Flood-associated mass mortality of fishes in the Sundays Estuary

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Abstract

Mass mortalities of fishes in South African estuaries have been linked to changes in salinity, temperature and dissolved oxygen concentrations. This short communication documents two fish kills which were associated with high suspensoid levels during flash floods in January 1995. A total of 16 fish species, belonging to freshwater, estuarine and marine taxa, were recorded dying in the Sundays Estuary. Both juvenile and adult fish appeared to be affected by the high levels of silt and clay carried by the flood waters. Although the available evidence suggests that clogging of the fish gill filaments by suspended sediments was primarily responsible for the mass mortalities on 16 January 1995, osmoregulatory and other stress factors (e.g. reduced dissolved oxygen levels associated with the flood waters) may also have contributed to the fish kills.

Introduction

Heavy rains over the Eastern Cape on 14 January caused the Sundays and other rivers to come down in flood on 15 and 16 January 1995. The water level at Addo Bridge (Department of Water Affairs and Forestry Recorder N4H003), less than 20 km from the head of the Sundays Estuary (33°43'S; 25°51'E), increased by 3.4 m (i.e. from 0.6 m to 4.0 m) between 08:30 and 10:30 on 15 January, with the initial 2.4 m rise occurring in less than 20 min. The water level then continued to rise at a slower rate, reaching a gauge plate peak reading of 4.98 m at 08:00 on 16 January. The initial flood waters carried large amounts of silt into the Sundays Estuary, creating an environment which resembled "liquid chocolate" according to one observer. Reports of dying fishes, their gills clogged with silt, were first received on Monday 16 January. Fishes were observed gulping air at the surface and attempting to leave the water along the supratidal estuary margins. By the end of the day thousands of dead fishes of all sizes were left stranded as the flood waters receded.

On Tuesday 17 January no further mortalities were observed, but thousands of dead fishes floated down the estuary towards the sea. Hundreds of kelp gulls (*Larus dominicanus*) descended on the estuary to feed on the decomposing fish. Most of the fishes which died were concentrated in the lower reaches of the estuary, with decreasing numbers in the middle reaches and none recorded in the upper reaches. Fishes which may have died in the channel-like upper reaches would have been transported into the middle and lower reaches by the flood waters. Those fishes which survived the flood appeared to have remained in the estuary because fish activity was observed in the lower reaches of the system on 18 January.

Great Fish River discharge at Outspan (Department of Water Affairs and Forestry Recorder Q9H018), less than 30 km from the head of the estuary, increased from 23 $m^3 \cdot s^{-1}$ at 11:00 on 15 January 1995 to 270 $m^3 \cdot s^{-1}$ an hour later. At the peak of the flood on 16 January 1995, 1 190 $m^3 \cdot s^{-1}$ flowed down the system and a radio report indicated that weir sluices on the Great Fish River were being opened because of the excessively high sediment loads being carried by the flood waters (Cowley, pers. comm.). In the estuary, spotted grunter (*Pomadasys commersonnii*), kob (*Argyrosomus hololepidotus*), mullet (Mugilidae), carp (*Cyprinus carpio*) and Mozambique tilapia (*Oreochromis mossambicus*) exhibited the same stress symptoms (gulping air at the water surface) observed in the Sundays Estuary. Large numbers of the above taxa were collected by hand in the mouth region of the Great Fish Estuary (33°30'S; 27°08'E) on 16 January 1995 (Cowley, pers. comm.). All the above species, including the marine taxa, are regularly recorded in freshwater areas immediately above the estuary (Ter Morshuizen, 1994) and are therefore acclimatised to riverine conditions.

The aim of this paper is to document the findings of the Estuarine Research Group at the JLB Smith Institute of Ichthyology, based on a field visit to the Sundays Estuary on 18 January 1995 and interviews with eyewitnesses to the flood event and subsequent fish kill.

Materials and methods

Samples of fishes were examined in the lower reaches (4 sites) and middle reaches (3 sites) of the Sundays Estuary (Fig. 1) on 18 January 1995. No dead fishes were observed in the upper reaches during a boat survey of the area. Each specimen was identified and measured to the nearest 5 mm total length (TL).

Selected physico-chemical measurements were conducted at 10 channel stations (Whitfield, 1994) between the head (Station 1) and mouth (Station 10) of the estuary on 18 January 1995. Water temperatures 30 cm below the surface were determined *in situ*, with salinity and turbidity samples collected in glass containers for subsequent laboratory analysis. Salinity was measured using a temperature compensated optical salinometer and turbidities (nephelometric turbidity units) with a calibrated turbidimeter.

Results and discussion

A total of 16 fish species, belonging to freshwater, estuarine and marine groups (Table 1), were recorded dying in the Sundays Estuary (Fig. 2). Most of the taxa which were adversely affected by the flood event are demersal species which feed on benthic organisms or detritus. However, some pelagic species such as *Monodactylus falciformis* also suffered extensive mortalities. Indications are that

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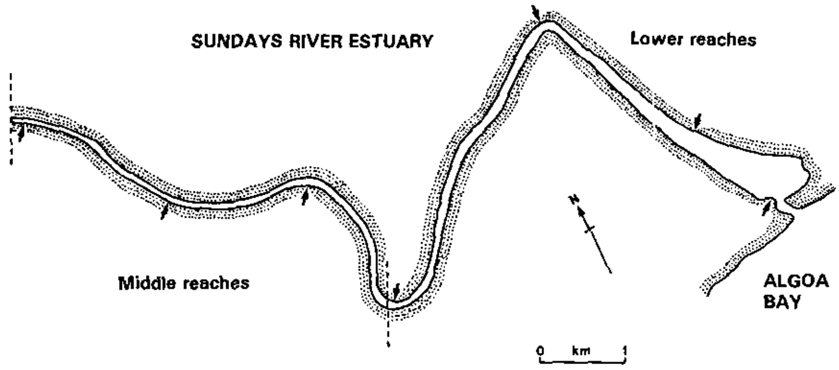

Figure 1
Map of the Sundays Estuary showing the lower and middle reaches, as well as the fish sampling sites (arrows)

Figure 2
Photograph of some of the fish species killed by the January 1995 flood in the Sundays system. Note the macrophytic plant debris deposited on the banks of the estuary by the river flood

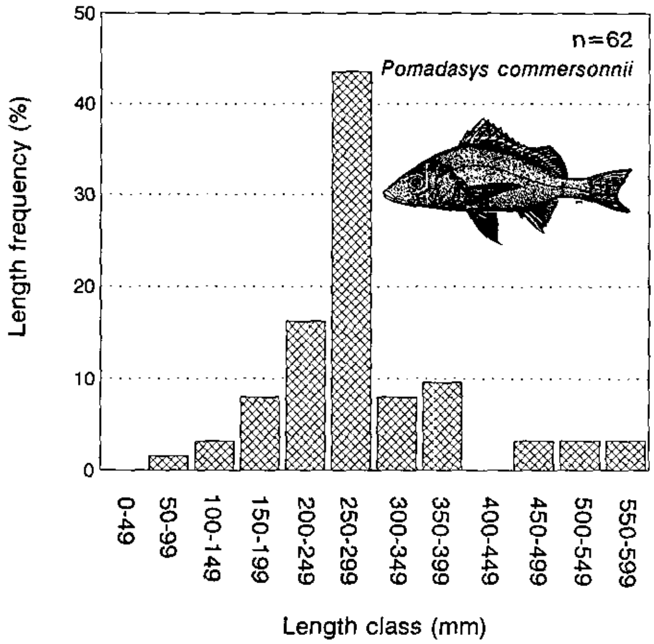

Figure 3
Length frequency distribution of spotted grunter Pomadasys commersonnii *sampled from the banks of the Sundays Estuary on 18 January 1995*

TABLE 1
FISH SPECIES RECORDED DYING IN THE SUNDAYS ESTUARY DURING THE JANUARY 1995 RIVER FLOOD

Species	Common name	Length range (mm)	Group
Acanthopagrus berda	Riverbream	260-330	Marine
Argyrosomus hololepidotus	Kob	95-470	Marine
Caffrogobius multifasciatus	Prison goby	90	Estuarine
Cyprinus carpio	Carp	450-650	Freshwater
Diplodus cervinus hottentotus	Zebra	95	Marine
Elops machnata	Ladyfish	Not recorded	Marine
Gilchristella aestuaria	Estuarine roundherring	30	Estuarine
Liza richardsonii	Southern mullet	265-390	Marine
Liza tricuspidens	Striped mullet	230-490	Marine
Monodactylus falciformis	Cape moony	80-130	Marine
Myxus capensis	Freshwater mullet	320-580	Marine
Oreochromis mossambicus	Mozambique tilapia	340-400	Freshwater
Platycephalus indicus	Bartail flathead	320-670	Marine
Pomadasys commersonnii	Spotted grunter	70-590	Marine
Rhabdosargus holubi	Cape stumpnose	30-210	Marine
Rhinobatos annulatus	Lesser guitarfish	Not recorded	Marine

both juvenile and adult fish were affected, an example of which is shown in Fig. 3. Marais (1981) recorded size classes between 120 mm and 580 mm SL for *Pomadasys commersonnii* captured in Sundays Estuary gill nets, a size range which is similar to that shown in Fig. 3.

Species which are known to be relatively common in the Sundays Estuary (Marais, 1981; Beckley, 1984), and were not recorded in the fish samples examined on 18 January, included the groovy mullet *Liza dumerilii*, white steenbras *Lithognathus lithognathus*, white sea catfish *Galeichthys feliceps*, blacktail *Diplodus sargus*, Blackhand sole *Solea bleekeri*, Cape sole *Heteromycteris capensis*, Cape silverside *Atherina breviceps* and Knysna sand goby *Psammogobius knysnaensis*. The latter two species would have been targeted by scavenging birds because of their small size and this view is supported by observations on foraging gulls and terns in the estuary on 18 January. The most abundant fish species in the Sundays system is the small estuarine roundherring *Gilchristella aestuaria* (Beckley, 1984), yet only one dead specimen was found on the shores of the estuary during this survey. *G. aestuaria* is a pelagic, weak-swimming fish species, and dying individuals may well have been flushed directly out to sea by the flood waters. *D. sargus* and *L. lithognathus* occur mainly in the lower reaches of the estuary (Marais, 1981) where the impact of the suspended sediment on the fish fauna would have been reduced due to dilution of the flood waters *en route* to the mouth. *S. bleekeri* and *H. capensis* usually occur throughout the Sundays Estuary (Beckley, 1984) and would therefore have been exposed to the high silt loads which entered the system. The absence of these two sole species from the fish kill suggests that they survived the flood waters as a result of their specialised benthic habits which condition them to elevated silt levels.

The catchments of both the Sundays and Great Fish Rivers include erodible Ecca, Dwyka and Beaufort Group shales, and large amounts of silt and clay are associated with the tributaries of these systems (Reddering and Esterhuysen, 1981; Reddering and Esterhuysen, 1982; Day, 1981). The mobilisation of these fine sediments, together with a scouring of accumulated mud and silt in the upper reaches of these estuaries by the rapid flood peak on 15 January, probably caused the mass fish mortalities. The uprooting of the submerged and emergent macrophytes at the head of the Sundays Estuary would also have released large amounts of fine sediment which had been trapped by these plants over the years.

According to Horkel and Pearson (1976), the green sunfish (*Lepomis cyanellus*) increases ventilation rates under highly turbid conditions (>1 000 formazin turbidity units) possibly as a means of compensating for reduced respiratory efficiency and maintaining a constant oxygen uptake. These authors also suggested that the costs of increased ventilation rates were met by a reduction in fish activity. In the turbulent flood situation within the Sundays and Great Fish estuaries, the fishes would have had to increase muscular activity and hence oxygen demand at a time when ventilation rates would probably have been high as a result of reduced respiratory efficiency. The surfacing of stressed fish during both the Sundays and Great Fish flood events is similar to the laboratory behaviour of juvenile Arctic greyling (*Thymallus arcticus*) when exposed to suspended inorganic sediment strengths >10 000 mg·ℓ^{-1} (McLeay et al., 1987).

Although the available evidence points towards silt clogging of the gill filaments as having been the primary cause of the fish mortalities, the freshwater conditions which prevailed following the floods may also have contributed to the death of some of the marine taxa. Species such as *Argyrosomus hololepidotus*, *Pomadasys commersonnii* and *Rhabdosargus holubi* have been recorded dying in salinities <3 g·kg^{-1} when water temperatures reached 12°C (Blaber and Whitfield, 1976; Bennett, 1985). Although surface salinities in the Sundays Estuary at low tide on 18 January 1995 were zero (except for the mouth area where a salinity of 2 g·kg^{-1} was recorded), channel water temperatures ranged from 23 to 24°C (Table 2). Of the marine species recorded dying in the Sundays Estuary, only *Diplodus cervinus*, *Rhinobatos annulatus* and *Platycephalus indicus* have not been found in freshwater areas above estuaries in the Eastern Cape. Despite the tolerance of temporary freshwater conditions by certain euryhaline marine taxa, the sudden exposure of these species to the river flood would

TABLE 2
PHYSICO-CHEMICAL VARIABLES RECORDED IN THE SUNDAYS ESTUARY ON 18 JANUARY 1995

Station No.	Salinity ($g \cdot kg^{-1}$)	Temperature (°C)	Turbidity (NTU)
1	0	24.0	120
2	0	23.5	125
3	0	24.0	110
4	0	23.5	110
5	0	24.0	145
6	0	23.5	140
7	0	23.5	150
8	0	24.0	165
9	0	24.0	170
10	2	23.5	150

have induced osmoregulatory stress which, in combination with the respiratory stress created by the elevated suspensoid levels, may have led to the death of these fishes.

Although the freshwater carp *Cyprinus carpio* and Mozambique tilapia *Oreochromis mossambicus* have both been recorded in the Sundays Estuary (Marais, 1981; Beckley, 1984) under normal tidal conditions, many of the dead specimens found in the system on 18 January may have succumbed to the silt-laden waters in the river and then been washed into the estuary by the flood. According to Skelton (1993) *C. carpio* thrives in large turbid rivers and forages by grubbing in sediments. Presumably the suspended silt load in the Sundays River flood waters was too high even for this species, resulting in clogging of the gill filaments (Bruton, 1985). According to Wallen (1951) *C. carpio* show adverse reactions to suspensoid levels above 20 000 $mg \cdot \ell^{-1}$ and first deaths were recorded at 175 000 $mg \cdot \ell^{-1}$. Alabaster and Lloyd (1980) have suggested that suspended sediment concentrations of several hundred thousand $mg \cdot \ell^{-1}$ are unlikely to occur in surface waters for extended periods, but silt loads up to•6 000 $mg \cdot \ell^{-1}$ have been recorded persisting in flooding rivers for 15 to 20 d.

Another factor which would have increased the respiratory stress level of the fishes in the Sundays and Great Fish systems was the relatively high summer water temperatures which reduce the oxygen absorption coefficient of the water (Ruttner, 1963). In addition, oxygen levels within the water column could have been lowered further, since evidence from the Swartvlei Estuary suggests that dissolved oxygen conditions are reduced following river flooding (Liptrot and Allanson, 1978).

Previously recorded water turbidities within the Sundays Estuary were low and averaged 10 NTU (range 2 to 32 NTU)(Whitfield, 1994). Post-flood turbidities in the Sundays Estuary on 18 January averaged 139 NTU and ranged between 120 NTU at the head of the estuary to 170 NTU near the mouth (Table 2). The slightly higher values in the lower reaches were probably due to partial resuspension of silt which had been deposited in the intertidal areas of the estuary over the previous three days. Silt deposits in the upper and middle reaches were more restricted due to the channel-like structure of the system in these areas. Suspensoid levels associated with turbidities within the range described above are not harmful to fishes in estuaries (Cyrus and Blaber, 1987) and this view was supported by fish activity observed in the Sundays system on 18 January. Unfortunately no turbidity or suspensoid samples were collected on 15 January when sediment loads were reputed to have been exceptionally high.

Species such as *Argyrosomus hololepidotus* and *Pomadasys commersonnii*, which suffered major mortalities in the January 1995 flood, were recorded in moderate numbers two weeks after the 1979 floods in the Sundays Estuary (Marais, 1982). Both species survived salinities as low as 0 $g \cdot kg^{-1}$ (surface) and 4 $g \cdot kg^{-1}$ (bottom) in the post-flood Sundays Estuary (Marais, 1982), and sampling in the Great Fish Estuary has shown that *A. hololepidotus* and *P. commersonnii* are found in the freshwater upper reaches of this system (Whitfield et al., 1994). These results lend support to the view that osmoregulatory problems were not responsible for the mass mortalities of marine species in January 1995. The fact that freshwater species in the Sundays and Great Fish systems were similarly affected to the estuarine and marine groups of fishes also supports the hypothesis that exceptionally high sediment loads, and not freshwater conditions, were responsible for the fish kill.

Why have previous floods in the Sundays and Great Fish estuaries not resulted in extensive marine fish mortalities arising from silt-induced clogging of gill membranes? Perhaps the answer may be found in the abruptness with which the sediment-laden water entered each system, leaving no time for the euryhaline marine fish species in the upper and middle reaches to escape towards the sea. Once the ichthyofauna had been enveloped by the initial flood waters, clogging of the gill filaments occurred, which affected subsequent oxygen uptake by the fishes and ultimately resulted in their death. Previous experience by the Estuarine Research Group of collecting fish such as *Pomadasys commersonnii* over muddy substrata in estuaries has revealed that individuals whose gills are exposed to silt-laden water subsequently die within 24 h. even if transferred to clean estuarine water immediately after capture.

In conclusion, the Eastern Cape flood event of January 1995 has highlighted the need for research on the suspensoid tolerance limits of fish species in South African rivers and estuaries, as well as a monitoring of suspended sediment and dissolved oxygen levels during river floods. Only when this information becomes available will we be able to provide a detailed answer to the questions raised above.

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