorous; Zoopl = zooplanktonivorous; Inv = invertebrate; U = upper reaches; M = middle reaches; L = lower reaches)

	1980 D		1981 J		F		M		A		M		J		J		A		S		O		N				
Species	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	Areas	Food	Origin
Ambassis natalensis			x																						L	Zoopl Inv Benthos	Eur/Mar
Ambassis productus											x		x		x		x		x						UML	Zoopl Inv Benthos	Eur/Mar
Anguilla bicolor											x														L	Pisciv	FW
Barbus paludinosus							x																		L	Inv Benthos	FW
Caranx sem				x																					L	Pisvic	Eur/Mar
Caranx sexfasciatus						x																			L	Pisvic	Eur/Mar
Clarias gariepinus	x				x		x		x						x		x		x		x				UML	Omnivor	FW
Gerres acinaces										x		x													L	Inv Benthos	Eur/Mar
Gilchristella aestuarius	x	x			x		x																		L	Zoopl	Est
Glossogobius giuris						x																			L	Inv Benthos	FW/Est
Gobius acutipennis					x		x				x		x												L	Inv Benthos	Eur/Mar
Leiognathus equula								x																	L	Zoopl Inv Benthos	Eur/Mar
Liza alata																			x						UML	Ilio	Eur/Mar
Liza dumerili			x	x				x						x				x						x	ML	Ilio	Eur/Mar
Liza macrolepis		x			x	x		x													x	x			ML	Ilio	Eur/Mar
Megalops cyprinoides					x																				U	Pisciv	Eur/Mar
Monodactylus argenteus									x																L	Zoopl	Eur/Mar
Mugil cephalus	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	UML	Ilio	Eur/Mar
Myxus capensis	x	x	x	x	x	x	x	x			x	x	x		x	x	x	x	x	x	x		x		UML	Ilio	Eur/Mar
Platycephalus indicus											x														L	Pisvic	Eur/Mar
Pomadasys commersonii										x			x	x											L	Inv Benthos	Eur/Mar
Pomadasys olivaceum		x		x																					L	Zoopl Inv Benthos	Eur/Mar
Pseudocrenilabrus philander																						x			L	Pisvic Inv Benthos	FW
Rhabdosargus holubi				x																		x			L	Inv Benthos	Eur/Mar
Rhabdosargus sarba		x								x				x						x					L	Inv Benthos	Eur/Mar
Sarotherodon mossambicus	x	x	x			x		x				x		x			x	x			x				UML	Ilio	FW
Sphyraena jello						x																			L	Pisvic	Eur/Mar
Stigmatogobius sp.			x	x																					L	Inv Benthos	Est
Terapon jarbua		x		x		x		x	x	x		x		x				x		x					L	Zoopl Inv Benthos	Eur/Mar
Tilapia rendalli				x		x		x					x	x	x	x		x							ML	Plant	FW
Valamugil cunnesius	x		x	x	x	x	x	x	x	x				x	x	x		x			x	x			UML	Ilio	Eur/Mar
Valamugil robustus																						x			L	Ilio	Eur/Mar
Totals	6	8	7	10	8	10	5	9	5	7	6	5	6	7	6	4	4	7	5	4	6	6	2	2			
	10		12		14		12		9		9		10		6		9		7		9		3				

tween the various species are available (Blaber 1977; Whitfield & Blaber 1978). However, the foods of a selection of other species were analysed according to the frequency of occurrence of food items and the results shown in Table 11. The major food items of many of the juveniles and of *G. aestuarius* were zooplankton and insect larvae, particularly chironomid larvae. *Tilapia rendalli* consumed mainly aquatic macrophytes and filamentous algae but not *Eichornia*. The only piscivores of note in Tongati were *Clarias gariepinus*, which is also an omnivore, and juvenile *Caranx sem*.

Mdloti

The monthly occurrence of adults and juveniles of the 29 species recorded from Mdloti estuary is shown in Table 12. The catch per unit effort of species from the middle and upper reaches is shown in Table 10. The species diversity for the estuary as a whole was highest during the open phase and lowest when the estuary was closed in winter. The only freshwater species were *S. mossambicus* and *Anguilla bicolor*. The former was common in the middle and upper reaches but only one specimen of the latter was captured. With the exception of the estuarine clupeid *Gilchristella aestuarius* the remainder of the fish were euryhaline marine species. Mugilidae were abundant throughout the system, particularly *M. cephalus, M. capensis* and *Valamugil cunnesius*. Likewise Ambassidae and *Monodactylus falciformis* occurred in all parts of the estuary. The rest, mainly juveniles, were found only in the lagoon area of the lower reaches adjacent to the mouth. Species diversity was highest in the summer owing to the presence of these juveniles. Iliophagous species including Mugilidae and *S. mossambicus* were the most common trophic category. The diets of juveniles of eight other species are shown in Table 13. The predominant food items were from the water column such as zooplankton and larger mobile crustacea and fish, and Insecta from the water surface. Benthic invertebrata did not feature strongly in the diets of even the usually benthic feeding species such as *Pomadasys commersonni* and *Rhabdosargus sarba*. The absence of plant material in the usually herbivorous

Table 10 Catch per unit effort (per 40 casts using a 2 m diameter cast-net) of fish species in the combined middle and upper reaches of Tongati (T) and Mdloti (M) estuaries from December 1980 to November 1981

	D 1980		J 1981		F		M		A		M		J		J		A		S		O		N	
Species	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M
Ambassis natalensis	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ambassis productus	–	–	–	1	–	1	–	2	–	–	2	–	1	1	–	–	8	–	1	2	–	–	–	3
Caranx sexfasciatus	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Clarias gariepinus	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
Leiognathus equula	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Liza alata	–	–	–	1	–	2	–	1	–	4	–	1	–	–	–	3	–	3	1	8	–	3	–	–
Liza macrolepis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
Megalops cyprinoides	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Monodactylus falciformis	–	2	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mugil cephalus	–	2	7	1	8	–	3	–	–	3	–	–	–	2	–	1	–	–	–	4	–	–	–	1
Myxus capensis	12	2	9	–	9	3	1	2	–	–	3	3	1	–	–	–	–	–	–	7	3	3	–	6
Pomadasys commersonii	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sarotherodon mossambicus	–	12	1	–	–	13	1	20	–	12	–	–	2	1	–	–	–	–	–	17	1	15	–	2
Tilapia rendalli	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Valamugil connesius	–	10	3	–	–	–	3	2	2	2	–	1	–	–	–	5	4	–	–	9	1	–	–	–
Number of species	1	6	4	3	3	4	4	7	5	4	3	3	3	3	0	3	3	1	2	6	4	3	0	4
$\bar{x}$ = 2,6(T); 3,9(M)																								
SE = 0,5(T); 0,5(M)																								

Table 11 Diet of seven species of fish from Tongati estuary according to the percentage of occurrence of food items in the stomach (SL = Standard length)

	Food items																										
Fish species	Aquatic macrophytes	*Eichornia crassipes*	Filamentous algae	Oligochaeta	Polychaeta	*Acartia natalensis*	Cyclopoida	*Pseudodiaptomus hessei*	Brachyuran zoeae	Cladocera	Isopoda	Macruran zoeae	Mysidacea	Ostracoda	Penaeidae	Chironomid larvae	Chironomid adults	Coleoptera adults	Diptera larvae	Diptera adults	Ephemeroptera larvae	*Musculus virgiliae*	*Glossogobius giuris*	Unidentified fish	Microchiroptera (bats)	Unidentifiable remains	SL range (mm)
Ambassis productus	–	–	–	6	21	2	–	8	–	–	2	–	–	–	–	10	2	–	–	–	2	–	–	12	–	–	
Caranx sem	–	–	–	–	–	–	–	14	–	–	–	–	–	–	43	–	–	–	–	–	–	–	29	57	–	–	52–66
Clarias gariepinus	–	40	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	20	–	340–520
Gilchristella aestuarius	–	–	–	–	–	–	41	18	–	5	–	33	–	–	–	38	3	–	–	–	–	3	–	–	–	72	10–49
Pomadasys olivaceum	–	–	10	–	–	–	–	–	–	–	5	–	20	5	5	–	–	–	25	–	–	–	–	5	–	75	34–63
Terapon jarbua	–	–	–	–	–	–	11	11	5	26	–	5	–	–	–	32	–	5	26	16	–	–	–	–	–	89	10–50
Tilapia rendalli	75	–	13	–	–	–	13	–	–	–	–	–	–	–	–	13	–	–	–	–	–	–	–	–	–	50	43–97

Rhabdosargus holubi (Blaber 1974) was significant. The only true piscivores captured were juvenile Carangidae and one adult *Anguilla bicolor*.

Birds

Monthly counts and the mean number per month of each water-associated species are shown in Table 14. On both systems relatively few birds were recorded although several piscivorous species were present each month. A variable, but small, number of invertebrate-feeding Palaearctic waders were present during summer. These waders were most numerous when the estuary mouths were open and flats were exposed at low tide in the lower reaches. Herbivorous ducks and geese were associated mainly with the macrophyte *Eichornia crassipes* at Tongati. The mean numbers of the most regularly occurring species, *Ceryle rudis* (pied kingfisher), *Anas undulata* (yellow-billed duck) and *Tringa hypoleucos* (common sandpiper) were interestingly similar for both estuaries. Large numbers of terns roosted on sandbanks in both estuaries but were observed fishing only in the sea.

Discussion

There are marked differences in the physical nature and biota of Tongati and Mdloti estuaries and these are summarized in relation to the comparatively natural Mhlanga estuary in Table 15.

Table 12 Species of fish recorded each month (X) in Mdloti estuary, together with areas of occurrence, food and origin. (A = adult; J = juvenile; FW = freshwater; Est = estuarine; Eur/Mar = euryhaline marine; Ilio = iliophagous; Pisciv = piscivorous; Zoopl = zooplanktivorous; Inv = invertebrate; U = upper reaches; M = middle reaches; L = lower reaches)

	1980 D		1981 J		F		M		A		M		J		J		A		S		O		N				
Species	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	Areas	Food	Origin
Acanthopagrus berda								x																	L	Inv Benthos	Eur/Mar
Ambassis natalensis	x	x			x	x																			UML	Zoopl	Eur/Mar
Ambassis productus	x		x	x	x	x	x	x	x				x		x		x		x		x		x		UML	Zoopl	Eur/Mar
Anguilla bicolor			x																						L	Pisciv	FW
Caranx sem				x																					L	Pisvic	Eur/Mar
Caranx sexfasciatus				x		x		x						x											ML	Pisvic	Eur/Mar
Gerres rappi		x						x						x											L	Inv Benthos	Eur/Mar
Gilchristella aestuarius	x		x																x	x	x	x			L	Zoopl	Est
Glossogobius giuris		x		x				x									x			x		x			ML	Inv Benthos	Est/FW
Leiognathus equula								x						x		x									L	Zoopl	Eur/Mar
Lichia amia				x																					L	Pisciv	Eur/Mar
Liza alata				x		x		x		x		x				x	x	x		x		x		x	UML	Ilio	Eur/Mar
Liza dumerili						x		x				x						x						x	L	Ilio	Eur/Mar
Liza macrolepis		x	x	x	x	x	x	x				x		x				x						x	L	Ilio	Eur/Mar
Liza tricuspidens								x																	L	Ilio	Eur/Mar
Megalops cyprinoides				x																					L	Pelagic Inv & Fish	Eur/Mar
Monodactylus falciformis		x		x		x		x										x							UML	Zoopl	Eur/Mar
Mugil cephalus		x		x	x	x		x		x	x	x	x	x		x		x		x		x		x	UML	Ilio	Eur/Mar
Myxus capensis	x	x	x	x	x	x		x			x	x	x	x	x	x	x	x	x	x	x	x		x	UML	Ilio	Eur/Mar
Pomadasys commersonii								x								x						x			L	Zoopl Inv Benthos	Eur/Mar
Rhabdosargus holubi		x		x		x		x						x						x					L	Inv Benthos Zoopl	Eur/Mar
Rhabdosargus sarba																				x					L	Inv Benthos Zoopl	Eur/Mar
Sarotherodon mossambicus	x	x		x		x	x	x		x				x						x	x	x		x	UML	Ilio	FW
Sillago sihama												x													L	Inv Benthos	Eur/Mar
Solea bleekeri																				x					L	Inv Benthos	Eur/Mar
Stolephorus commersonii								x																	L	Zoopl	Eur/Mar
Terapon jarbua						x		x				x										x		x	L	Inv BenthosZoopl	Eur/Mar
Valamugil cunnesius	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	UML	Ilio	Eur/Mar
Valamugil robustus					x		x	x		x	x										x	x	x	x	L	Ilio	Eur/Mar
Totals	6	10	6	14	7	13	5	20	2	5	4	8	4	9	3	6	5	7	4	10	6	10	3	9			
	12		16		14		20		6		9		10		7		9		11		11		10				

Nutrient levels

Tongati has very high levels of ammonia, probably as a result of treated sewage effluent. This, together with adequate levels of SRP, was sufficient to promote rapid and sustained growth of *Eichornia crassipes*, causing in turn a high biological oxygen demand and consequent low oxygen tensions in the water. Mdloti, although low in organic nitrogen was relatively high in nitrates, perhaps derived from agricultural fertilizers. The low levels of SRP in Mdloti probably limited primary production. Levels of both SRP and organic and inorganic nitrogen in Mhlanga were sufficient to maintain primary production in both aquatic macrophytes and phytoplankton.

Benthic floc

The energy values of floc in Mhlanga and Mdloti are similar but that of Tongati was four times greater. These differences cannot be easily explained, but it is probable that the high values from Tongati are a result of the large organic input from sewage works in the upper reaches of the river. The floc values reflect only the standing crops and it is likely that the turnover situation may tell a different story. In Mhlanga the utilization of benthic floc may be greater owing to the abundant benthos, and the low standing crop is a result of this utilization. In Mdloti, however, the low standing crop may represent an accumulation of energy or a slow turnover since the benthos is impoverished. Perhaps in Tongati the frequent oscillations in oxygen tensions and benthos could lead to some accumulation of organic material and hence high standing crops.

Zooplankton

The significant feature of the zooplankton of Tongati and Mdloti is the low standing crop in relation to the situation in Mhlanga. This cannot be due to grazing pressure from planktivores since few were recorded and hence must represent a genuine impoverishment. The reasons for the low levels of zooplankton at Tongati may be different from those at Mdloti and the probable causes are listed below for each estuary separately.

Tongati

(i) Tongati was usually open owing to human interference but freshwater conditions prevailed. Thus many marine forms may have been excluded.

(ii) Low oxygen tensions were common and would exclude

Table 13 Diet of eight species of fish from Mdloti estuary according to the percentage frequency of occurrence of food items in the stomach

Prey	*Ambassis natalensis*	*Ambassis productus*	*Caranx sexfasciatus*	*Monodactylus falciformis*	*Pomadasys commersonii*	*Rhabdosargus holubi*	*Rhabdosargus sarba*	*Terapon jarbua*
Acartia natalensis	–	2	–	19	29	–	–	–
Cyclopoida	–	1	–	3	–	–	33	–
Harpacticoida	–	2	–	19	29	58	–	–
Marine Calanoida	–	–	–	19	57	25	–	–
Pseudodiaptomus hessei	52	23	39	29	71	67	33	–
Amphipoda	26	10	–	–	–	–	–	20
Afrochiltonia sp.	–	–	6	3	–	–	–	–
Caprella sp.	–	–	–	3	–	–	–	–
Corophium sp.	–	–	–	–	14	–	–	–
Grandidierella sp.	–	–	–	10	29	–	–	–
Apseudes sp.	–	–	–	–	29	–	–	40
Caridina nilotica	–	2	6	–	–	–	–	–
Macrobrachium equidens	–	1	–	–	–	–	–	–
Penaeidae	13	2	6	6	–	–	–	–
Cladocera	–	–	–	3	–	–	–	–
Cumacea	–	6	6	–	–	–	–	–
Isopoda	–	4	–	10	–	8	–	–
Mysidacea	–	–	22	3	–	17	–	–
Ostracoda	–	3	–	–	–	–	–	–
Zoeae – Brachyura	–	–	–	3	–	–	–	–
Zoeae – Macrura	78	39	6	13	–	17	33	–
Aranea	–	1	–	–	–	–	–	–
Chironomidae larvae	–	2	–	–	14	–	–	–
Chironomidae adult	–	1	–	–	–	–	–	–
Coleoptera larvae	–	–	–	–	–	8	–	–
Coleoptera adult	–	1	–	3	–	–	–	–
Diptera adult	–	2	–	–	–	–	–	–
Ephemeroptera larvae	–	–	–	3	–	–	–	–
Formicidae	–	5	–	23	–	–	–	–
Hemiptera	–	1	–	–	–	–	–	–
Trichoptera larvae	–	6	–	–	–	–	–	–
Polychaeta	–	3	6	3	14	17	–	–
Desdemona ornata	–	–	–	–	14	–	33	–
Ancylus sp.	–	–	–	3	–	–	–	–
Bivalvia (small white sp.)	–	–	–	3	–	–	–	–
Littorina sp.	–	–	–	–	–	8	–	–
Opisthobranchia	–	–	–	10	–	–	–	–
Fish eggs	–	7	–	–	–	8	–	–
Glossogobius giuris	–	–	6	–	–	–	–	–
Mugilidae (fry)	–	–	6	–	–	–	–	–
Rhabdosargus holubi	–	–	–	–	–	–	–	20
Valamugil cunnesius	–	–	6	–	–	–	–	–
Unidentified fish (fry)	22	3	6	6	–	–	–	40
Plant material	–	2	–	6	–	–	–	–
Unidentifiable remains	43	11	6	35	29	17	66	–

most euryhaline marine forms.

(iii) Almost the entire zooplankton consisted of larvae of hardy benthic species such as chironomid larvae and *Prionospio* sp. The appearance of these forms in the plankton coincided with high standing crops of adults in the benthos (Tables 3 – 6).

Table 14 Monthly counts of water associated birds at Tongati (T) and Mdloti (M) estuaries and their major foods

		1980 D		1981 J		F		M		A		M		J		J		A		S		O		N		$\bar{x}$	
Bird species	**Food**	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M
Tachybaptus ruficollis	Frogs, Crustacea, Insecta	–	–	–	–	–	–	–	–	–	1	–	2	–	–	–	4	–	3	–	–	–	–	–	1	–	0,9
Phalacrocorax africanus	Fish	–	–	–	–	–	–	–	–	–	–	–	2	–	–	1	–	–	1	–	1	–	–	1	3	0,17	0,6
Anhinga rufa	Fish	–	–	–	–	–	–	–	–	1	–	1	–	1	3	1	–	–	–	2	–	–	–	–	1	0,5	0,25
Ardea cinerea	Fish	–	–	–	–	–	1	–	1	–	–	–	–	1	–	–	–	–	–	–	1	–	–	–	1	0,08	0,3
Ardea goliath	Fish	1	–	–	–	–	–	–	–	–	–	1	–	1	–	1	–	1	–	1	–	1	–	2	–	0,42	–
Ardea purpurea	Fish	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	0,08
Casmerodius albus	Fish	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	1	–	1	–	1	–	–	0,17	0,75
Egretta garzetta	Fish and Crustacea	–	1	–	–	–	–	–	–	–	–	–	–	1	–	2	–	1	–	2	1	1	–	2	–	0,75	0,16
Ardeola ralloides	Fish and frogs	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	0,08
Nycticorax nycticorax	Fish and frogs	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	0,25	–
Scopus umbretta	Frogs and Crustacea	–	–	–	–	–	–	–	4	–	–	1	–	2	–	2	–	–	–	–	–	–	–	–	–	0,42	0,3
Plectropterus gambensis	Plant material	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1	–	–	–	0,08	0,08
Alopochen aegyptiacus	Plant material	–	–	–	1	–	–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	2^{+8}	–	2^{+7}	–	0,58	0,08
Anas sparsa	Crustacea, Insecta, Plants	–	2	1	–	–	–	–	–	–	–	2	2	–	2	–	–	–	–	–	–	–	–	1	–	0,33	0,5
Anas undulata	Plant material	2	7	5	9	3	–	–	–	–	–	6	4	–	3	7	2	2	–	2	4	–	–	–	6	2,25	2,9
Dendrocygna viduata	Plant material	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2	0,25	0,16
Haliaeetus vocifer	Fish	1	–	–	–	–	1	–	2	–	–	1	–	1	–	1	1	1	–	1	–	1	1	2	–	0,75	0,4
Pandion haliaetus	Fish	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	0,08
Limnocorax flavirostris	Insecta, Mollusca, fish	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,17	–
Gallinula chloropus	Insecta, Plant material	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,17	–
Actophilornis africanus	Insecta, Plant material	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	0,17	0,08
Arenaria interpres	Crustacea, Mollusca	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	0,08
Charadrius hiaticula	Crustacea, Mollusca	1	3	2	–	2	6	–	8	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	0,67	1,4
Charadrius marginatus	Insecta, Polychaeta, Crustacea	1	–	2	–	–	2	2	6	–	2	–	–	2	–	–	–	–	–	–	2	–	–	2	–	0,75	1,0
Charadrius tricollaris	Invertebrates generally	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	0,08	0,08
Pluvialis squatarola	Crustacea, Mollusca	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,08
Calidris ferruginea	Crustacea, Polychaeta	–	–	–	–	–	10	–	24	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	3,0
Calidris minuta	(Zooplankton) Crustacea, Insecta	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,33	–
Calidris alba	Benthic invertebrates	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	0,17
Tringa hypoleucos	Insecta, Mollusca, Crustacea	12	9	10	6	2	4	4	6	4	2	1	–	1	1	–	1	1	–	3	7	5	5	3	3	3,83	3,7
Tringa nebularia	Insecta, Benthic invertebrates	3	9	2	12	1	6	–	4	–	–	1	–	–	–	–	1	–	1	1	7	–	7	3	8	0,92	4,6
Tringa glareola	Insecta, Benthic invertebrates	6	1	2	2	–	1	–	2	–	–	–	–	–	–	–	–	–	–	1	3	–	–	3	2	1,0	0,9
Numenius phaeopus	Benthic invertebrates	–	2	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,25
Ceryle rudis	Fish	1	2	2	2	1	2	2	1	2	5	2	2	1	2	1	2	1	–	1	2	3	–	2	3	1,58	1,9
Megaceryle maxima	Fish	–	2	–	1	1	–	1	2	–	1	–	1	2	–	1	2	–	2	–	1	–	1	1	1	0,5	1,2
Alcedo semitorquata	Fish	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,08
Corythornis cristata	Fish	–	–	–	2	–	1	–	1	–	–	1	1	–	–	–	1	–	–	–	–	–	–	–	1	0,08	0,6

Mdloti

(i) The sudden opening of the mouth when the estuary was full, for example in September, is likely to have a flushing effect. This is well illustrated by Figure 9 which shows the standing crop of *P. hessei* in relation to the state of the mouth.

(ii) The nutrient status of Mdloti indicates a low primary production which may then restrict the diversity and abundance of zooplankters.

(iii) Larval forms of benthic species dominated the plankton, as at Tongati, but the low numbers of benthic animals would restrict the number of larvae produced.

It is interesting to note that the winter peak in zooplankton at Mdloti mirrored the situation in Mhlanga (Whitfield 1980a) where productivity increased gradually during the closed phase. Any opening during this build-up in standing crop would obviously have far-reaching effects which are illustrated by the present situation in Mdloti. Therefore in neither Mdloti nor Tongati could high standing crops of zooplankton be attained, due in the former to digging of the mouth and lack of nutrients and in the latter to low salinities and oxygen tensions as well as the lack of a closed phase.

Zoobenthos

Tongati

With the exception of *Prionospio* sp. and chironomid larvae the benthos was impoverished. The peak energy values reached in all regions were due almost entirely to *Prionospio* sp. The total energy value of the standing crop of zoobenthos was similar to that recorded at Mhlanga (Whitfield 1980a) but the dominant organisms at Mhlanga were the amphipod *Corophium triaenonyx* and the polychaetes *Ceratonereis erythraeensis* and *Dendronereis arborifera* together with the burrowing sandprawn *Callianassa kraussi*. No burrowing prawns were found at either Tongati or Mdloti. The peaks in zoobenthic standing crop in Tongati did not correspond with times of mouth closure as in Mhlanga, nor with periods of high floc energy values. Nevertheless the peak from March to May and subsequent decline in June (Figure 11) in the upper reaches may have been related firstly, to rises in salinity in March – April and secondly, to a great reduction in oxygen

Table 15 Summary of major abiotic and biotic features of Tongati and Mdloti estuaries compared with Mhlanga estuary. Standing stocks of biomass are compared using arbitrary values of x for J m^{-3} and y for J m^{-2}

	Tongati	Mdloti	Mhlanga
$\bar{x}$ Nutrient levels (μg/ℓ)	SRP: 118 NO_3: 4 Ammonia: 1711	SRP: 38 NO_3: 259 Ammonia: 26	SRP: 998 NO_3: 112 Ammonia: 94
Physical condition	Frequent low O_2 levels, surface water usually fresh, high turbidities. Mouth usually open.	Typically estuarine when open, remained closed in winter. No low oxygens or salinities, except in floods. High turbidities.	Closed for much of year. Typical estuarine when open. No low O_2 or salinities except in flood periods. Medium to low turbidities.
Benthic floc	Very high energy values (4y)	Peaks in late summer (y)	Peaks in winter (y)
Zooplankton	Impoverished (due to physical conditions?) (2x)	Impoverished (x)	Diverse (22x)
Zoobenthos	Low species diversity due to physical conditions but peaks of high energy value (52y)	High species diversity but year-round very low standing crops due to pesticides? (13y)	High diversity and high energy values for most of year (56y)
Epifauna and flora	Abundant with energy values equivalent to zoobenthos but only on roots of *Eichornia crassipes*. Absent on *Phragmites* (81y)	Absent on *Phragmites* (0y)	Abundant on *Phragmites* and energy value 5x of that of zoobenthos (257y)
Fish	Dominated by iliophagous species (Mugilidae and *Sarotherodon mossambicus).* Marked freshwater component. Very low numbers of plankton and benthic feeding species.	Dominated by iliophagous species (Mugilidae and *Sarotherodon mossambicus*). Very low numbers of benthic feeding species. Species diversity similar to Tongati.	Dominated by iliophagous species (Mugilidae and *Sarotherodon mossambicus*) but a considerable diversity of plankton and benthos feeding species.
Birds	Very low numbers of fish eaters and invertebrate feeders. Herbivorous ducks common.	Very low numbers of fish eaters and invertebrate feeders. Herbivorous ducks common.	No data.

concentration in June (Figure 4). The peaks in Figure 11 suggest a movement of *Prionospio* sp. down the estuary, perhaps initiated by successful breeding in the upper reaches. The declines in the middle reaches in September and in the lower reaches in November may have been due to sudden reductions in oxygen and salinity. These spasmodic peaks in an otherwise impoverished fauna suggest instability in an artificially simplified community.

Mdloti

This estuary was remarkable for the low standing crop of benthos although species diversity was higher than in Tongati. Definite peaks corresponding with mouth closure (Figure 3) follow the pattern described for Mhlanga. Periods of higher floc values followed the summer rains and may have provided energy for the winter zoobenthic peaks. The benthic fauna of Mdloti is similar to that of Mhlanga (Whitfield 1980a) and more typically estuarine than that of Tongati. In the presence of well-oxygenated water and typical estuarine salinity patterns the low standing crops of Mdloti are difficult to explain unless they are a result of the relatively high levels of the pesticide dieldrin which is highly toxic to most invertebrates (van Emden 1974). It is perhaps significant that floc and zooplankton levels in Mdloti are also relatively low. If a low detritus input were combined with a reduced primary production, as suggested for Mdloti by the nutrient levels, then the lack of zoobenthos might be attributed to lack of energy input into the system as a whole or to pesticide pollution. Much of the floc is probably washed out by frequent opening of the mouth.

In both Tongati and Mdloti the substrata were relatively uniform and the absence of large quantities of silt in the upper reaches is noteworthy since silt was predominant in the upper reaches of Mhlanga (Whitfield 1980b). The absence of much fine sediment, probably due to flushing, is perhaps also detrimental to the establishment of a rich infaunal benthos.

Eichornia crassipes in Tongati

The standing crop of animals associated with *Eichornia* was as high, if not higher, in most months than that of the zoobenthos (Table 8) and provided an important extra energy input into the food web. The growth of *Eichornia* was undoubtedly due to the large volumes of nutrients entering the system from the sewage works upstream. The roots provided a suitable substratum for many insects and Crustacea near the surface of the water where oxygen saturations usually remained above 25%. *Eichornia* growth took place mainly during closed phases of the estuary but surface salinities in the middle and upper reaches seldom exceeded a lethal level for this plant (Edwards & Musil 1975). Lack of tidal movement, which during open phases carried the plants out to sea, was probably the reason for their proliferation during the quiet water closed periods.

The absence of epifauna on *Phragmites* at Tongati and Mdloti compared with Mhlanga was most striking. The lack of sessile organisms is probably due to frequent but irregular changes in water levels and also in Tongati to low oxygen levels and possibly in Mdloti to pesticides.

Fish

The fish faunas of Tongati and Mdloti are similar in that they are dominated by Mugilidae. The species lists (Tables 9 & 12) indicate a similar species diversity in the two estuaries. Mullet species distribution is influenced by substrata particle size distribution (Blaber 1977) and hence the similar composition of the substrata in all regions of each estuary, with grain sizes from 0,125 to 0,5 mm available, may be responsible for the widespread distribution of *Mugil cephalus, Myxus capensis* and *Valamugil cunnesius* in both estuaries. The predominance of Mugilidae may be linked to their iliophagous feeding which is dependent on benthic floc and its associated micro-organisms. The epipsammic flora which forms an important part of the diet of Mugilidae was diverse and abundant.

Both Tongati and Mdloti may be considered as having impoverished fish faunas; probably due in Tongati to a seasonal lack of invertebrate benthos and zooplankton coupled with low oxygen tensions, and in Mdloti to a year-round extremely low standing crop of zoobenthos and zooplankton despite otherwise apparently healthy physical conditions.

No correlations could be established between the density of fish species or species diversity and the cycles of abundance of zooplankton or zoobenthos. In Tongati many of the fish were dependent on insect larvae (Table 11), probably captured from among *Eichornia* roots. The seasonally abundant polychaete *Prionospio* sp. was not recorded in the diet of any of the fish examined with the possible exception of *Ambassis productus*. Similarly in Mdloti zoobenthic invertebrates were not an important feature of fish diets and planktonic and pelagic foods were taken (Table 13). These results are in marked contrast to the situation in Mhlanga where zoobenthos and the epifauna of *Phragmites* feature extensively in the diet of a more diverse and abundant fish fauna (Whitfield 1980a,b,c).

The results of monthly bird counts do not reveal much other than relatively low numbers of all species dependent on aquatic invertebrates and fish. No comparable data are available for Mhlanga.

Whitfield (1980a) described three major energy pathways to fish in Mhlanga, leading from zooplankton, zoobenthos and benthic floc. Evidently in Tongati and Mdloti those involving zooplankton and zoobenthos are impoverished or absent while that going from benthic floc to iliophagous fishes remains. It is significant that this food chain is the most important in Mhlanga and accounts for about 90% of energy (standing crops) (Whitfield 1980a). In Tongati and Mdloti the food chains involving zooplankton and zoobenthos are impoverished owing to the greater sensitivity of these organisms to environmental perturbations compared with benthic floc and micro-organisms. This suggests that in terms of energy flow these small estuaries remain viable, through the iliophagous chain, under a variety of environmental stresses.

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