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CHANGES IN ICHTHYOFAUNAL DIVERSITY AND ABUNDANCE WITHIN THE MBASHE ESTUARY, TRANSKEI, FOLLOWING CONSTRUCTION OF A RIVER BARRAGE

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A three-year gill-net survey of the ichthyofauna of the Mbashe Estuary, conducted between 1980 and 1982, i.e. prior to the construction of a barrage on the river in 1984, was repeated during the period 1985–1988. The mean number of species caught per month, the mean total abundance of fish and the mean abundance of *Mugil cephalus* per sample decreased significantly after the construction of the barrage. The later period was characterized by high rainfall, but no significant changes in the salinity or transparency regime were recorded. The decline in total abundance of fish, and in *M. cephalus* in particular, may have occurred as a result of a depleted food web caused by the removal of silt and organic matter from the Mbashe Estuary by the severe flood of February 1985, the subsequent lack of replenishment as a result of retention of most of the suspended material by the barrage as well as the continued sediment scour of successive but less severe floods during the following years.

'n Opname van visse in die Mbasheriviermonding d.m.v. kieunette van Januarie 1980 tot Desember 1982 is in Januarie 1985 hervat. Na die bou van 'n keerwal in die rivier gedurende 1984 het die gemiddelde aantal spesies per maand, die gemiddelde totale vistalrykheid asook die gemiddelde talrykheid van *Mugil cephalus* per monster beduidend gedaal. Die periode 1985–1988 is deur buitengewoon hoë reënval gekenmerk, maar geen beduidende veranderings in soutgehalte of die deursigtigheidsregime is as gevolg daarvan aangeteken nie. Die afname in die totale vistalrykheid, veral dié van *M. cephalus*, was moontlik as gevolg van uitputting van die voedselweb veroorsaak deur die verwydering van slik en organiese stof uit die Mbasheriviermonding tydens die hewige vloed van Februarie 1985, die terughouding van die meeste van die gesuspendeerde materiaal deur die keerwal asook volgehoue uitspoeling van sediment deur herhaalde dog minder hewige vloede in die jare daarna.

Much research has been carried out into factors which influence the abundance, diversity and utilization of estuaries by fish. Important fields studied in southern Africa have been the effects of turbidity (Blaber and Blaber 1980, Cyrus and Blaber 1987a, b, 1988) and the occurrence and severity of floods on ichthyofaunal communities (Whitfield 1980, 1982, Marais 1982, 1983, Plumstead *et al.* 1985). More recently, Marais (1988) found a positive correlation between catchment area and fish abundance, whereas correlations with water transparency and salinity were negative.

As Read and Whitfield (1989) point out, the demand for freshwater in southern Africa is increasing. Concomitant is the increase in the number of dams being built, with the result that the freshwater input to many of the estuaries along the coast of southern Africa is diminishing (Whitfield and Bruton 1989). This has led to a national programme in which the needs of estuaries with regard to freshwater input are being investigated. In Transkei, the demand for electricity has resulted in a hydro-electric facility being established on the Mbashe River.

A gill-net survey of the ichthyofauna of the Mbashe Estuary, carried out between January 1980 and December 1982 (Plumstead 1984, Plumstead *et al.* 1989a), was resumed in January 1985 in an attempt to determine if the fish population of the Mbashe Estuary changed as a result of a barrage being built farther upstream.

STUDY AREA

The Mbashe Estuary (Fig. 1) has a catchment area of 5 880 km^2 and mean annual runoff of 581 Mm^2 (Stephenson and Associates 1988). The river is perennial, with 76 per cent of the mean annual precipitation (844 mm) falling between October and March (Weather Bureau 1972). This results in high flow in summer and low flow in winter.

The upper parts of the Mbashe River and its tributaries dissect the Permotriassic Karoo sequence rocks, which consist of Elliot formation mudstone and sandstone overlying Molteno formation mudstone and sandstone. The middle reaches dissect Beaufort group sediments and the lower reaches cut through Ecca shales and mudstones (Plumstead *et al.* 1989a). Vegetation in the upper catchment areas consists mainly of Dohne and Highland Sourveld, while the river is bounded by Valley bushveld from Engcobo to the

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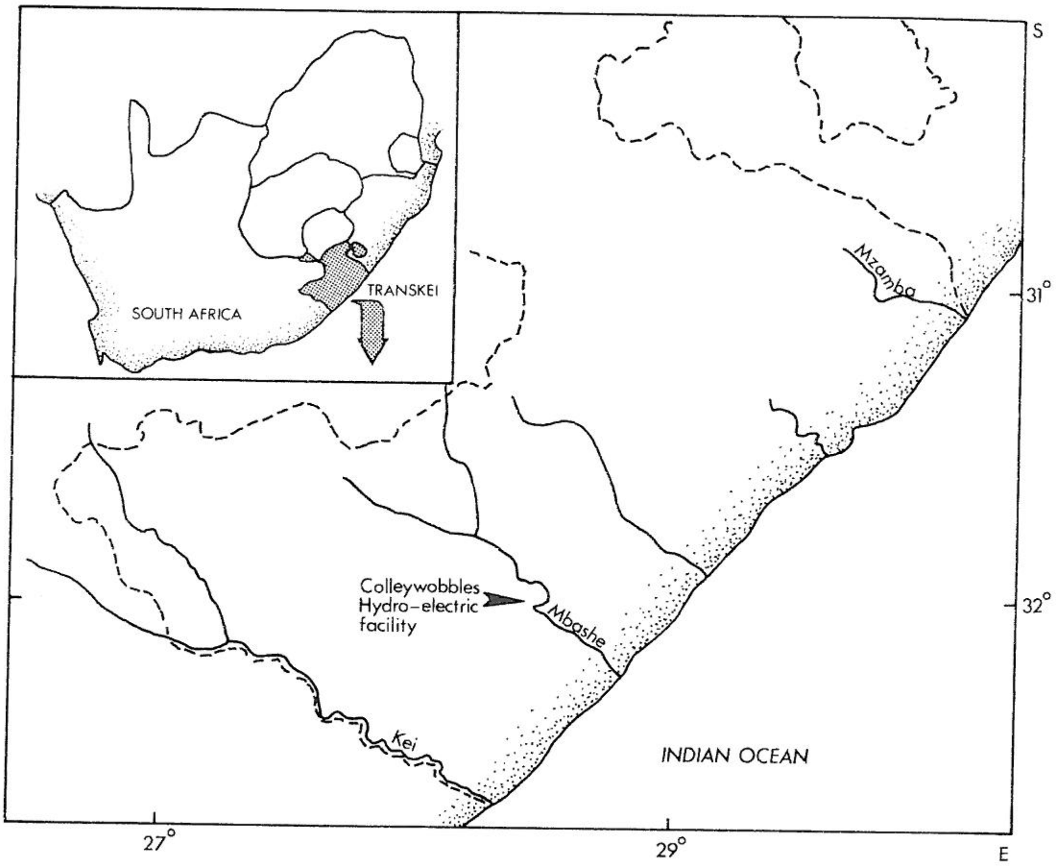

Fig. 1: Geographical position of the Mbashe River and the Colleywobbles hydro-electric facility

coast. Owing to the geology of the catchment, the bad agricultural practices (Wallace and Van der Elst 1975, Branch and Grindley 1979) and the lack of any soil conservation measures, the Mbashe River carried a heavy silt load, and there was high sedimentation in the estuary prior to barrage construction.

Approximately 50 km upstream of the estuary, a hydro-electric facility was completed in 1984. The barrage basin had an initial capacity of $8,8 \times 10^6$ m^3, but by 1988 this was 90 per cent down ($0,92 \times 10^6$ m^3) because of the accumulation of silt (Watermeyer *et al.* 1989). This facility did little to alter the quantity but did, however, by retaining inorganic and organic material, influence the quality of water entering the estuary.

METHODS

A description of the gear and methods used to collect the physicochemical and biological data is given by Plumstead *et al.* (1985). Nets were usually set at neap tides in the evening and removed 12 h later. All fish were collected by means of brown 60-m multifilament gill nets. Each fleet of nets comprised six 10-m panels, 3 m deep with stretched mesh sizes of 45, 57, 73, 93, 118 and 150 mm. Nets were laid perpendicular to the river bank at three stations representative of the lower, middle and upper reaches, 1, 4 and 7 km respectively from the mouth.

Samples of surface and bottom waters, collected for the measurement of physical data, were taken from the middle of the channel, in the morning, prior to removing each net. Bottom water samples were collected by lowering a stoppered, weighted bottle (250 mℓ), which was filled when resting on the sediment by jerking the cord to remove the stopper. Salinity was measured on a salinometer accurate to 1×10^{-3} and adjusted to 0×10^{-3} with distilled water. Temperature was measured with a mercury thermometer accurate to

0,1°C. A Secchi disc of 20 cm diameter was used to measure water transparency.

Fish were identified according to Smith (1965) and Smith and Heemstra (1986). The biological data are based on 99 gill-net catches made between January 1980 and December 1982 and 114 gill-net catches made between January 1985 and December 1988. One-way ANOVA (Sokal and Rohlf 1969) in conjunction with the LSD multiple range test was used to test for differences between the numbers of individuals, species and diversity indices for each year over the study period. Due to the heteroscedascity of the variances (Bartlett's test $p = 0,41$), the mean salinity and Secchi disc transparencies per year were compared by means of the Kruskal–Wallis analysis of variance by ranks. Species diversity was tested with the Shannon–Wiener diversity index H', Pielou's evenness index J' (Zar 1974) and the richness index R (Odum 1971).

Data on annual runoff (Mm^3) for the estuary were obtained from a study by Stephenson and Associates (1988) and the Transkei Electricity Supply Corporation (R. Taylor pers. comm.)

RESULTS

Physical data

Kruskal–Wallis analysis of variance by ranks showed that there was no significant ($p < 0,01$) change in the Secchi disc transparency in the upper, middle and lower reaches (Fig. 2a) and hence no obvious change in the turbidity of the estuary. Analysis of mean salinities in the upper, middle and lower reaches, based on Kruskal–Wallis tests, indicated no significant ($p < 0,05$) differences between the years prior to and following the completion of the barrage (Fig. 2b). The period 1985–1988 was characterized by exceptionally high runoff (Fig. 2c), whereas that of 1982 was well below 581 Mm^3, the most recent estimate of the mean annual runoff (Stephenson and Associates 1988) for this river.

The barrage on the Mbashe River was completed in 1984 (Watermeyer *et al.* 1989). At that stage the dam had a capacity of $8,8 \times 10^6$ m^3. The high rainfall in the catchment area results in the heavy erosion of sills and sediments which are subsequently transported into the Colleywobbles storage basin (Watermeyer *et al.* op. cit.). By February 1986, $5,3 \times 10^6 m^3$ of silt had been deposited behind the barrage wall, resulting in a capacity of only $3,5 \times 10^6$ m^3 remaining above the silt, or 39 per cent of the original volume. During this period an average of $2,36 \times 10^6$ m^3 of silt was trapped annually. As at March 1989, only $0,92 \times 10^6$ m^3, or 10,5 per cent of the original storage, remained, indicating that a further $2,58 \times 10^6$ m^3 of silt had been introduced to the barrage basin, in other words $0,8 \times 10^6$ m^3 per annum.

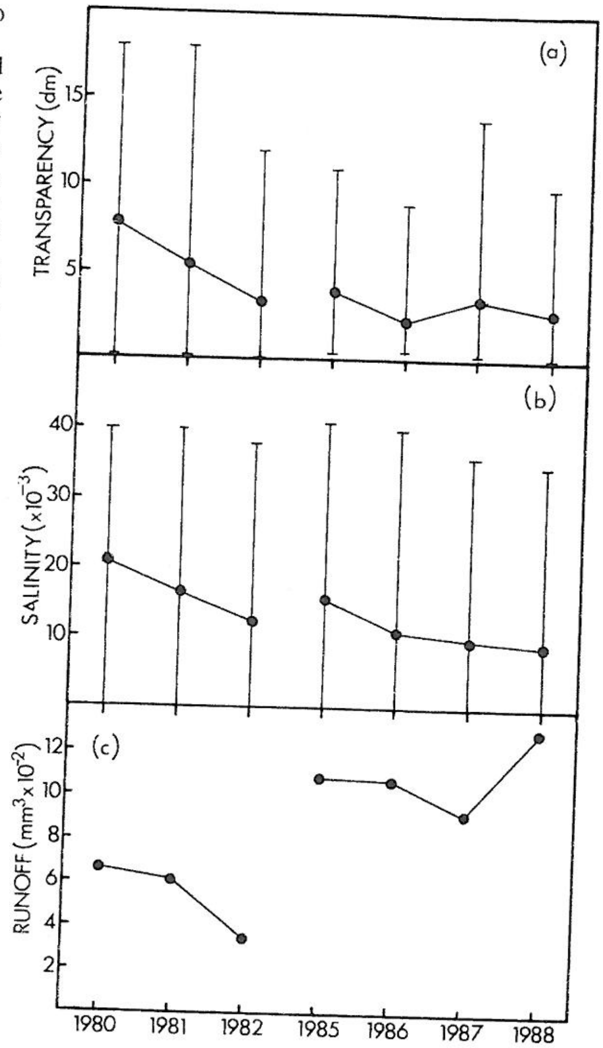

Fig. 2: (a) Mean monthly Secchi disc transparency, (b) mean monthly salinity and (c) annual runoff in the Mbashe Estuary. Bars denote the range

Therefore, a total of $7,88 \times 10^6$ m^3 of silt were retained by the barrage over a period of just 64 months, an annual deposition rate of $1,48 \times 10^6$ m^3 of silt. It has been estimated that, at the present level of siltation, the water storage behind Colleywobbles weir will have stabilized at $0,2 \times 10^6$ m^3 or 2,3 per cent of the original storage capacity by October 1990 (Watermeyer *et al.* 1989). Thereafter, most of the silt emanating from the Mbashe catchment will pass over the barrage wall, thereby returning the estuary to its original silt regime.

Table I: Annual occurrence of fish species in gill-net catches from the Mbashe Estuary

Species	Number caught						
	1980	1981	1982	1985	1986	1987	1988
Carcharhinus leucas		2					1
Rhinobatos annulatus		1					
Torpedo sinuspersici		1					
Elops machnata	15	11	5	29	40	18	27
Thryssa vitrirostris	6	10					1
Galeichthys feliceps				2		3	
Caranx spp.		1		1			
Lichia amia	43	22	12	3		14	14
Pomatonus saltatrix	8			1			2
Argyrosomus hololepidotus	228	268	261	129	109	177	255
Umbrina canariensis						1	1
Johnius dussumieri	9	18	9		1	3	14
Monodactylus falciformis			1			1	
Leiognathus equula			1				1
Gerres acinaces							1
Ambassis spp.							1
Pomadasys commersonnii	70	84	98	11	22	50	51
Acanthopagrus berda		5	4	2			
Lithognathus lithognathus	1	1	2	1	1		
Rhabdosargus sarba	3	2	1				
Rhabdosargus holubi		2					2
Liza alata	1						
Liza dumerilii	1	1					
Liza richardsonii	8	1					2
Liza tricuspidens	35	50	9	5	2	2	10
Mugil cephalus	481	394	556	156	102	142	164
Myxus capensis	12	35	41	19	7	1	2
Valamugil buchanani	16	2	6	1		1	3
Valamugil cunnesius	7	3	8			1	1
Valamugil robustus			1	4			
Sphyraena acutipinnis		1					
Muraenesox bagio							1
Number of nettings	11	12	9	10	7	10	11

Because the deposition of silt reduced the efficiency of the turbines, dredging of the weir basin was introduced in November 1987. However, this proved to be extremely inefficient and, by April 1989, only $0{,}52 \times 10^6$ m^3 of silt had been reintroduced to the river below the barrage wall.

Biological data

The total number of species collected by gill net annually declined from a high of 22 in 1981 to a low of 8 in 1986, but thereafter increased towards its original level (Table I). Of the 27 species gill-netted during the initial survey, 11 were not found between 1985 and 1987. A further five species were netted following but not prior to the erection of the barrage. The mean number of species collected monthly (Fig. 3a) varied significantly (Kruskal–Wallis $H = 30{,}97$; $df = 6$; $p < 0{,}05$) between 1980/82 and 1985/88, although it is evident that the number of species caught per sample in 1988 was approaching the number caught in 1982.

The diversity of the fish community, as indicated by the Shannon–Wiener index H' (Fig. 3b), Pielou's evenness index J' and the richness index R, showed no significant changes over the study period. Changes in these indices are not expected because the ichthyofauna of turbid Transkeian estuaries are dominated by a few species, chiefly *Mugil cephalus*, *Argyrosomus hololepidotus* and *Liza tricuspidens* (Plumstead *et al.* 1985, 1989a, b).

The mean number of fish taken each year (Fig. 3c) varied significantly between years (ANOVA, $p < 0{,}05$). A multiple-range analysis (LSD, $p > 0{,}05$) showed that the number of fish caught during the years 1980–82 was significantly higher ($\bar{x} = 90{,}2$ p.a.) than those caught between 1985 and 1988 ($\bar{x} = 42{,}2$ p.a.). Of the three numerically dominant species present, only *M. cephalus* (Fig. 4a) varied significantly (ANOVA, $p < 0{,}05$), with numbers much reduced following the

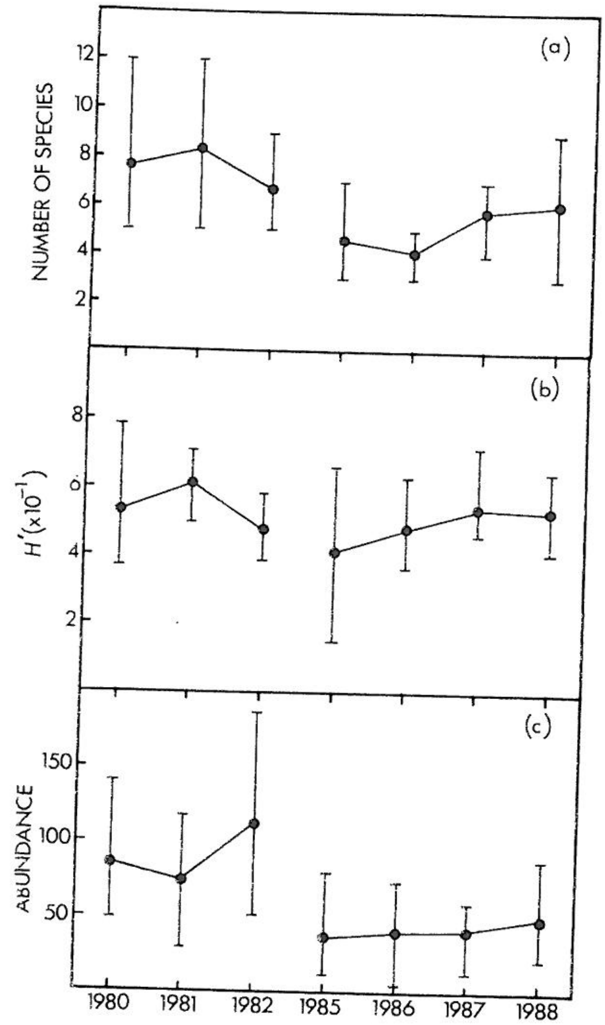

Fig. 3: (a) Mean monthly number of species, (b) mean monthly Shannon–Wiener H' and (c) mean monthly abundance of fish in the Mbashe Estuary. Bars denote the range

completion of the barrage (LSD, $p > 0{,}05$). Although the numbers of *A. hololepidotus* and *Pomadasys commersonnii* (Figs 4b, c) did drop, these changes were not statistically significant. If grouped, the abundance of the remaining fish species (Fig. 4d) decreased significantly (ANOVA, $p < 0{,}05$) from the period 1980–82 to the period 1985–88.

Significant negative correlations were found between annual runoff and both total fish abundance and *M. cephalus* abundance ($p < 0{,}01$). Secchi disc transparency and salinity were positively correlated ($p < 0{,}01$), but neither were correlated with annual

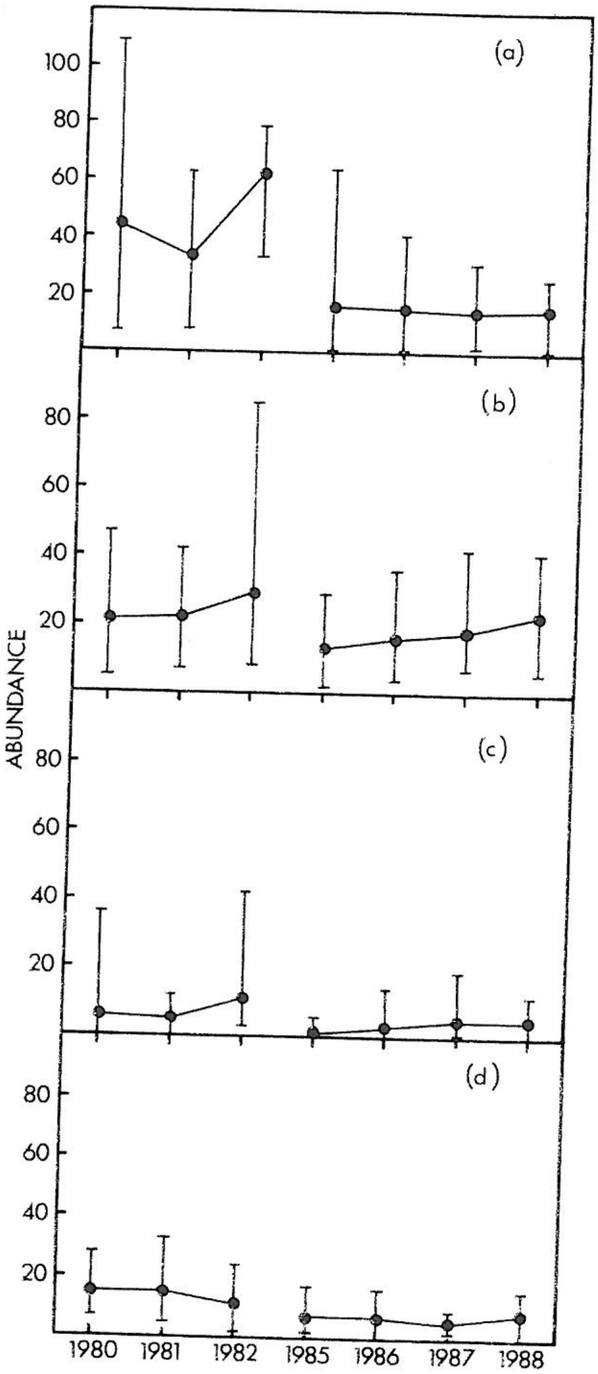

Fig. 4: Mean monthly abundance of (a) *Mugil cephalus*, (b) *Argyrosomus hololepidotus*, (c) *Pomadasys commersonnii* and (d) others in the Mbashe Estuary. Bars denote the range

runoff or fish abundance in this estuary.

An analysis based on the upper, middle and lower reaches (Fig. 5) of the Mbashe Estuary revealed clear trends. The total number of fish in the lower reach showed no significant variation (ANOVA, $p < 0{,}44$), but numbers varied significantly in the middle and upper reaches ($p < 0{,}005$ and $< 0{,}05$ respectively). In the middle reach, numbers caught between 1980 and 1981 ($\bar{x} = 36{,}0$) were higher than those caught between 1985 and 1988 ($\bar{x} = 14{,}0$). In the upper reach, the numbers caught in 1980 ($\bar{x} = 38{,}6$) differed from the catch in 1985–88 ($\bar{x} = 12{,}6$). With regard to *M. cephalus*, numbers in the upper and lower reaches did not vary significantly. Abundance of this species in the middle reach during the period 1985–88 ($\bar{x} = 3{,}6$) was very much lower ($p < 0{,}005$) than for the period 1981/82 ($\bar{x} = 21{,}9$).

DISCUSSION

Species diversity in southern African estuaries depends on many factors. According to Whitfield (1983), the physiological adaptation of fish to changing salinities is most important. Other factors that influence the diversity include turbidity (Blaber 1981, Day 1981a, Cyrus and Blaber 1987a, b, Whitfield op. cit.), the occurrence and severity of floods (Whitfield 1980, Day *et al.* 1981, Marais 1982, 1983, Plumstead 1984), and habitat variation (Whitfield 1983). Whitfield (1983) further suggests that the indirect effects of excessive siltation, i.e. the reduction of light penetration and smothering of submerged vegetation and associated invertebrate prey, contribute to the lower species diversity in very turbid estuaries and not the turbidity itself. Albeit a turbid estuary (Plumstead *et al.* 1989a), the Mbashe, contrary to reports (Day 1981b, Marais 1988) in which only 10 fish species were referred to, has both a diverse and abundant ichthyofauna. During a three-year investigation of this estuary (Plumstead *et al.* 1989a), 27 species, comprising 2 908 fish, were gill-netted, with subsequent gill- and seine-netting yielding a further 33 species.

It is clear from Figure 3a that, following the completion of the hydro-electric facility, there was a marked decrease in the number of species caught per month. This was accompanied by a significant ($p < 0{,}05$) reduction in the catch. Neither the decrease in species diversity or abundance of fish could be attributed to salinity or turbidity because these showed no statistically significant differences between the two study periods. Although there was a generally declining trend in both salinity and transparency, comparison

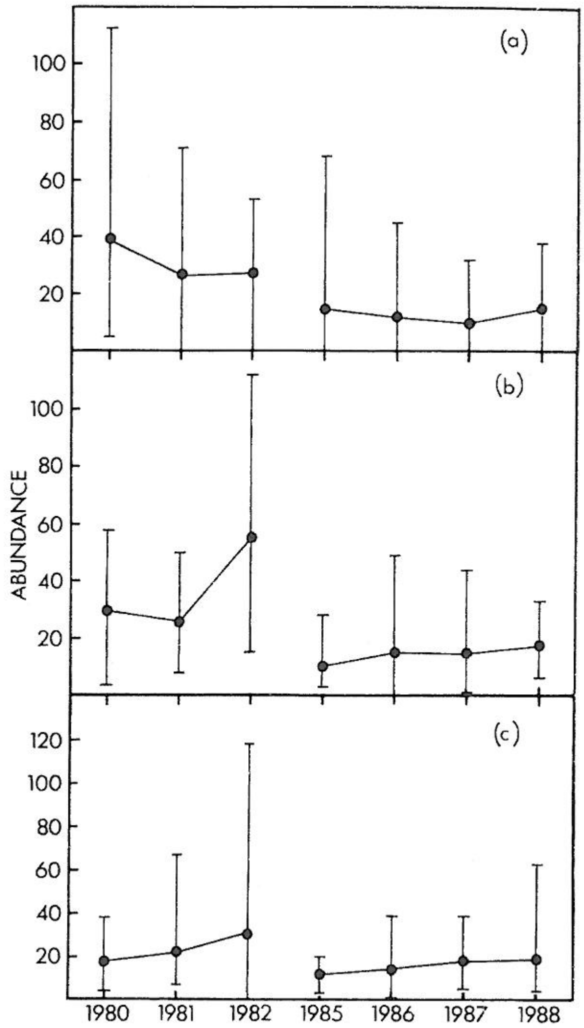

Fig. 5: Mean monthly abundance of fish in (a) the upper, (b) the middle and (c) the lower reaches of the Mbashe Estuary. Bars denote the range

of Figures 2, 3, 4 and 5 shows that the highest catches were taken in 1982, when both salinity and water transparency were indistinguishable from those of 1985–88. Investigations in the Mhlanga and Swartvlei estuaries also revealed no reduction in species diversity associated with decreased water transparency (Whitfield 1983).

Various factors, including the intensity and duration of floods and the type of estuary, are responsible for changes in estuarine ichthyofaunal composition and abundance. Marked increases in abundance of fish were observed in the Swartkops (Marais and Baird 1980) and Kei estuaries (Plumstead *et al.* 1985) following floods, whereas numbers dropped in the Sundays Estuary (Marais 1981) after floods. The family Mugilidae, particularly *M. cephalus*, was more abundant after some floods (Plumstead *et al.* op. cit.) and less abundant (Marais 1982, Plumstead *et al.* op. cit.) after others. *A. hololepidotus* and *P. commersonnii* usually increased in numbers and biomass as a result of increased vulnerability and exposure of their prey species (Van der Westhuizen and Marais 1977, Hanekom 1989). Following heavy floods in the Mbashe Estuary during early February 1985, the total fish catch fell to a minimum in February and March. Fish abundance usually takes up to six months (Marais 1982, 1983, Plumstead *et al.* 1985, 1989a) to return to pre-flood levels. However, by December 1988, there had been a slight recovery only, possibly a function of a disrupted benthic food web.

The catchment area of an estuary is one of its major sources of nutrients (Taft 1979 as quoted by Pritchard and Schubel 1981). This input is usually highest during the rainy season when runoff is greatest (Flint 1985), whereas the types of nutrient depend on the geology of the catchment area, the agricultural practices, pollution, etc. In Transkei, the large estuaries draining the interior receive enormous quantities of fluvial sediment during summer, much of which is deposited in the estuarine basins as mud/silt (Day 1981b). Nutrients entering the estuaries become adsorbed to this suspended matter, settle out and become part of the estuarine sediment. The silt is an important reservoir for nutrients, acting at various times as both sink and source (Pritchard and Schubel op. cit.). The regeneration of these nutrients is largely dependent on physical, chemical and biological processes occurring within the system (Webb 1981). Severe floods remove the sediment down to the erosion base (Marais 1982), particularly in channel-like estuaries. During the initial survey of the Mbashe Estuary (Plumstead *et al.* 1989a), the estuary was covered in a thick layer of soft silt, all of which was scoured out by the flood of February 1985. Mean HWN depths increased from 199 to 372 cm in the lower reaches and from 124 to 180 cm in the upper reaches. During the following months and years, this layer of silt and organic matter did not accumulate in the Mbashe Estuary even though the period was characterized by above-average runoff. Payne (1976) established that mullet feed principally on detritus and algae and are most abundant when organic material in the sediment is at a maximum. Any agent causing the removal of these resources or preventing their entering the estuarine basin would conceivably cause significant changes in the abundance of this group of fish. The decline in numbers of mullet in the Mbashe Estuary appears to be as a result of the removal of the organic-rich sediments and detritus. A similar decline in mullet abundance in the Gamtoos and Sundays estuaries has been thought to be due to the removal by floodwaters of silt, clay and colloidal humus (Marais op. cit.), whereas an increase in mullet abundance in the Swartkops Estuary following a severe flood (Marais and Baird 1980) has been attributed to the deposition of a thin layer of silt over much of the estuary (Marais op. cit.).

Many investigators have suggested that estuarine productivity is attributable either directly or indirectly to the fertilizing effects of freshwater inflow (Flint 1985). However, it is important to note that high estuarine productivity is maintained by the synergistic effects of several different factors, none of which can act independently with similar results (Flint op. cit.). In the case of the Mbashe Estuary, two events occurred within a short space of time. The barrage was completed and, soon afterwards, a severe flood removed the silt and organic material from the estuarine basin. There was an immediate and dramatic decrease in fish abundance (February 1985), with no significant recovery of numbers up to four years later (December 1988).

Episodic events such as floods can act as significant forcing factors in an estuary by replacing losses and sustaining productivity (Flint 1985), yet in the Mbashe Estuary, productivity did not increase despite the high annual runoff during the years 1985–88. The decline in fish numbers and diversity appears to have resulted from a depleted food web caused by the flood of February 1985 scouring the estuarine basin of silt and organic material. It was probably maintained by the subsequent lack of replenishment caused by the retention of most of the suspended material by the Colleywobbles barrage as well as the continued sediment scour of successive but less-severe floods during the following years. With the barrage having silted up in October 1990 (Watermeyer *et al.* 1989), continued sampling will be necessary to determine if the abundance of fish will return to pre-barrage levels.

Major scientific endeavour appears to revolve around the consequences of increased inorganic nutrient-loading (Webb 1981), freshwater requirements (Read and Whitfield 1989) and siltation of estuaries. Although it is widely accepted by the scientific community that silt plays a role in estuaries of South-East Africa, it is usually associated with negative effects, i.e. siltation of estuaries, high turbidities, smothering of the aquatic vegetation, etc. It must be realized, however, that these estuaries and the organisms within them have evolved under a high sedimentation load (Day and Grindley 1981), and removal of this input may have detrimental effects on the estuarine biota.

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