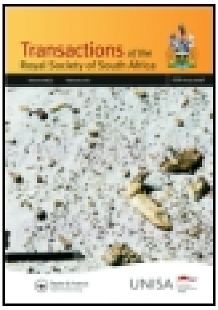

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A PRELIMINARY SURVEY OF THE COASTAL RIVER SYSTEMS OF FALSE BAY, SOUTH-WEST COAST OF SOUTH AFRICA, WITH PARTICULAR REFERENCE TO THE FISH FAUNA

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A PRELIMINARY SURVEY OF THE COASTAL RIVER SYSTEMS OF FALSE BAY, SOUTH-WEST COAST OF SOUTH AFRICA, WITH PARTICULAR REFERENCE TO THE FISH FAUNA.

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SUMMARY

The estuaries of False Bay were surveyed during the period October to November 1993. The ichthyofaunal and physico-chemical characteristics of each system are presented and their suitability as estuarine nursery areas is discussed. Eleven systems drain into False Bay and most of these have, in one way or another, been impacted and modified by human activities. Two systems, the Buffels (Wes) and Elsies appear to be little more than coastal streams which only flow during the winter rainy period and offer little habitat for either resident or estuarine-dependent marine fishes. One system, the Seekoe, has been reduced to an outfall for treated sewage effluent and does not appear to support any fish fauna. A further two systems, the Silwermyn and Sir Lowry's Pass, have been severely altered and their fish fauna appears to be limited. The remaining six systems still appear to serve a viable estuarine nursery function and estuarine and estuarine-dependent marine species were a dominant component of their fish fauna.

INTRODUCTION

The 3 000 km South African coastline from the Orange River (28° 38'S; 16° 28'E) on the west (Atlantic Ocean) coast to Kosi Bay (26° 54'S; 32° 53'E) on the east (Indian Ocean) coast has some 300 aquatic systems entering the coastal zone ranging from small water bodies which are only occasionally connected to the ocean, to large permanently open systems, and coastal lakes connected to the sea via one or more narrow channels (Heydorn, 1991). Estuaries are typically shallow systems, sheltered from major wave action; they have variable temperatures, salinities, turbidities and oxygen content and are among the most productive of ecosystems on earth (Odum, 1983). By providing abundant food and shelter, estuaries are utilised by many fish species and their most important role is the provision of nursery grounds for juveniles of certain marine species, many of which are of direct or indirect commercial and recreational importance to man (Wallace *et al.*, 1984).

After reviewing the available scientific information on South African estuarine systems, Whitfield (1995) revealed that, of the 250 systems included in his appraisal, the state of information of 68% of South Africa's estuaries was "nil" (37%) or "poor (31%). The state of information of 22% was classified as "moderate" while only 10% were regarded as having "good" (7%) or "excellent" (3%) information. This paper reports on ichthyofaunal surveys conducted in False Bay on the south-west coast of South Africa during 1993 and describes aspects of water quality, presents basic fish community data, and provides an appraisal of the nursery potential of these systems for fishes.

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STUDY AREA

False Bay is a square-shaped, semi-enclosed bay situated between Cape Point and Cape Hangklip on the south-west coast of South Africa (Figure 1). It is the largest bay in South Africa and covers an area of approximately 900 km^2 with a maximum depth of 80 m at its mouth (Gründlingh & Largier, 1991). False Bay falls within the influence of the south-eastern Atlantic Ocean and surface water temperatures range between approximately 15°C in winter to about 19°C in summer (Gründlingh & Largier, 1991). The bay also experiences localised, wind-induced upwelling particularly off Cape Hangklip and to a lesser degree off Gordon's Bay (Gründlingh & Largier, 1991). The False Bay catchment is bounded by the Peninsula mountain chain to the west and the Hottentots Holland mountains to the east; much of the catchment of the northern shore is flat, comprising the Cape Flats, grading into the Tygerberg Hills and Bottelary mountains in the north (Quick, 1993). This area has an annual average rain-

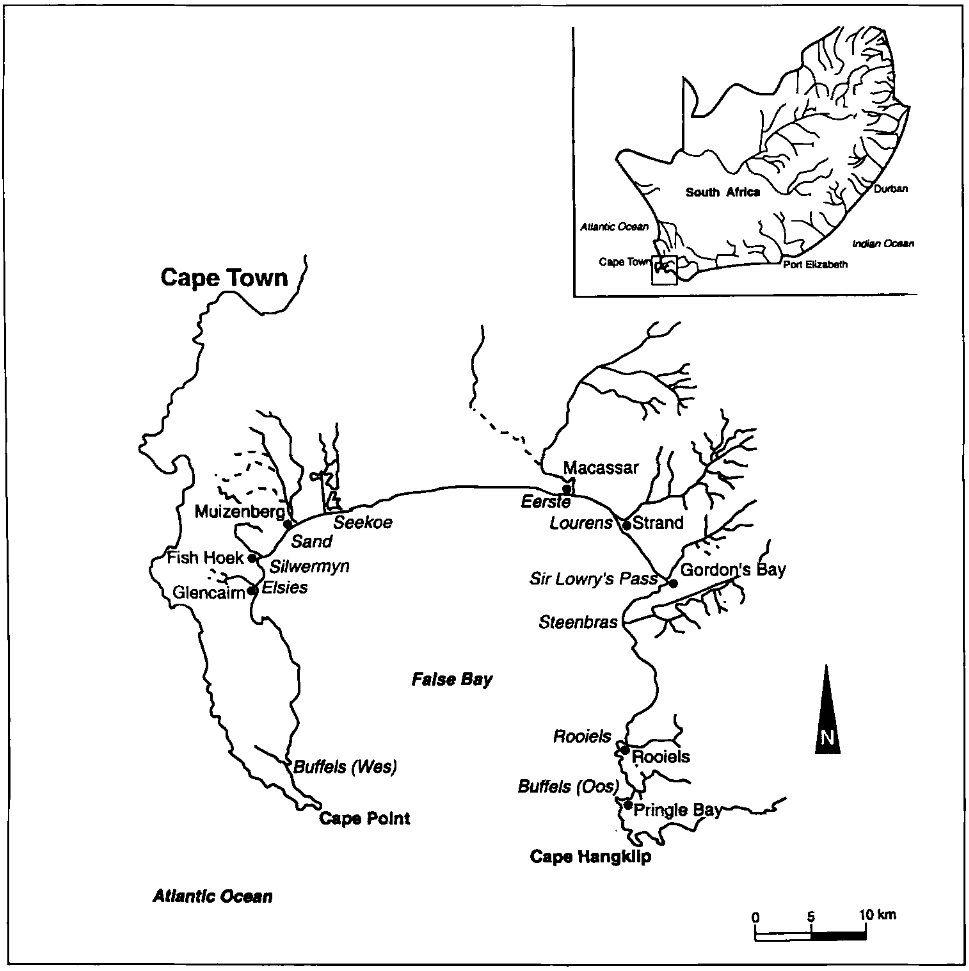

Figure 1. Map of False Bay, southwest coast of South Africa.

fall of between 500 and 1000 mm, most of which falls during winter (Heydorn & Tinley, 1980). Eleven rivers drain into False Bay and river flow is sensitive to rainfall with peak runoff occurring in winter (June- September) (Morant, 1991).

MATERIALS AND METHODS

Physico-chemical

The estuaries in False Bay were sampled during the period October to November 1993. Each system was sampled once and, depending on the size of the system, took one to three days to complete. During each survey, selected physico-chemical parameters were measured at various sites within each system. Water depth was measured using a weighted shotline graduated at 10 cm intervals. Temperature (°C), salinity (‰), conductivity (mS cm^{-1}), pH, dissolved oxygen (mg l^{-1}) and turbidity (NTU) were measured using a Horiba U-10 Water Quality Checker. Where water depth permitted, both surface and bottom waters were measured. The mouth condition of each system at the time of sampling was also noted.

Ichthyofauna

The ichthyofauna of each system was sampled using a 30 m x 1.7 m x 15 mm bar mesh seine net fitted with a 5 mm bar mesh purse and, where possible, a fleet of gill nets. Each gill net comprised three 45 mm, 75 mm and 100 mm stretch mesh monofilament panels. Each panel was 3.3 m long and 1.7 m deep, producing a 10 m by 1.7 m gill net with a range of mesh sizes. Seine netting was carried out during daylight hours and was limited to shallow (<1.5 m deep), unobstructed areas with gently sloping banks. Specimens collected in each seine net haul were immediately placed in a 20 litre plastic bucket of water. A minimum of 25 specimens of the abundant species as well as those specimens that could not be identified in the field were placed in labelled plastic bags and preserved in 10% formalin for transport to the laboratory. The remaining specimens were measured to the nearest mm standard length (SL) in the field, using a measuring board, and returned to the system. Gill netting was generally carried out in deep (>1 m) open, mid-channel waters with the nets being deployed in the evening and lifted the following morning. In most cases only the larger, deeper systems could be sampled using gill nets. Specimens collected in the gill nets were, where possible, identified in the field, measured to the nearest mm SL, using a measuring board and batch weighed to the nearest 100g using a Super Samson spring balance. Specimens that could not be identified in the field were placed in labelled plastic bags and preserved in 10% formalin for transport to the laboratory.

In the laboratory, specimens collected during the surveys were identified by reference to Smith & Heemstra (1991) and Skelton (1993). It should be noted that, due to difficulties in identifying juvenile mugilids, specimens below 50 mm SL were assumed to be *Liza richardsonii* which was the most common mullet encountered during this survey. A minimum of 25 specimens of the abundant species were measured to the nearest mm SL, using a measuring board, and weighed to the nearest 0.01g (wet mass) using a Mettler PJ 3000 balance. The remaining specimens were counted and batch weighed.

The total species composition, both by number and by mass, of the fish community within each system was calculated. The relative mass contribution of each species was calculated using actual recorded masses and masses derived from length - mass relationships presented in

Harrison & Whitfield (1995). For species not presented in Harrison & Whitfield (1995), mass was estimated from lengths by combining the data of weighed specimens from the surveys and calculating the regressions by the method of least squares.

Where appropriate, the most abundant species within each system were divided into 10 mm size classes and the percent frequency each size class made to the total catch calculated. Using information from Whitfield (1994) the species collected in each system were divided into four categories: freshwater species, estuarine species, estuarine-dependent marine species and marine species. The percent contribution made by each category to the total ichthyofaunal assemblage of each system was calculated in terms of number of species, relative abundance and relative mass.

RESULTS AND DISCUSSION

1. Buffels (Wes)

The Buffels (Wes) (34° 19′ S; 18° 28′ E) is situated on the western side of False Bay near the tip of the Cape Peninsula and falls within the Cape of Good Hope Nature Reserve. The river, which is 2.3 km long with a catchment area of 3 km^2 (NRIO, 1987), has a spring as its source and there are three small dams in the catchment (Heinecken *et al.*, 1982). At the coast the Buffels (Wes) drains into a small seasonally flooded wetland above a ridge of hummock dunes surrounding Buffels Bay (Heinecken et al., 1982; Morant, 1991).

Physico-chemical

Physico-chemical parameters were measured at two sites in the Buffels (Wes) during this survey. Site 1 was situated near the mouth while site 2 was situated approximately 50 m upstream from the mouth. The system was open at the time of sampling and was flowing out to sea. According to Heinecken *et al.* (1982) the Buffels (Wes) only flows during the winter months from May to August, and after heavy rains a small stream runs across Buffels Bay beach to the sea. Under normal circumstances, however, the marsh drains by sub-surface seepage through the dunes (Heinecken *et al.*, 1982). Due to the shallowness of the system (<0.2 m) only the surface waters were measured during this survey. Water temperatures in the system ranged between 19.4 to 21.1°C and the salinity did not exceed 0.9‰ indicating little sea water penetration. Heinecken *et al* . (1982) note that, due to the steep high energy beach configuration, the system receives little sea water input and usually serves as an overflow from the marsh behind the dunes. The Buffels (Wes) has been described as a typical brown peat-stained acid water system (Heinecken *et al.*, 1982), however, a pH of between 7.1 and 8.0 was recorded during this survey. Dissolved oxygen concentrations in the water were above 8.0 mg l^{-1} and the water in the system was clear (<10 NTU) (Table 1).

Ichthyofauna

Owing to its small size, only a single seine net haul was conducted in the Buffels (Wes). No fishes were captured during this survey. The system has been described as nothing more than a seasonal stream with no estuarine characteristics and of no importance to fish (Heinecken *et al.*, 1982; Morant, 1991).

Table 1. Physico-chemical parameters measured in False Bay estuaries, October/November 1993.

System	Site	Depth (m)	Temperature (°C)		Salinity (‰)		Conductivity ($mScm^{-1}$)		pH		Dissolved oxygen ($mg\ l^{-1}$)		Turbidity (NTU)	
			Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Buffels (Wes)	1	0.1	21.1		0.6		1.5		8.0		8.0		10.0	
	2	0.2	19.4		0.9		2.0		7.1		8.5		3.0	
Elsies	1	0.3	21.4	20.6	16.0	20.4	22.1	33.2	7.4	7.8	6.7	7.5	3.0	10.0
	2	0.7	21.4	21.3	0.4	0.4	1.0	1.0	7.7	7.6	6.1	5.6	0.0	1.0
	3	1.0	20.6	20.1	0.4	0.4	1.0	1.0	8.1	7.8	7.6	7.0	4.0	1.0
Silwermyn	1	0.4	21.7	22.8	0.7	26.9	1.6	39.0	8.2	8.4	9.4	8.5	1.0	2.0
	2	0.7	21.1	21.1	0.2	0.2	0.6	0.6	8.0	7.9	11.0	9.2	5.0	2.0
	3	0.3	20.9	21.1	0.2	0.2	0.7	0.6	7.4	7.6	9.3	8.9	1.0	3.0
Sand	1	0.4	20.9	20.8	13.7	13.7	22.7	22.6	8.0	8.0	6.5	6.3	13.0	9.0
	2	1.2	20.8	20.7	10.6	10.7	17.9	18.1	8.2	8.2	8.4	7.7	20.0	21.0
	3	2.1	20.7	20.8	9.6	9.6	16.3	16.4	7.8	8.2	9.3	9.2	27.0	27.0
Seekoe	1	0.2	21.7	21.7	0.5	0.5	1.3	1.3	8.6	8.7	11.0	10.9	21.0	32.0
	2	0.5	21.7	21.8	0.5	0.5	1.2	1.2	9.0	8.9	10.9	11.1	27.0	25.0
	3	0.8	21.2	21.2	1.6	1.6	3.4	3.3	7.7	7.7	5.0	5.0	18.0	15.0
Eerste	1	0.8	20.2	18.7	9.5	33.5	16.3	46.8	7.6	8.0	4.4	6.5	3.0	0.0
	2	2.8	20.4	18.1	2.9	32.7	5.1	49.2	7.6	7.9	2.5	4.7	3.0	5.0
	3	0.7	20.5	20.6	0.8	0.8	1.8	1.8	7.6	7.6	1.2	1.1	3.0	3.0
Lourens	1	0.4	22.3	22.5	10.5	24.2	17.7	37.1	8.7	8.4	11.6	10.3	8.0	9.0
	2	0.6	22.4	21.2	10.0	23.3	16.9	37.0	8.6	8.3	10.9	8.6	5.0	13.0
	3	0.8	23.0	22.7	10.8	12.2	18.4	20.4	8.9	9.1	13.4	19.8	7.0	22.0
Sir Lowry's	1	0.1	22.6		26.1		37.7		7.9		8.3		33.0	
	2	0.2	21.8		0.2		0.5		8.2		10.4		5.0	
Steenbras	1	0.7	19.1	18.9	32.5	33.5	49.9	51.2	8.2	8.2	9.0	8.8	4.0	4.0
	2	0.8	20.5	20.1	29.1	29.7	44.2	45.8	8.2	8.2	9.6	8.9	6.0	5.0
	3	0.7	22.2	21.6	15.1	19.4	23.8	30.4	7.9	8.1	7.7	8.5	3.0	4.0
Rooiels	1	1.2	20.1	20.3	30.6	30.8	47.3	47.2	7.3	7.8	7.6	8.1	2.0	1.0
	2	0.7	19.6	19.7	24.1	24.3	37.8	38.2	7.8	7.9	7.0	6.9	3.0	1.0
	3	1.6	20.2	19.4	25.4	32.6	40.0	49.0	7.8	8.2	7.0	8.8	1.0	2.0
Buffels (Oos)	1	0.6	18.6	18.4	18.0	27.3	28.8	38.9	7.7	7.9	7.2	7.0	1.0	0.0
	2	0.6	18.6	17.8	10.2	31.4	17.5	46.9	7.6	7.8	7.7	6.1	1.0	1.0

2. *Elsies*

The Elsies (34° 10′ S; 18° 26′ E) is situated in the north-western part of False Bay near the township of Glencairn. The river is 7.5 km long with a catchment area of 17 km^2 (NRIO, 1987). Two dams are situated in the upper catchment and below these are a few smaller weirs and low-level road crossings (Heinecken *et al.*, 1982). In its lower reaches near the coast, there is a freshwater wetland or vlei 500 m long and 200 m wide and this is largely a result of impoundment by road embankments and the construction of a small weir (Heinecken *et al.*, 1982; Morant, 1991). The area below the weir, which was previously a marshy vlei, is now a canal approximately 130 m long which drains the wetland (Heinecken *et al.*, 1982). Between the weir and the coast two road bridges and one railway bridge cross the system.

Physico-chemical

Physico-chemical parameters were measured at three sites in the Elsies. Site 1 was situated near the mouth, site 2 was approximately 100 m from the mouth, and site 3 was located in the wetland area above the weir. The mouth of the system was open at the time of this survey. Heinecken *et al.* (1982) note that sand tends to accumulate in the channel near the mouth and this is only breached after heavy rains. The river generally flows from May to November and during dry seasons the vlei often dries out leaving no free standing water (Heinecken *et al.*, 1982). At the time of this survey, the water depth of the system ranged from 0.3 m measured near the mouth to 1.0 m measured in the wetland. Water temperatures in the Elsies ranged between 20.1 and 21.4°C with surface temperatures, particularly near the mouth, being slightly higher that those recorded at the bottom. Salinities recorded near the mouth were also stratified and indicated some sea water input (16.0 - 20.4‰). Further upstream the salinities were low (0.4‰) and uniform from top to bottom. Heinecken *et al.* (1982) reports that sea water seldom flows into the Elsies canal. Although the water in the Elsies has been described as peat-stained and acid (Morant, 1991), the pH recorded during this survey was between 7.4 and 8.1. The dissolved oxygen concentration of the waters recorded during this survey ranged between 7.5 and 5.6 mg l^{-1}. The water in the Elsies was relatively clear (<10 NTU) both in the wetland and in the canal (Table 1).

Ichthyofauna

Two seine net hauls were conducted in the canal below the weir. Sampling was also conducted in the wetland and this comprised two seine net hauls and two gill nets. No fishes were captured in the wetland area during this survey and only one small (20 mm SL) *Galaxias zebratus* was captured in the canal below the weir. *Galaxias zebratus* is a small indigenous freshwater species which occurs in Cape coastal streams and rivers (Skelton, 1993). It is most likely that this specimen represents a stray that was washed over the weir from further upstream. Although Heinecken *et al.* (1982) report that numerous shoals of small fish, which were presumed to be mullet (Mugilidae), were observed in the shallows in the Elsies in October 1959, the results of this survey indicate that the system is of little value as a habitat for fishes. According to Heinecken *et al.* (1982) and Morant (1991) the Elsies is a small relatively insignificant stream, similar to the Buffels (Wes), which cannot really be classified as an estuary.

3. Silwermyn

The Silwermyn (34° 07′ S; 18° 27′ E) is located in the north-western corner of False Bay near the township of Fish Hoek. The river is 12.2 km long with a catchment area of 26 km^2 (NRIO, 1987). A reservoir is situated in the upper catchment and retains most of the run-off, particularly during the dry summer and drought periods (Heinecken, 1982a). At the coast the Silwermyn comprises a small waterbody situated at the northern end of Fish Hoek beach. Historical maps and photographs show that originally, the Silwermyn River was diverted southwards at the coast by a belt of low barrier dunes and was then joined by the old "Fish Hoek River" before entering the sea approximately 0.8 km south of the present mouth (Heinecken, 1982a). Today most of this area has been built up and the old "Fish Hoek River" has been incorporated into the town's stormwater drainage system and emerges as a drain outlet at Fish Hoek beach (Heinecken, 1982a). The fixing of the course of the Silwermyn under road and railway bridges has stabilised the position of the mouth at the northern side of Fish Hoek beach; the system also receives stormwater input from the greater part of Fish Hoek and the surrounding residential area (Heinecken, 1982a).

Physico-chemical

Physico-chemical parameters were measured at three locations in the Silwermyn. Site 1 was located near the mouth, site 2 was situated approximately 100 m from the mouth, and site 3 was situated approximately 150 m from the mouth, above the road bridge. The mouth of the system was open at the time of this survey and was flowing out to sea. The Silwermyn is connected to the sea only for very limited periods during strong river flow; during the summer low flow season the system is usually closed and a small lagoon forms at the beach (Heinecken, 1982a). The system was relatively shallow during this survey with a maximum depth of 0.7 m being recorded (Table 1).

Surface temperatures during this survey decreased upstream and ranged between 20.9 and 22.8°C with stratification evident near the mouth (Table 1). Heinecken (1982a) reports that water temperatures in the Silwermyn range from 11.9°C in winter to 25.8°C in the shallows during summer. Salinities recorded in the Silwermyn during this survey indicated limited sea water input. Salinities at the middle and upper sites were uniformly low (0.2‰) and stratification was only observed near the mouth where surface and bottom salinities were 0.7 and 26.9‰ respectively (Table 1). Heinecken (1982a) states that the Silwermyn is only tidal on rare occasions and appears to be slightly elevated above sea level which results in an almost constant flow or seepage of fresh water seaward. Salinity measurements taken in April 1982 with the mouth closed, but with evidence of overtopping of the bar at high tide, ranged from 11‰ at the seaward end of the system to 0‰ in the river channel above the road bridge (Heinecken, 1982a). Overall, salinities recorded in the Silwermyn ranged from 0.1‰ recorded during winter to 19.3‰ during the summer (Heinecken, 1982a).

The pH recorded during this survey ranged between 7.4 and 8.4 and decreased upstream from the mouth (Table 1). The higher pH recorded near the mouth is probably due to sea water influence. In April 1982 a typical marine pH value of 8.0 was recorded at the mouth while just upstream of the road bridge a value of 7.0 was recorded (Heinecken, 1982a). The waters in the catchment are acidic with a pH of 4.9 being measured in the reservoir (Heinecken, 1982a). Dissolved oxygen concentrations during this survey ranged between 8.5 and 11.0 mg l^{-1} and were higher in the surface waters (Table 1). In April 1982, oxygen levels in the lagoon seaward of the railway bridge were 90% of saturation but they dropped substantially to 26% above the road bridge (Heinecken, 1982a). The waters in the Silwermyn during this survey were relatively clear and turbidities did not exceed 5 NTU (Table 1).

Ichthyofauna

Three seine net hauls were conducted in the Silwermyn during this survey and two species of fish were captured. A total of 153 specimens with a mass of over one kilogram were captured. *Liza richardsonii* was the dominant species and accounted for 99.4% of the catch numerically and 99.9% of the species mass. *Lithognathus lithognathus* accounted for the remaining 0.7% numerically and 0.1% of the species mass (Tables 2 & 3). Surveys conducted in May and July 1982 recorded *L. richardsonii* and *Psammogobius knysnaensis* in the system (Heinecken, 1982a). Morant (1991) has suggested that the fishes recorded in the Silwermyn probably represent the remnants of a far larger species assemblage which utilised the system before human interference. Monthly seine netting in the surf zone of Fish Hoek beach during the period May 1980 to May 1981 captured a total of 20 fish species of which, 12 are dependent on estuaries to some degree (Bennett, 1989a). Overall, the dominant species included *Atherina breviceps, Lithognathus mormyrus, L. richardsonii* and *Rhabdosargus globiceps* (Bennett, 1989a). *Atherina breviceps* is regarded as an estuarine species while *L. richardsonii* and *R. globiceps* are estuarine-dependent marine species. The *L. richardsonii* captured during this survey were all juveniles below 100 mm SL and were mostly between 50 and 90 mm. Heinecken (1982a) also reported numerous juvenile mullet (*L. richardsonii* ?) between 20 and 120 mm (TL?) in the system in July 1982. The presence of juvenile *L. richardsonii* during this survey and by Heinecken (1982a) indicates that the Silwermyn may serve a limited estuarine nursery function. Furthermore, the occurrence of *P. knysnaensis* which is an estuarine species, further indicates that the system is able to support a permanent fish fauna.

4. Sand

The Sand (34° 06′ S; 18° 29′ E) is situated on the north-western shore of False Bay near Muizenberg. The system, which is also known as Sandvlei or Zandvlei, comprises a shallow basin approximately 2.5 km long and 0.5 km wide at its widest point (Day, 1981; Morant & Grindley, 1982). The Sand has a catchment area of 83 km 2 (NRIO, 1987) and the main rivers are the Keysers and Westlake rivers which enter the system through an extensive reed bed in the north-west, and the Sand River which flows into the system in the north-east (Morant & Grindley, 1982). The Sand has been subjected to many years of human modification. In 1882 a railway embankment was constructed across the north-west corner where the Keysers and Westlake rivers enter the system (Morant & Grindley, 1982; Morant, 1991). The main waterbody has been dredged to various degrees since 1948, and during the mid 1970s the Marina da Gama housing scheme was constructed on the eastern shore by cutting a series of channels adjoining the main basin (Day, 1981; Quick & Harding, 1994). Since dredging, the original gently graded shores with their fringing wetland vegetation have been replaced by steep banks which are often artificially stabilised (Morant & Grindley, 1982). A promenade, a road bridge and a foot bridge span the outlet which has been canalised; a rubble weir has also been constructed in the outlet (Morant & Grindley, 1982; Quick & Harding, 1994). The surrounding area of the Sand is heavily urbanised and the system is extensively used for recreation (Morant & Grindley, 1982).

Physico-chemical

Physico-chemical parameters were measured at three locations in the Sand. Site 1 was located near the mouth, site 2 was situated in the main waterbody, approximately 1.2 km from the mouth, and site 3 was situated near the head of the system, approximately 2.2 km from the mouth. At the time of this survey the mouth of the system was closed. The mouth of the Sand is usually open during the winter rainfall period but during summer it closes with the formation of a sandbar (Morant & Grindley, 1982; Morant, 1991; Quick & Harding, 1994). When the mouth is open, the rubble weir in the outlet channel helps maintain the water level in the system (Morant & Grindley, 1982; Morant, 1991; Quick & Harding, 1994). Day (1981) reports that the Sand is between 1.0 and 3.0 m deep, however, Morant & Grindley (1982) note that much of the system scarcely exceeds 1.0 m in depth particularly at the northern end. Harding (1994) reports that the average depth of the system is 1.4 m. The depth of the Sand during this survey ranged from 0.4 m recorded near the mouth to 2.1 m recorded at the uppermost site (Table 1).

Water temperatures recorded during this survey were fairly uniform (20.7 - 20.9°C) and showed little stratification indicating a well mixed system (Table 1). Morant & Grindley (1982) found that thermal stratification occurs infrequently in the Sand because of the shallowness of the system and good wind-induced mixing of the water. Only under calm conditions in the late autumn (May - June) do surface temperatures differ significantly from bottom temperatures (Morant & Grindley, 1982). According to Day (1981) water temperatures in the Sand vary between 12.0 and 18.0°C in winter and from 15.0 to 21.0°C in summer. Data from Morant & Grindley (1982) report surface water temperatures in the Sand ranging from 11.0 to 24.3°C and bottom water temperatures of between 12.0 and 24.2°C. Harding (1994) found that water temperatures in the Sand between March 1978 and December 1991 ranged between 8.0 and 26.0°C with maximum temperatures recorded during January and February and minimum temperatures during June and July. Clark *et al.* (1994) sampled the Sand in August and November 1991 and January and May 1992. The average temperature in the system ranged from 14.5°C in August 1991 and May 1992 to 24.0°C in January 1992 (Clark *et al.*, 1994).

The salinities recorded in the Sand during this survey decreased from 13.7‰ measured near the mouth to 9.6‰ at the uppermost site and also showed little stratification (Table 1). Day (1981) reports that the salinity in the Sand is fairly constant for most of the year and ranges from 10‰ at the head to 15‰ at the weir near the mouth except in spring when it rises to between 25 and 32‰. Data presented in Morant & Grindley (1982) report salinities of between 0.9 and 21.7‰. Harding (1994) found that mean salinity and conductivity values in the Sand were highest in the outlet channel and lowest at the northern end of the system. Mean salinities of 9 to 11‰ were recorded in the outlet channel while in the main waterbody the mean salinities were between 6 and 7‰ (Harding, 1994). Over the period March 1978 to December 1991 salinities in the Sand ranged from less than 1‰ to 34‰ with the lowest values recorded during winter and highest during summer (Harding, 1994). Morant & Grindley (1982) state that the water in the Sand is generally well mixed but salinity stratification occurs mainly in winter when the estuary mouth is open and sea water penetrates the system under the outflowing fresh water. Harding (1994) noted some stratification in the lower reaches of the Sand where the salinity of the bottom waters were 5‰ higher than at the surface. Wind-induced mixing of the water generally removed any stratification between surface and bottom waters in the middle and upper part of the system (Harding, 1994).

The pH of the waters in the Sand ranged between 7.8 and 8.2 (Table 1). According to Morant & Grindley (1982) the pH of the rivers that flow into the system tends to be circumneutral to slightly alkaline but the main waterbody is generally more alkaline. Day (1981) reports a pH of between 8.0 and 9.0 in the Sand while data in Morant & Grindley (1982) report pH values ranging between 5.9 and 9.2. Harding (1994) found that the pH of the water in the Sand ranged between 5.4 and 10.4 with the average value exceeding 8.0. Morant & Grindley (1982) suggested that the elevated pH values may be due to photosynthetic activity. Seasonal fluctuations in pH have been noted with the highest values being obtained in the late spring to early summer period (October - December) (Morant & Grindley, 1982; Harding, 1994) when dense growths of *Potamogeton pectinatus* and *Ruppia maritima* occur in the system (Day, 1981). Both aquatic grasses are "mowed" when they get too dense, however, in winter the shoots die back naturally (Day, 1981).

The dissolved oxygen of both the surface and bottom waters in the Sand increased from the mouth upstream. Surface water dissolved oxygens were slightly higher than those recorded at the bottom. Overall, the dissolved oxygen concentrations ranged between 6.3 and 9.3 mg l^{-1} (Table 1). From Morant & Grindley (1982) the dissolved oxygen concentrations in the surface waters of the Sand ranged from 2.5 to 17.0mg l^{-1} and at the bottom they ranged between 0.0 and 12.0 mg l^{-1}. Harding (1994) found that dissolved oxygen concentrations in the Sand ranged between 1.8 and 15.5 mg l^{-1} . It was suggested that the anoxic conditions are probably due to large amounts of organic matter accumulating on the bottom particularly during the winter die-back of *Potamogeton* (Morant & Grindley, 1982). Harding (1994), however, found that surface dissolved oxygen concentrations in the Sand displayed a distinct seasonality with maximum values being recorded in winter and minimum values in summer.

Both surface and bottom water turbidities increased upstream from the mouth and ranged between 9 and 27 NTU (Table 1). Harding (1994) found a similar situation where water transparencies in the Sand increased from the head of the system toward the mouth. Clark *et al.* (1994) recorded turbidities ranging from 24 NTU measured in May 1992 to 40 NTU measured in November 1991.

Ichthyofauna

Four seine net hauls and four gill nets yielded a total of 1541 specimens representing 10 species in the Sand during this survey. *Gilchristella aestuaria* was the most abundant species comprising 78.0% of the catch followed by *A. breviceps* (8.8%), *L. richardsonii* (8.7%) and Mugil cephalus (2.7%) (Table 2). Together these fishes comprised over 98% of the total catch numerically. A total species mass of over 31 kilograms was captured. *Mugil cephalus* was the dominant species comprising 65.3% of the total mass, followed by *Lichia amia* (21.7%), *L. richardsonii* (10.2%) and *G. aestuaria* (2.2%) (Table 3). Together these fishes comprised over 99% of the total species mass.

In Morant & Grindley (1982) a total of 24 species of fish have been recorded in the Sand. These included: *Amblyrhynchotes honckenii, Argyrosomus japonicus, A. breviceps, Caffrogobius nudiceps, Carassius auratus, Clinus superciliosus, Cyprinus carpio, Diplodus sargus, G. zebratus, G. aestuaria, Heteromycteris capensis, Iso natalensis, L. amia, L. lithognathus, L. richardsonii, Micropterus salmoides, Monodactylus falciformis, M. cephalus, Oreochromis mossambicus, Pomatomus saltatrix, P. knysnaensis, R. globiceps, Sandelia capensis and Syngnathus acus.* According to Morant & Grindley (1982) *L. richardsonii* and *M. cephalus* are both common in the Sand while common smaller fish include *A. breviceps,*

Table 2. Relative abundance of fishes captured in False Bay estuaries, October/November 1993.

Species	Species		Elsies		Silwermyn		Sand		Seekoe		Eerste		Lourens		Sir Lowry's Pass		Steenbras		Rooiels		Buffels (Oos)	
	n	%n	n	%n	n	%n	n	%n	n	%n	n	%n	n	%n	n	%n	n	%n	n	%n	n	%n
Amblyrhynchotes honckenii											1	0.19										
Atherina breviceps							136	8.83			7	1.35									3	1.13
Caffrogobiu nudiceps							2	0.13														
Diplodus sargus																	7	7.95				
Etrumeus whiteheadi											1	0.19										
Galaxias zebratus			1	100.00																		
Gilchristella aestuaria							1202	78.00					2	0.22			3	3.41	2	0.96		
Heteromycteris capensis							12	0.78											1	0.48		
Lichia amia							5	0.32														
Lithognathus lithognathus					1	0.65															2	0.75
Lizia dumerilii							4	0.26														
Liza richardsonii					152	99.35	134	8.70			482	92.69	876	97.65	28	93.33	55	62.5	205	98.09	219	82.64
Mugil cephalus							42	2.73			7	1.35	2	0.22								
Oncorhynchus mykiss													1	0.11								
Psammogobius knysnaensis							1	0.06			21	4.04	16	1.78	2	6.67			1	0.48	41	15.47
Rhabdosargus globiceps							3	0.19			1	0.19										
Sarpa salpa																	23	26.14				

Table 3. Relative species mass of fishes captured in False Bay estuaries, October/November 1993.

Species	Species		Elsies		Silwermyn		Sand		Seekoe		Eerste		Lourens		Sir Lowry's Pass		Steenbras		Rooiels		Buffels (Oos)	
	g	%g	g	%g	g	%g	g	%g	g	%g	g	%g	g	%g	g	%g	g	%g	g	%g	g	%g
Amblyrhynchotes honckenii											154.26	1.74										
Atherina breviceps							143.56	0.45			16.24	0.18									6.34	0.03
Caffrogobiu nudiceps							1.45	0.00														
Diplodus sargus																	2055.00	37.42				
Etrumeus whiteheadi											58.87	0.66										
Galaxias zebratus			0.07	100.00																		
Gilchristella aestuaria							682.08	2.15					2.44	0.03			6.24	0.11	1.51	0.01		
Heteromycteris capensis							5.64	0.02											0.53	0.00		
Lichia amia							6900.00	21.72														
Lithognathus lithognathus					0.70	0.06															220.10	1.16
Lizia dumerilii							69.80	0.22														
Liza richardsonii					1161.93	99.94	3223.84	10.15			4744.46	53.51	5579.40	79.97	9.21	88.64	805.41	14.67	18774.37	99.98	18659.89	98.72
Mugil cephalus							20735.00	65.27			3875.00	43.70	965.00	13.83								
Oncorhynchus mykiss													425.00	6.09								
Psammogobius knysnaensis							4.82	0.02			14.87	0.17	4.71	0.07	1.18	11.36			1.17	0.01	15.41	0.08
Rhabdosargus globiceps							1.40	0.00			4.19	0.05										
Sarpa salpa																	2625.00	47.80				

C. nudiceps, and *P. knysnaensis. Lithognathus lithognathus, R. globiceps, P. saltatrix* and *L. amia* occur in smaller numbers (Morant & Grindley, 1982). Morant (1991) provides a checklist of 28 fish species for the Sand and, apart from *A. honckenii* which is not indicated in his list, includes *Clarias gariepinus, Gambusia affinis, Rhabdosargus holubi, Solea bleekeri* and *Tilapia sparmanii* as additional species. Quick & Harding (1994) also provide a checklist of 28 fish species for the Sand, however, their list does not include *C. auratus* or *T. sparmanii* but does include *Caffrogobius multifasciatus.* A total of 15 fish species were captured in the Sand by Clark et al. (1994) during the period August 1991 to May 1992. Additional species recorded by Clark *et al.* (1994) include *Scomberoides* sp. and *L. mormyrus* and together with the occurrence of *Liza dumerilii* during this survey gives a total fish species checklist of 33 species for the system. The species composition captured in the Sand by Clark *et al.* (1994) was similar to that recorded during this survey where *G. aestuaria* (49.1%), *L. richardsonii* (42.0%), *A. breviceps* (6.8%) and *P. knysnaensis* (1.0%) were numerically dominant. A similar species assemblage also dominated the fish community of the surf zone at Muizenberg beach where, of a total of 15 species netted, *L. richardsonii* (75.6%), *A. breviceps* (20.7%), *G. aestuaria* (1.5%) and *P. saltatrix* (1.0%) were the most abundant species (Clark *et al.*, 1994).

Gilchristella aestuaria captured in the Sand during this survey ranged from 20 to 50 mm SL and were mostly in the 30-40 mm size class. *Atherina breviceps* ranged between 10 and 60 mm SL but were mostly between 30 and 50 mm. Both *G. aestuaria* and *A. breviceps* are small fish species which live and breed in estuaries and their occurrence indicates that the Sand serves a viable habitat for these species. Furthermore, the occurrence of small *A. breviceps* (10 - 20 mm) suggests recent spawning of this species. *Atherina breviceps* and *G. aestuaria* were also among the most abundant species captured in the surf zone at Muizenberg beach (Clark *et al.*, 1994), however, these individuals, particularly *A. breviceps*, were generally larger than those captured in the estuary. *Atherina breviceps* >70 mm (TL), which comprised the bulk of the surf zone sample, were poorly represented in the estuary (Clark *et al.*, 1994).

Three size classes of *L. richardsonii* were represented during this survey. The one class comprised small individuals between 50 and 70 mm SL, a second size class comprised individuals from 80 to 110 mm while a third size class comprised larger specimens between 210 and 240 mm. *Mugil cephalus* captured during this study were relatively large individuals (>170 mm SL) and it appears that at least two size classes were represented. The one size class ranged between 170 and 220 mm and were mostly between 170 and 190 mm. The second group ranged between 260 and 390 mm but most of the individuals were between 270 and 310 mm. Both *L. richardsonii* and *M. cephalus* are estuarine-dependent marine species which spawn at sea and whose juveniles utilise estuaries as nursery areas. The range of size classes represented during this survey suggests regular recruitment into the Sand indicating that the system is being utilised as a juvenile nursery area for these species. *Liza richardsonii* was also the most abundant species captured in the surf zone at Muizenberg beach by Clark *et al.* (1994). Although juveniles (<120 mm TL) were abundant in both the estuary and in the surf zone, larger individuals (>160 mm TL) were virtually absent from the estuarine samples but remained important in the surf zone (Clark *et al.*, 1994). Quick & Harding (1994) found that, although juvenile *L. richardsonii* also occur at sea, the number of juveniles found in the Sand far exceeded those recorded in the surf zone and thus the system should be regarded as valuable nursery area for this species.

Of the taxa collected in the Sand during this survey, four species (40%) live and breed in estuaries. These were *A. breviceps*, *C. nudiceps*, *G. aestuaria* and *P. knysnaensis*. The remaining six species (60%) were estuarine-dependent marine fishes represented by *H. capensis*, *L. amia*, *L. dumerilii*, *L. richardsoni*, *M. cephalus* and *R. globiceps*. Estuarine species comprised 87.0% of the total catch numerically and only 2.6% of the biomass while estuarine-dependent marine species comprised 13.0% of the total number of fishes captured and 97.4% of the total mass.

Based on the classification provided in Whitfield (1994), estuarine and estuarine-dependent marine species also dominated the fish community captured by Clark *et al.* (1994). Four (26.7%) estuarine species (*A. breviceps*, *C. multifasciatus*, *G. aestuaria* and *P. knysnaensis*) made up 56.9% of the total number of fish caught in the Sand and seven (46.7%) estuarine-dependent marine species (*L. lithognathus*, *L. richardsonii*, *M. cephalus*, *P. saltatrix*, *R. globiceps*, *Scomberoides* sp. and *S. bleekeri*) made up 43.6% of the total catch (Clark *et al.*, 1994). Three (20.0%) freshwater species (*C. carpio*, *O. mossambicus* and *T. sparmanii*) were also captured and comprised 0.4% of the catch and one marine species (*L. mormyrus*) comprised less than 0.05% to the total catch (Clark *et al.*, 1994). Of the checklist of 33 fish species reported from the Sand, nine (27.3%) are freshwater species represented by *C. auratus*, *C. carpio*, *C. gariepinus*, *G. zebratus*, *G. affinis*, *M. salmoides*, *O. mossambicus*, *S. capensis* and *T. sparmanii*. Apart from *G. zebratus* and *S. capensis* all of the remaining freshwater fishes are introduced species (Morant, 1991). A total of seven (21.2%) estuarine species have been reported from the system and these include: *A. breviceps*, *C. multifasciatus*, *C. nudiceps*, *C. superciliosus*, *G. aestuaria*, *P. knysnaensis* and *S. acus*. Fourteen (42.4%) species are estuarine-dependent marine forms represented by *A. japonicus*, *D. sargus*, *H. capensis*, *L. amia*, *L. lithognathus*, *L. dumerilii*, *L. richardsonii*, *M. falciformis*, *M. cephalus*, *P. saltatrix*, *R. globiceps*, *R. holubi*, *Scomberoides* sp. and *S. bleekeri*. The remaining three taxa (9.1%) are marine species and include: *A. honckenii*, *I. natalensis* and *L. mormyrus*.

The predominance of estuarine and estuarine-dependent marine species in indicates that the system serves a viable nursery function. Quick & Harding (1994) state that the Sand should be regarded as an important nursery area particularly for *L. lithognathus*, *L. amia*, *L. richardsonii* and *M. cephalus*, and according to Morant & Grindley (1982) the Sand is the only estuary of any significance as a fish nursery in False Bay.

5. Seekoe

The mouth of the Seekoe (34° 06′ S; 18° 30′ E) is situated on the north-western shore of False Bay. The system, which is also known as the Zeekoe, has a catchment area of 93 km^2 (NRIO, 1987) which falls mostly in the Cape Flats area (Bickerton, 1982). There are three major waterbodies in the catchment and these are Princess Vlei in the north-west, and Rondevlei and Zeekoevlei in the south. The main rivers which feed these vleis are the Southfield Canal which drains into Rondevlei via Princess Vlei and the Big Lotus and Little Lotus rivers which flow into Zeekoevlei. In their original undisturbed state Zeekoevlei and Rondevlei were connected and drained to the sea via a swampy area running from the south-eastern corner of Zeekoevlei (Bickerton, 1982). In 1942 the outflow from Zeekoevlei was modified by the construction of a weir and the drainage confined to a narrow canal, approximately 3 km in length, through the dunefields of the Cape Flats to the coast (Bickerton, 1982).

In 1958 Zeekoevlei and Rondevlei were separated; a weir was built at the south-eastern corner of Rondevlei and a canal constructed to allow the outflow to join the Seekoe canal (Bickerton, 1982). In 1962 the extensive Cape Flats Wastewater Treatment Works, situated immediately to the east of the canal near the coast, began discharging oxidation pond effluent into the system approximately 500 m upstream of the mouth (Bickerton, 1982). The section of the canal between a road bridge situated near the coast and the sea has been lined with concrete to allow the system to flow directly into the sea (Bickerton, 1982). Aerial photography in 1944 showed that before construction of the sewage works and concrete walls, the Seekoe formed a small lagoon on the eastern and sometimes also western backshore area (Bickerton, 1982).

Physico-chemical

Physico-chemical parameters were measured at three locations in the Seekoe. Site 1 was located near the mouth, site 2 was situated above the road bridge, approximately 170 m from the mouth, and site 3 was situated approximately 540 m from the mouth, near a sewage pipeline crossing. The system was open at the time of this survey and the depth ranged from 0.2 m near the mouth to 0.8 m recorded at the uppermost site (Table 1). According to Bickerton (1982), the straightening of the outlet seaward of the road bridge has resulted in the mouth being kept permanently open. However, occasionally the canal is dammed up behind a 2-3 m high beach bar which leads to the formation of a shallow longshore orientated lagoon similar to that of the Eerste to the east (Bickerton, 1982).

The system appeared well mixed and water temperatures during this survey ranged between 21.2 and 21.8°C (Table 1). Bickerton (1982) states that the lower reaches of the Seekoe are largely dominated by the effluent from the Cape Flats Wastewater Treatment Works. In June 1982 a temperature of 15.2°C was measured above the outfall where the raw sewage pipeline crosses the canal while from the outfall to the mouth, temperatures were between 12.8 and 13.0°C (Bickerton, 1982). The salinities measured in the Seekoe during this survey indicated little sea water penetration (<1.6‰) (Table 1). Bickerton (1982) notes that, because of the high elevation of the backshore above sea level, the Seekoe is non-tidal, however, salinity layering may occur in the lower reaches particularly during high spring tides.

The pH of the waters in the Seekoe during this survey ranged from 7.7 to 9.0 (Table 1). In June 1982, Bickerton (1982) recorded surface water pH values of between 7.3 and 7.6 which was the same as that of the effluent from the Cape Flats Wastewater Treatment Works. The dissolved oxygen of the waters ranged from 5.0 to 11.1 mg l^{-1} and decreased upstream from the mouth (Table 1). The dissolved oxygen in the surface waters recorded by Bickerton (1982) ranged from 5.9 mg l^{-1} to close to zero at the sewage pipeline crossing above the outfall. He suggested that the low dissolved oxygens in the upper reaches are due to sewage effluent being pushed upstream into the canal above the outfall at high tide where, because of the low flow, it becomes de-oxygenated. This probably also accounts for the lower dissolved oxygens recorded at the uppermost station during this survey. Water turbidities in the Seekoe ranged between 15 and 32 NTU (Table 1).

Ichthyofauna

Sampling in the Seekoe comprised four seine net hauls and three gill nets. No fishes were captured during this survey. Bickerton (1982) recorded only one juvenile *L. richardsonii* from surveys conducted during September 1980 and June 1982. Although Bickerton (1982) notes that the canal is apparently well stocked with the exotic freshwater fish *Gambusia affinis*, this species was not captured during his surveys or during this survey. Bickerton (1982) has suggested that the paucity of fish fauna in the Seekoe is due to the high ammonia levels in the sewage effluent entering the system. According to Bickerton (1982) fish species such as *Anguilla mossambica, L. lithognathus* and *M. cephalus* used to be common in Zeekoevlei which indicated that there must have been a direct connection to the sea and that the system was being utilised by estuarine-dependent marine species. Fishes that apparently occur in the Zeekoevlei today, however, are all introduced species and include: *Clarias gariepinus, C. carpio, M. salmoides, Myxus capensis, O. mossambicus, Tilapia rendalli* and *T. sparmanii* (Bickerton, 1982; Morant, 1991). Although historical evidence suggests that the Seekoe probably served a nursery function for fishes in the past, the results of this and previous surveys indicate that the system no longer provides a suitable habitat fishes. Both Bickerton (1982) and Morant (1991) state that the Seekoe, which effectively serves as an outfall for the Cape Flats Wastewater Treatment Works, displays no estuarine characteristics and is of little value as a fish nursery habitat.

6. Eerste

The Eerste (34° 05′ S; 18° 46′ E) is situated on the north-east shore of False Bay near the township of Macassar. The system has a catchment area of 710 km² (NRIO, 1987) which is the largest of all the systems in False Bay. The catchment of the major tributary, the Kuils River, comprises approximately 45% of the entire Eerste catchment (Morant, 1991). Early maps show the Kuils River discharging directly into False Bay, but a series of vegetated dunes forced the river to turn eastwards and join the Eerste River about four kilometres from the present mouth (Grindley, 1982). At the coast the Eerste forms a small elongated lagoon in the slack of the backshore area of the beach (Grindley, 1982). Originally the lagoon extended both to the east and west along the beach, however, the construction of a causeway in 1977 cut off the eastern arm which has now become a marshy area (Grindley, 1982). The Macassar Sewage Works lies to the west of the estuary and the system receives treated sewage effluent directly from this plant as well as indirectly from sewage works upstream on the Eerste and Kuils rivers (Grindley, 1982).

Physico-chemical

Physico-chemical parameters were measured at three locations in the Eerste. Site 1 was situated near the mouth, site 2 was located approximately 950 m from the mouth, and site 3 was situated approximately 1.4 km from the mouth. The mouth of the system was open at the time of this survey and the depth ranged between 0.7 and 2.8 m (Table 1). According to Grindley (1982), under normal conditions, the mouth of the Eerste would close in summer and break open after the first winter rains in about May, however, due to increased discharge in the river, the mouth now appears to remain open for most of the year.

Water temperatures recorded in the Eerste during this survey ranged between 18.1 and 20.6°C with some stratification evident at the lower and middles sites (Table 1). Grindley (1982) noted that surface temperatures in the Eerste in June 1982 ranged between 10 and 14°C and in December 1981 they ranged from 19 to 26°C. Clark et al. (1994) recorded average temperatures in the Eerste ranging from 12.4°C in August 1991 to 24.0°C in January 1992. The lower bottom temperatures recorded in the middle and lower stations during this survey is probably due to salinity layering with warmer fresh waters overlying cooler marine waters.

The salinities at the lower and middle stations were markedly stratified and both surface and bottom salinities decreased upstream from the mouth. Surface salinities ranged from 9.5 to 0.8‰ while at the bottom they ranged between 33.5 and 0.8‰ (Table 1). Grindley (1982) states that, because of its high elevation, the Eerste is only slightly tidal when the mouth is open. Sea water may enter the system as a result of waves overtopping the beach berm at the mouth during high spring tides (Grindley, 1982; Morant, 1991). Surface salinities measured at Low Water Spring Tide on 28 June 1982 were 0.0‰ throughout with river water flowing strongly out to sea; at High Water Spring Tide, however, waves were flooding over the sand-bar and salinities ranged from 22.0‰ at the mouth to 1.0‰ 350 m upstream (Grindley, 1982). In summer when the river flow is reduced, and if the mouth is open, the estuary may show substantial tidal penetration and if the mouth is closed, it may become hypersaline (Grindley, 1982). On 1 December 1981 surface salinities ranged from 6.0‰ in the mouth to 0.0‰ at a footbridge 1.5 km from the mouth while bottom salinities ranged from 15.0 to 2.0‰ for the same areas respectively (Grindley, 1982).

The pH of the bottom waters at the lower and middle sites were higher than those recorded at the surface during this survey and is probably a result of sea water intrusion. The pH of the surface waters were 7.6 throughout while at the bottom they ranged between 8.0 near the mouth to 7.6 at the upper site (Table 1).

The dissolved oxygen of both the surface and the bottom waters in the Eerste decreased upstream and ranged from 6.5 to 1.1 mg l^{-1} (Table 1). Dissolved oxygen concentrations recorded in summer (December 1981) ranged from 6.8 to 10.8 mg l^{-1} in the surface waters and between 4.0 and 8.5 mg l^{-1} in the bottom waters while in winter (24 June, 1982) dissolved oxygen concentrations ranged from 8.5 to 10.4 mg l^{-1} (Grindley, 1982).

The waters in the Eerste during this survey were relatively clear and turbidities did not exceed 5 NTU (Table 1). Turbidities measured by Clark *et al.* (1994) ranged from 18 NTU in August and November 1991 to 26 NTU in January 1992.

Ichthyofauna

Four seine net hauls and four gill nets yielded a total of 520 specimens representing seven taxa in the Eerste during this survey. *Liza richardsonii* was the most abundant species comprising 92.7% of the catch. *Psammogobius knysnaensis* contributed 4.0% to the catch numerically and both *A. breviceps* and *M. cephalus* each contributed 1.4% to the total (Table 2). Together these fishes comprised over 99% of the total catch numerically. A species mass of almost nine kilograms was captured. *Liza richardsonii* was the dominant species comprising 53.5% of the total mass, followed by *M. cephalus* (43.7%) and *A. honckenii* (1.7%) (Table 3). Together these fishes comprised approximately 99% of the total species mass recorded during this survey.

A survey in December 1982 recorded *H. capensis, L. richardsonii* and *P. knysnaensis* in the Eerste (Grindley, 1982). *Lichia amia* are reported to be caught in the system occasionally and sea-run rainbow trout (*Oncorhynchus mykiss*) have also been recorded in the system (Grindley, 1982). A total of 13 species were captured by Clark *et al.* (1994) with *L. richard-*

sonii (85.8%), *L. dumerilii* (6.9%), *M. cephalus* (2.7%), *G. aestuaria* (2.2%) and *P. knysnaensis* (2.0%) being the most abundant species. It is interesting to note that netting in the surf zone adjacent to the Eerste River at Macassar yielded 13 fish species of which, *L. richardsonii* (54.0%), *A. breviceps* (37.9%) and *P. saltatrix* (6.2%) were the most abundant (Clark *et al.*, 1994). All of these species depend on estuaries to some degree. Overall, a total of 17 fish species have been reported from the Eerste to date. Morant (1991) lists the five species (*H. capensis, L. richardsonii, L. amia, O. mykiss* and *P. knysnaensis*) given by Grindley (1982) and Clark *et al.* (1994) provides an additional ten species (*A. breviceps, C. gariepinus, C. carpio, G. aestuaria, L. dumerilii, L. tricuspidens, M. cephalus, P. saltatrix, R. globiceps* and *S. bleekeri*) from their study. From this survey an additional two species, *A. honckenii* and *Etrumeus whiteheadi*, were captured.

The *L. richardsonii* captured during this survey were mostly juveniles between 40 and 60 mm SL as well as a few small specimens between 10 and 30 mm. A few larger specimens (>210 mm) were also captured. A wide size range of *L. richardsonii* was also reported by Grindley (1982) with juvenile and post-larval stages ranging between 20 and 65 mm (TL?) and larger specimens between 202 and 302 mm also being captured. Grindley (1982) also reported shoals of several hundred juvenile *L. richardsonii* in the upper estuary. The high proportion of small individuals captured during this survey indicate that the Eerste is being utilised as a juvenile nursery area for this species. *Liza richardsonii* was also the dominant species captured in the adjacent surf zone (Clark *et al.*, 1994). Although juveniles were abundant in both the estuary and the surf zone, estuarine catches appeared to be restricted to specimens below 160 mm TL (Clark *et al.*, 1994). *Psammogobius knysnaensis* captured during this survey ranged from 20 to 50 mm SL and were mostly between 20 and 40 mm. Its occurrence in the Eerste indicates that the system is also a viable habitat for resident species.

Of the taxa collected during this survey, *A. breviceps* and *P. knysnaensis* are species which live and breed in estuaries. *Liza richardsonii, M. cephalus* and *R. globiceps* are estuarine-dependent marine fishes while *A. honckenii* and *E. whiteheadi* are marine species. Estuarine-dependent marine species were the dominant group of fishes and comprised 94.2% of the catch numerically and 97.3% of the mass. Estuarine species comprised 5.4% of the total catch numerically and only 0.4% of the biomass while marine species comprised 0.4% of the total numerically and 2.4% by mass.

A similar fish community structure was captured in the Eerste by Clark *et al.* (1994). Estuarine-dependent marine species, namely *L. dumerilii, L. richardsonii, L. tricuspidens, M. cephalus, P. saltatrix, H. capensis, S. bleekeri* and *R. globiceps*, comprised 95.7% of the total catch numerically while estuarine species represented by *A. breviceps, G. aestuaria* and *P. knysnaensis* comprised 4.2% of the total catch. The remaining species, *C. carpio* and *C. gariepinus*, were freshwater species and comprised less that 1% of the total catch. No marine species were captured by Clark *et al.* (1994). Of the 17 fish species that have been reported from the Eerste to date, three (17.6%) were freshwater taxa represented by: *C. gariepinus, C. carpio* and *O. mykiss*. All of these, however, are introduced species. Three taxa (17.6%) are estuarine resident fishes namely *A. breviceps, G. aestuaria* and *P. knysnaensis*. A total of nine species (52.9%) are estuarine-dependent marine species and include: *H. capensis, L. amia, L. dumerilii, L. richardsonii, L. tricuspidens, M. cephalus, P. saltatrix, R. globiceps* and *S. bleekeri*. Two species (11.8%) represented by *A. honckenii* and *E. white-*

headi, are marine fishes.

The dominance of estuarine-dependent marine species in the Eerste indicates that this system serves a viable nursery function for these fishes. Morant (1991) states that the Eerste is one of the few systems in False Bay which serves a nursery function for fishes.

7. Lourens

The Lourens (34° 06′ S; 18° 49′ E) is situated in the north-east corner of False Bay near the township of Strand. At the coast the river, which is 19.4 km long with a catchment area of 140 km^2 (NRIO, 1987), forms a small lagoon in the slack area of the backshore zone (Cliff & Grindley, 1982). Aerial photographs from 1944 to 1981 show that the Lourens has always developed a backshore lagoon with a east/west orientation and that the dimensions of the lagoon varied from 100 to 400 m long and 20 to 50 m wide (Cliff & Grindley, 1982). A factory (AECI) is situated on the northern shore of the system near the mouth and the area between the sea and a road bridge near the coast is fenced off. The system receives pollution from several sources and about 200 m below the road bridge an overflow pond for AECI effluent opens into the estuary via a culvert (Cliff & Grindley, 1982).

Physico-chemical

Physico-chemical parameters were measured at three locations in the Lourens. Site 1 was situated near the mouth, site 2 was located above the road bridge, approximately 400 m from the mouth, and site 3 was located near a pipe bridge, approximately 875 m from the mouth. The mouth of the system was open at the time of this survey and the depth ranged from 0.4 m recorded near the mouth to 0.8 m recorded at the upper site (Table 1). Cliff & Grindley (1982) report that during periods of high flow in winter, the system usually forms an overflow channel at the west end of the lagoon, however, during the dry summer season, the system occasionally closes or has only a small outflow to the sea. Monthly sampling during the period December 1981 to May 1982 revealed that the mouth of the system was open on most occasions and was only reported closed in January 1982 (Cliff & Grindley, 1982).

Water temperatures recorded in the Lourens ranged between 21.2 and 23.0°C (Table 1). The average water temperatures recorded in the system by Cliff & Grindley (1982) ranged between 27°C in December 1981 to 12°C in May 1982. Surface salinities in the Lourens were lower than those recorded at the bottom and did not exceed 10.8‰. Bottom salinities decreased from 24.2‰ near the mouth to 12.2‰ at the upper site and indicated some tidal penetration (Table 1). Cliff & Grindley (1982) found that during winter, tidal influence in the Lourens is restricted and the system is practically fresh from head to mouth, however, during the summer months, saline water may extend as far as the pipe bridge. The average salinity recorded by Cliff & Grindley (1982) ranged from 27‰ in January 1982 to less that 1‰ in May 1982. Salinities at depths greater than 1.25 m were higher than surface salinities during the summer months and it appeared that during this period the estuary may become slightly hypersaline (Cliff & Grindley, 1982).

The pH of the waters of the Lourens ranged between 8.3 and 9.1 (Table 1). The mean pH recorded by Cliff & Grindley (1982) ranged from 8.3 in December 1981 to 4.1 in March 1982, however, low pH values recorded in February (5.4) and March 1982 (4.1) were attributed to the influx of factory effluent with a pH 3.0 into the system. Cliff & Grindley (1982) found that the water in the Lourens was well oxygenated during their six month sampling period.

Dissolved oxygen concentrations and did not fall below 74% saturation and in some cases the water was supersaturated (>113%) particularly during the summer (December 1981 - January 1982) (Cliff & Grindley, 1982). The dissolved oxygen of the waters in the Lourens during this survey ranged between 8.6 and 19.8 mg l^{-1} (Table 1). The surface water turbidities were lower than those recorded at the bottom and ranged between 5 and 8 NTU. The bottom water turbidity increased upstream and ranged from 9 NTU near the mouth to 22 NTU at the uppermost site (Table 1).

Ichthyofauna

Four seine net hauls and two gill nets yielded a total of 897 specimens representing five species in the Lourens during this survey. *Liza richardsonii* was the most abundant species comprising 97.7% of the catch followed by *P. knysnaensis* (1.8%) (Table 2). Together these fishes comprised over 99% of the total catch numerically. A total species mass of nearly seven kilograms was captured. *Liza richardsonii* was the dominant species comprising 80.0% of the total mass, followed by *M. cephalus* (13.8%) and *O. mykiss* (6.1%) (Table 3). Together these fishes comprised over 99% of the total species mass.

Five species of fish were noted in the Lourens after a fish kill resulting from the discharge of raw sewage into the estuary in January 1982 (Cliff & Grindley, 1982). These included *Galeichthys feliceps*?, *L. amia, L. lithognathus, L. richardsonii* and *P. saltatrix* (Cliff & Grindley, 1982). Six fish species were reported by Cliff & Grindley (1982) during surveys conducted in January, February and May 1982 and included *A. breviceps, Glossogobius* sp., *L. amia, L. richardsonii, P. knysnaensis* and *R. globiceps*. Morant (1991) provides a checklist of eight species for the Lourens. Apart from *A. breviceps* and *Glossogobius* sp., all of the above species were included in this list together with an additional species, *H. capensis*. The results of this survey produced an additional three species (*G. aestuaria* , *M. cephalus*, and *O. mykiss*) which brings the total number of fish species recorded in the Lourens to 13.

Most of the *L. richardsonii* captured during this survey were juveniles between 10 and 60 mm SL. A few larger specimens (>130 mm) were also captured. The high proportion of small individuals captured indicate that the Lourens is being utilised as a juvenile nursery area for this species. Cliff & Grindley (1982) also observed large shoals of juvenile *L. richardsonii* (20-30 mm TL?) in the shallows of the Lourens. The *P. knysnaensis* captured during this survey ranged from 20 to 40 mm SL and were mostly in the 20-30 mm size class. Its occurrence in the Lourens indicates that this system is also a viable system for resident fishes.

Of the taxa collected during this survey, one species (*O. mykiss*) was an exotic freshwater fish, two species (*G. aestuaria* and *P. knysnaensis*) live and breed in estuaries and two species (*L. richardsonii*, and *M. cephalus*) were estuarine-dependent marine fishes. No marine fish were captured during this survey. Estuarine-dependent marine species were the dominant group of fishes and comprised 97.9% of the catch numerically and 93.8% of the mass. Freshwater species comprised only 0.1% of the total catch numerically and 6.1% of the biomass while estuarine species comprised 2.0% of the total catch numerically and 0.1% of the total mass.

Of the checklist of 13 species from the Lourens, *O. mykiss* is an introduced freshwater species. Four taxa (30.8%) are estuarine species represented by *A. breviceps, G. aestuaria, Glossogobius* sp and *P. knysnaensis*. A total of eight species (61.5%) are estuarine-dependent marine fishes. These included *G. feliceps?*, *H. capensis*, *L. amia*, *L. lithognathus*, *L. richardsonii*, *M. cephalus*, *P. saltatrix* and *R. globiceps*. No marine species have been recorded in the Lourens to date.

Although Cliff & Grindley (1982) and Morant (1991) have described the fauna in the Lourens as impoverished, they suggest that the system may still play a minor role as a fish nursery. From the results of this survey, both estuarine and estuarine-dependent marine species were represented in the Lourens with the latter group of fishes dominating the fish community. This indicates that the system serves a viable estuarine nursery function.

8. Sir Lowry's Pass

The Sir Lowry's Pass system (34° 05′ S; 18° 49′ E) enters False Bay in the north-east corner at Gordon's Bay. The river is 13.7 km long with a catchment area of 49 km^2 (NRIO, 1987). No dams have been built on the main Sir Lowry's Pass River but there are several farm dams on the tributaries and water is abstracted directly from the river for agricultural and domestic purposes (Heinecken *et al.*, 1982). In the lower reaches, near the coast, two bridges cross the system and at the beachfront the river flows under a low causeway. The last half-kilometre of the river is partially canalised before it reaches the coast where it emerges onto the beach and forms a small lagoon 80 m long and 20 m wide and approximately 0.5 m deep (Heinecken *et al.*, 1982). Aerial photographs show that in the past, when the river apparently had a stronger discharge than at present, the lagoon extended beyond its present basin with elongated backshore arms of 75 - 200 m long and 20 - 30 m wide spreading either to the west or to the east of the main lagoon pool (Heinecken *et al.*, 1982).

Physico-chemical

Physico-chemical parameters were measured at two sites in the Sir Lowry's Pass system. Site 1 was located near the mouth while site 2 was situated approximately 100 m from the mouth. The system was open at the time of this survey. Heinecken *et al.* (1982) state that although the inflow is weak during most of the year, the Sir Lowry's Pass has an almost perennial outflow in the form of a small stream meandering across the flat backshore to the rocky foreshore zone. Due to the shallowness of the system (<0.2 m), only surface measurements were taken during this survey. Water temperatures ranged between 22.6 and 21.8°C. A survey conducted in April 1982 recorded water temperatures of between 17.5 and 17.9°C (Heinecken *et al.*, 1982). Salinities recorded during this survey suggested some limited sea water input and ranged from 26.1‰ near the mouth to 0.2‰ further upstream. Heinecken *et al.* (1982) recorded salinities of 3.0‰ near the mouth and 2.5‰ above the road bridge in April 1982. The pH of the water during this survey was between 7.9 and 8.2. Heinecken *et al.* (1982) noted that, although the water was dark brown and characteristic of acid, peat-stained, mountain water, the pH values showed it to be slightly alkaline (7.3 - 8.4). This was attributed to the presence of appreciable amounts of calcium, probably released by the breakdown of granites or leached from shales from the catchment (Heinecken *et al.*, 1982). The dissolved oxygen recorded during this survey ranged between 8.3 and 10.4 mg l^{-1}. Heinecken *et al.* (1982) found that the water in the Sir Lowry's Pass system was well oxygenated and recorded values of between 9.6 and 10.6 mg l^{-1}. The turbidity during this survey decreased from 33 NTU recorded at the mouth to 5 NTU upstream (Table 1).

Ichthyofauna

Two seine net hauls yielded two species of fish, *L. richardsonii* and *P. knysnaensis* in the Sir Lowry's Pass system during this survey. A total of 30 specimens with a total mass of just over 10 grammes were captured. *Liza richardsonii* accounted for 93.3% of the catch numerically and 88.6% of the mass. *Psammogobius knysnaensis* accounted for the remaining 6.7% numerically and 11.4% of the species mass (Tables 2 & 3). Heinecken *et al.* (1982) note that, with the exception of the observation that bait collectors obtain the sand prawn *Callianassa kraussi* from the vicinity of the river mouth, nothing has been recorded on the fauna of the Sir Lowry's Pass system. All the *L. richardsonii* specimens captured during this survey were small juveniles (<30 mm SL) indicating recent recruitment. According to Morant (1991), the Sir Lowry's Pass system has no estuarine characteristics and serves mainly as a conduit for winter stream flow and stormwater run-off. The occurrence, however, of both estuarine-dependent marine species (*L. richardsonii*) and resident estuarine species (*P. knysnaensis*) indicates that the system may provide a limited habitat for these fishes.

9. Steenbras

The Steenbras (34° 12′ S; 18° 49′ E) is situated in the north-east corner of False Bay. The river is 18.7 km long with a catchment area of 74 km^2 (NRIO, 1987) and water flow to the mouth is severely restricted by two dams in the catchment (Heinecken *et al.*, 1982; Morant, 1991). At the coast the Steenbras comprises a "fjord-like" valley incised into a rocky coastal strip (Heinecken *et al.*, 1982; Morant, 1991). This tidal inlet, which is approximately 360 m long and 50 m wide, is heavily influenced by the sea and waves reach right up to the head of the system (Heinecken *et al.*, 1982).

Physico-chemical

Physico-chemical parameters were measured at three locations in the Steenbras. Site 1 was located near the road bridge at the coast, site 2 was situated approximately 70 m from the road bridge, and site 3 was situated near the head, approximately 140 m from the road bridge. The mouth of the system is permanently open and the depth did not exceed 0.8 m. Both surface and bottom water temperatures increased upstream from the mouth. Heinecken *et al.* (1982) recorded temperatures of between 17.0 and 16.6°C during a survey in April 1982. Water temperatures during this survey ranged from 18.9 to 22.2°C and were higher at the surface than those at the bottom (Table 1). This is probably due to the intrusion of cooler, more dense sea water into the system. Salinities recorded during this survey decreased upstream from the mouth and ranged between 15.1 and 33.5‰. Surface salinities were also lower than those recorded at the bottom (Table 1). At low tide in April 1982, Heinecken *et al.* (1982) recorded a salinity of 26.5‰ where the river enters the inlet and approximately 95 m upstream from this, a salinity of 1.5‰ was measured. Heinecken *et al.* (1982) found that the pH of the water in the Steenbras was variable but was low in the river indicating the acidic nature of the water flowing from the catchment. The pH of the waters of the Steenbras during this survey ranged between 7.9 and 8.2 and is probably a result of the strong sea water influence in the system (Table 1). The dissolved oxygen of the waters in the Steenbras ranged between 7.7 and 9.6 mg l^{-1} (Table 1). Heinecken *et al.* (1982) found the system to be well oxygenated with a minimum dissolved oxygen saturation of 82%. The water in the Steenbras was relatively clear with turbidities not exceeding 6 NTU (Table 1).

Ichthyofauna

One seine net haul and two gill nets yielded a total of 88 specimens representing four taxa in the Steenbras during this survey. *Liza richardsonii* was the most abundant species comprising 62.5% of the catch followed by *Sarpa salpa* (26.1%), *D. sargus* (8.0%) and *G. aestuaria* (3.4%) (Table 2). A total species mass of over five kilograms was captured in the Steenbras. *Sarpa salpa* was the dominant species comprising 47.8% of the total biomass, followed by *D. sargus* (37.4%) and *L. richardsonii* (14.7%) (Table 3). Heinecken *et al.* (1982) note that there is very little information available on the fauna from the Steenbras River mouth area.

The *L. richardsonii* captured during this survey were mostly juveniles (<80 mm SL) and were predominantly in the 20-30 mm and 50-60 mm size classes. Larger specimens from 160 to 200 mm were also represented. Sarpa salpa in the Steenbras were relatively large individuals and ranged in size from 130 to 200 mm. Both *L. richardsonii* and *S. salpa* are estuarine-dependent marine species which spawn at sea and whose juveniles utilise estuaries as nursery areas although juveniles are also found in the marine environment. The high proportion of small *L. richardsonii* individuals captured during this survey suggests that the Steenbras is being utilised as a juvenile nursery area.

Estuarine-dependent marine species represented by *L. richardsonii, S. salpa* and *D. sargus*, dominated the fish community of the Steenbras and comprised 96.6% of the catch numerically and 99.9% of the species mass. Estuarine species (*G. aestuaria*) comprised 3.4% of the total catch numerically and 0.1% of the biomass. No freshwater or marine fish were recorded in the Steenbras during this survey, however, visual observations while snorkelling noted the presence of marine species such as *Coracinus capensis* and *Diplodus cervinus* in the system. According to Heinecken *et al.* (1982) the Steenbras is of little significance as an estuary and constitutes a mountain stream entering the sea via a "fjord-like" inlet. Furthermore, Morant (1991) states that the Steenbras appears to be entirely devoid of any estuarine characteristics. The results of this survey, however, revealed that both estuarine resident and estuarine-dependent marine species dominated the ichthyofauna in the Steenbras. This suggests that the system may serve some estuarine nursery function.

10. Rooiels

The Rooiels (34° 18′ S; 18° 49′ E) is situated on the eastern shore of False Bay near the township of Rooiels. The river is 10.4 km long with a catchment area of 21 km 2 (NRIO, 1987) and at the coast, enters False Bay across a broad beach. The original river followed a course along the south side of the beach before entering False Bay, however, the construction of a road bridge and embankment across the flood plain in the 1950s forced the river to follow a course northwards to pass under the bridge and then back to its original southerly channel before entering the sea alongside a rocky point (Heinecken, 1982b; Morant, 1991).

Physico-chemical

Physico-chemical parameters were measured at three locations in the Rooiels during this survey. Site 1 was situated near the mouth, site 2 was situated approximately 450 m from the mouth, and site 3 was located approximately 600 m from the mouth, above the road bridge. The mouth of the system was open and the water depth ranged from 0.7 to 1.6 m. According to Heinecken (1982b) the broad flat beach extending from the road to the sea acts as a sandbar for the system and this is periodically overtopped by high seas or covered by river flood water (Morant, 1991). The system is generally less that 1 m deep, however, a depth of 3 m was recorded in the main channel under the bridge in December 1979 (Heinecken, 1982b). The water depth may also increase slightly when the mouth is open due to sea water pushing up into the estuary at high tide (Heinecken, 1982b).

Water temperatures in the Rooiels during this survey ranged from 19.4 to 20.3°C (Table 1). From various surveys conducted in the Rooiels (Heinecken, 1982b), surface water temperatures in the southern arm of the system above the road bridge, ranged from 15.0°C recorded in September 1958 to 20.5°C recorded in March 1981. Salinities in the Rooiels ranged from 24.1 to 32.6‰ indicating some sea water influence. Bottom water salinities were also slightly higher that those recorded at the surface (Table 1). Although Morant (1991) states that tidal interchange upstream of the bridge is almost non-existent, Heinecken (1982b) noted that tidal influence in the Rooiels extends to approximately 450 m above the road bridge. Surface water salinities recorded in the southern arm of the system above the road bridge ranged between 24‰ recorded in April 1978 to 28‰ recorded in March 1981 (Heinecken, 1982b). After winter rains the system may become totally fresh, however, in summer the water may even become hypersaline due to evaporation, low in-flow from the river and overtopping of the sandbar at high spring tide (Heinecken, 1982b). The pH of the waters during this survey ranged from 7.0 to 8.2 (Table 1). The water in the Rooiels has been described as peat-stained and acid (Morant, 1991) and a pH of between 6.4 and 6.5 has been measured above the road bridge in the southern arm of the system (Heinecken, 1982b). The dissolved oxygen of the waters during this survey ranged from 6.9 to 8.8 mg l^{-1}. The water in the Rooiels was clear with turbidities below 3 NTU (Table 1).

Ichthyofauna

Two seine net hauls and two gill nets yielded a total of 209 specimens representing four species in the Rooiels during this survey. *Liza richardsonii* was the most abundant species comprising 98.1% of the catch (Table 2). A total species mass of over 18 kilograms was captured and *L. richardsonii* comprised over 99.9% of the total biomass recorded during this survey (Table 3). From Heinecken (1982b) and Morant (1991), six species have been recorded in the Rooiels and these included: *A. breviceps, H. capensis, L. lithognathus, L. mormyrus, L. richardsonii* and *P. knysnaensis*. The addition of *G. aestuaria*, recorded during this survey, brings the total number of species recorded in the Rooiels to seven.

A range of size classes of *L. richardsonii* were represented during this survey. Small size classes comprised individuals between 10 and 30 mm SL with a few individuals between 50 and 80 mm. Larger size classes included individuals from 90 to 120 mm and specimens between 130 and 170 mm while the largest class comprised individuals between 190 and 240 mm. The wide size range captured during this survey indicates regular recruitment into the system.

Of the taxa collected in the Rooiels during this survey, *G. aestuaria* and *P. knysnaensis* were estuarine species and comprised 1.4% of the total catch numerically and less than 0.1% of the total mass. Estuarine-dependent marine species represented by *L. richardsonii* and *H. capensis* comprised 98.6% of the catch numerically and over 99.9% of the mass. No freshwater or marine species were captured during this survey. Of the seven species that have been recorded in the Rooiels to date, *A. breviceps, G. aestuaria* and *P. knysnaensis* are estuarine species while *H. capensis, L. lithognathus* and *L. richardsonii* are estuarine-dependent marine species. *Lithognathus mormyrus* is a marine species. No freshwater species have been reported to date.

The occurrence of both estuarine and estuarine-dependent marine species in the Rooiels indicates that the system serves a viable habitat for fishes. Morant (1991) states that the Rooiels plays a minor role as a fish nursery and Heinecken (1982b) described the Rooiels as a small but ecologically healthy system.

11. Buffels (Oos)

The Buffels (Oos) (34° 20′ S; 18° 50′ E) enters False Bay on its south-eastern shore at Pringle Bay. The river, which is 7.5 km long and has a catchment area of 24 km (NRIO, 1987), is dammed about 3 km upstream from its mouth (Heinecken *et al.*, 1982). At the coast the system usually comprises a small waterbody, 50 to 60 m wide and 0.5 to 1.0 m deep, situated behind a sandbar at the northern end of Pringle Bay beach (Heinecken *et al.*, 1982). A temporary backshore lagoon (up to 800 m long, 50 - 100 m wide and 0.3 m deep) sometimes forms at right angles to the river course and occasionally inundates the whole backshore slack of Pringle Bay beach (Heinecken *et al.*, 1982).

Physico-chemical

Physico-chemical parameters were measured at two sites in the Buffels (Oos) during this survey. Site 1 was situated near the mouth while site 2 was located approximately 370 m from the mouth. The mouth of the system was open and the depth did not exceed 0.6 m. The Buffels (Oos) is generally closed during the dry summer period and opens only during winter spates (Heinecken *et al.*, 1982; Morant, 1991). During winter flood conditions the water in the system rises and eventually breaches the sandbar at the northern end of the beach (Heinecken *et al.*, 1982). Excess water is sometimes also discharged through a wide shallow overflow from the backshore lagoon at the southern end of the beach, however, when the water level drops, the backshore lagoon drains and only the northern mouth remains open (Heinecken *et al.*, 1982). Rocks situated at the mouth of the system prevent the Buffels (Oos) from draining completely when it opens (Heinecken *et al.*, 1982).

Water temperatures in the Buffels (Oos) ranged from 17.8 to 18.6°C and were slightly higher at the surface than those recorded at the bottom (Table 1). Water temperatures recorded during a survey in April 1982 ranged between 16.2°C in the backshore lagoon area to 17.0°C in the main water body (Heinecken *et al.*, 1982). The slightly lower temperatures recorded at the bottom during this survey may be due to salinity layering. Surface salinities ranged between 10.2 and 18.0‰ while bottom salinities ranged between 27.3 and 31.4‰ (Table 1). Marked salinity layering was also noted by Heinecken *et al.* (1982) in December 1982 where salinities of 1‰ were measured at the surface and 14‰ were recorded at the bottom in depths of 1 m. A survey in April 1982 recorded salinities of between 24 and 20‰ at the mouth and approximately 340 m upstream of the mouth respectively suggesting a strong marine influence in the lower reaches (Heinecken *et al.*, 1982). Sea water may also enter the system when the mouth is closed by waves overtopping the beach berm during high seas (Morant, 1991).

The pH recorded during this survey ranged between 7.6 and 7.9 (Table 1). High pH values were recorded by Heinecken *et al.* (1982) in April 1982 (7.4 - 8.2) and these were attributed to a strong sea water influence in the lower reaches. The dissolved oxygen of the waters in the Buffels (Oos) ranged between 6.1 and 7.7 mg l^{-1} and were higher at the surface than those recorded at the bottom (Table 1). This is probably a result of the stratified nature of the system. Heinecken *et al.* (1982) recorded dissolved oxygen values of between 10.1 and 7.5 mg l^{-1} in April 1982. The water in the Buffels (Oos) was clear and the turbidity did not exceed 1 NTU.

Ichthyofauna

Two seine net hauls and one gill net yielded a total of 265 specimens representing four species in the Buffels (Oos) during this survey. *Liza richardsonii* and *P. knysnaensis* were the most abundant species comprising 82.6% and 15.5% of the catch respectively (Table 2). A total species mass of over 18 kilograms was captured in the Buffels (Oos) of which *L. richardsonii* comprised 98.7% (Table 3). Heinecken *et al.* (1982) reported the following taxa in the system during surveys conducted in April and December 1982: *Caffrogobius* (*nudiceps?*), *G. aestuaria*, Mugilidae (*L. richardsonii?*) and *P. knysnaensis*.

Two size groups of *L. richardsonii* were represented during this survey. One group comprised individuals between 30 and 110 mm SL with most of them being in the 40 - 50 mm and 60 - 70 mm size classes. The second group comprised individuals from 170 to 260 mm and were mostly in the 220 - 230 mm size class. The size range of *L. richardsonii* captured during this survey suggests regular recruitment into the Buffels (Oos) indicating that the system is being utilised as a nursery area for this species. Heinecken *et al.* (1982) also observed shoals of juvenile mullet (Mugilidae) the shallows near the mouth of the system in April 1982. *Psammogobius knysnaensis* captured during this survey ranged from 10 to 40 mm SL and were mostly in the 20-30 mm size class. Its occurrence in the Buffels (Oos) indicates that this system is also able to support resident fishes.

Of the taxa collected in the Buffels (Oos) during this survey, estuarine-dependent marine species represented by *L. richardsonii* and *L. lithognathus*, dominated the fish community and comprised 83.4% of the catch numerically and 99.9% of the mass. *Atherina breviceps* and *P. knysnaensis* are both estuarine species and comprised 16.6% of the total catch numerically and 0.1% of the biomass. Of the fishes recorded in the system by Heinecken *et al.* (1982), *Caffrogobius* (*nudiceps?*), *G. aestuaria* and *P. knysnaensis* are estuarine species while the only estuarine-dependent marine fishes recorded were juvenile mullet (*L. richardsonii?*).

Although limited, the results of this survey indicate that estuarine-dependent marine species dominated the fish community of the Buffels (Oos) suggesting that this system may serve a viable estuarine nursery function for these fishes. Morant (1991) also states that, although only mullet fry have been observed in the Buffels (Oos), the system may function as a fish nursery. Heinecken *et al.* (1982) noted that the fauna in the Buffels (Oos) was impoverished but as a whole it was a small but ecologically healthy system.

GENERAL DISCUSSION

Eleven systems drain into False Bay and most of these have, in one way or another been impacted and modified by human activities. The Buffels (Wes), which has the smallest catchment (3 km^2), comprises a seasonal stream which only flows during the winter and enters the sea via a small coastal marsh or wetland. The Elsies, which also has a small catchment (17 km^2), was originally similar to the Buffels (Wes) (Heinecken *et al.*, 1982; Morant, 1991) but has been transformed into a canal which discharges into the sea during the winter via an artificial wetland. Both systems appear to be of little value as a habitat for fishes.

The Sand and Seekoe are systems which drain large coastal waterbodies (Zandvlei and Zeekoevlei). The Sand has been modified through dredging and urban development (Morant & Grindley, 1982), however, it is still regarded as an important nursery area for fishes (Morant & Grindley, 1982; Morant, 1991; Quick & Harding, 1994). The Seekoe has been transformed into a narrow canal which serves largely as an outfall for treated sewage effluent (Bickerton, 1982; Morant, 1991). Although historical evidence indicates that the Seekoe and Zeekoevlei systems supported estuarine-dependent marine species (Bickerton, 1982) and thus probably served a viable nursery function, the system is now heavily degraded and is almost devoid of fish life.

The Steenbras is a unique system in False Bay in that it discharges into the sea via an incised rocky mouth. Despite the fact that this system is regarded as being of little significance as an estuary (Heinecken *et al.*, 1982; Morant, 1991), the results of this survey suggests that it may serve a limited estuarine nursery function.

The Eerste and Lourens have the largest catchments in the study area (710 and 140 km^2) and appear to be similar (Morant, 1991). The mouths of both systems are usually open throughout the year (Grindley, 1982; Cilff & Grindley, 1982) and both estuarine and estuarine-dependent marine species were well represented in these estuaries with the latter group (mostly *L. richardsonii*) dominating the fish community.

The remaining estuaries in False Bay are all relatively small systems (catchment size 21-49 km^2) which are frequently open to the sea during the winter rainy period but usually close during the dry summer season. Prior to human interference, the Silwermyn used to comprise a river mouth with an associated backshore lagoon similar to the Buffels (Oos) (Morant, 1991), however, development in the Fish Hoek area has restricted the system (Heinecken, 1982a). The Sir Lowry's Pass system also used to form a backshore lagoon at the coast but reduced discharge and partial canalisation has resulted in the system serving mainly as a channel for winter stream flow and stormwater run-off (Heinecken *et al.*, 1982; Morant, 1991). The estuarine nursery function of these two systems appears to be limited. The remaining systems, the Rooiels and Buffels (Oos) have been described as being similar (Heinecken *et al.*, 1982) although Morant (1991) suggests that the Rooiels is similar to the Lourens. Both estuarine and estuarine-dependent marine species were well represented in both the Rooiels and Buffels (Oos) suggesting a viable nursery function.

Overall the mugilid, *L. richardsonii*, was the dominant species captured in most of the systems during this survey. *Liza richardsonii* is an endemic species known only from the Kunene River in Namibia to St. Lucia in KwaZulu-Natal (Smith & Heemstra, 1991) and is less abundant in warmer waters (Day *et al.*, 1981). In the Cape *L. richardsonii* is an important commercial species (De Villiers, 1987) and in False Bay it is the most important species in the beach-seine fishery (Lamberth *et al.*, 1994). *Liza richardsonii* spawns at sea, close inshore during spring and summer (September - March) (van der Horst & Erasmus, 1981; Lasiak, 1983; Blaber, 1987; De Villiers, 1987) with recruitment of juveniles into estuaries occurring from

January to July (Day *et al.*, 1981; Blaber, 1987). Bennett (1989b) and Whitfield & Kok (1992) found that on the south-western and southern Cape coasts, recruitment of *L. richardsonii* (17-50 mm TL) into estuaries occurs throughout the year with peak immigration between November and May. Juvenile *L. richardsonii* below 60 mm SL were well represented in all of the systems during this survey indicating recent recruitment. Juvenile *L. richardsonii* have also been recorded in the inshore waters of many sheltered embayments on the Cape coast (De Villiers, 1987). Both adult and juvenile *L. richardsonii* were found in the surf zone at Fish Hoek (Bennett, 1989a) and at Muizenberg and Macassar (Clark *et al.*, 1994). Although juvenile (<120 mm TL) *L. richardsonii* were abundant both in estuaries and the adjacent surf zone in False Bay, larger individuals (>160 mm TL) were virtually absent from the estuaries but remained important in the surf zone (Clark *et al.*, 1994).

Mugil cephalus also made significant contribution, particularly in terms of biomass, to the ichthyofauna of the Sand, Eerste and Lourens systems. *Mugil cephalus* is a circumglobal mullet species found in all warm and temperate seas, rivers and estuaries (Smith & Heemstra, 1991). It spawns in the shallow inshore marine environment between May and September (Wallace, 1975) with recruitment of juveniles (<40 mm TL) into estuaries occurring from June to October (Wallace & van der Elst, 1975; Bok, 1979; Blaber, 1987). Recruitment of juveniles (<40 mm TL) into estuaries on the southern coast of South Africa occurs from August to December, with a peak during September to November (Whitfield & Kok, 1992) while in the south-western Cape juvenile *M. cephalus* (20 - 50 mm TL) recruited into estuaries from September to October and in March (Bennett, 1989b). No juvenile (<50 mm SL) *M. cephalus* were captured during this survey indicating that either recruitment had not yet taken place into these systems or was not yet evident.

Psammogobius knysnaensis was numerically an important component of the fish fauna of the Eerste, Lourens and Buffels (Oos). *Psammogobius knysnaensis* is an estuarine species which is endemic to southern Africa, ranging from Port Nolloth to KwaZulu-Natal (Smith & Heemstra, 1991). It matures at a length of 37 mm TL and breeds mainly during the spring and summer (September - February) (Bennett, 1989b). Spawning takes place within estuaries, however, the larvae are carried passively out to sea by the ebb tide, and later return to estuaries as postlarvae (Beckley, 1985; Whitfield, 1989). Adult *P. knysnaensis* have not been recorded from the surf zone in False Bay (Bennett, 1989a; Clark *et al.*, 1994) but their occurrence in most of the systems during this survey suggests that these systems may represent important habitats for this species.

Other relatively important estuarine species captured during this survey were *A. breviceps* and *G. aestuaria*. *Gilchristella aestuaria* is a small shoaling species which is endemic to southern Africa occurring in estuaries, coastal lakes and rivers from the Kosi system in KwaZulu-Natal to the Orange River on the west coast (Smith & Heemstra, 1991). *Gilchristella aestuaria* spawns in estuaries throughout the year with a peak in spring and early summer (August - March) (Blaber, 1979; Talbot, 1982; Ratte, 1989). To reduce the loss of eggs and fry to the marine environment, *G. aestuaria* spawns in the upper reaches of estuaries and as the larvae grow, their distribution extends toward the mouth (Melville-Smith & Baird, 1980; Talbot 1982). *Atherina breviceps* is also a small shoaling species which is endemic to southern Africa and is found from Luderitz, Namibia to northern KwaZulu-Natal (Smith & Heemstra, 1991) but is mostly found in cooler waters (Day *et al.* 1981). It is an estuarine species with spawning taking place throughout the spring and summer with a peak in September to January (Melville-Smith & Baird, 1980; Ratte, 1989). The eggs have adhesive filaments and are attached to submerged plants and other objects (Neira *et al.*, 1988). *Atherina breviceps* and *G. aestuaria* have also been captured in the surf zone in False Bay but these were mostly adults with the juveniles being centred in estuaries (Bennett, 1989a; Clark *et al.*, 1994).

It is interesting to note that the dominant fishes recorded in False Bay estuaries were also among the dominant species found in the surf zone of False Bay (Bennett, 1989a; Clark *et al.*, 1994). Clark *et al.* (1994) found that although the estuarine and adjacent surf zone ichthyofaunal assemblages in False Bay were similar, fish densities in the estuaries were almost an order of magnitude greater than in the surf zone. This serves to emphasise the importance of these systems as fish nursery areas.

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REFERENCES

BECKLEY, L. E. 1985. Tidal exchange of ichthyoplankton in the Swartkops estuary mouth, South Africa. *South African Journal of Zoology* **20**: 15-20

BENNETT, B. A. 1989a. The fish community of a moderately exposed beach on the southwestern Cape coast of South Africa and an assessment of this habitat as a nursery for juvenile fish. *Estuarine, Coastal and Shelf Science*. **28**: 293-305.

BENNETT, B. A. 1989b. A comparison of the fish communities in nearby permanently open, seasonally closed and normally closed estuaries in the south-western Cape, South Africa. *South African Journal of Marine Science* **8**: 43-55.

BICKERTON, I. B. 1982. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 15: Zeekoe (CSW 5). Stellenbosch. *CSIR Research Report* **414** . 54 pp.

BLABER, S. J. M. 1979. The biology of filter feeding teleosts in Lake St Lucia, Zululand. *Journal of Fish Biology* **15**: 37-59.

BLABER, S. J. M. 1987. Factors affecting recruitment and survival of mugilids in estuaries and coastal waters of south-eastern Africa. *American Fisheries Society Symposium* **1**: 507-518.

BOK, A. H. 1979. The distribution and ecology of two mullet species in some fresh water rivers in the eastern Cape. *Journal of the Limnological Society of Southern Africa*. **5**: 97-102.

CLARK. B. M., BENNETT, B. A. & LAMBERTH, S. J. 1994. A comparison of the ichthyofauna of two estuaries and their adjacent surf zones, with an assessment of the effects of beach-seining on the nursery function of estuaries for fish. *South African Journal of Marine Science*. **14**: 121-131.

CLIFF, S. & GRINDLEY, J. R. 1982. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 17: Lourens (CSW 7). Stellenbosch. *CSIR Research Report* **416**. 39 pp.

DAY, J. H. 1981. Summaries of current knowledge of 43 estuaries in southern Africa. In Day, J. H. (Ed) *Estuarine ecology with particular reference to southern Africa*. A.A. Balkema, Cape Town. 251-329.

DAY, J. H., BLABER, S. J. M. & WALLACE, J. H. 1981. Estuarine fishes. In Day, J. H. (Ed) *Estuarine ecology with particular reference to southern Africa*. A.A. Balkema, Cape Town. 197-221.

De Villiers, G. 1987. Harvesting harders *Liza richardsonii* in the Benguela upwelling region. In Payne, A. I. L., Gulland, J. A. & Brink, K. H. (Eds) *The Benguela and Comparable Ecosystems. South African Journal of Marine Science* **5**: 851-862.

Grindley, J. R. 1982. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 16: Eerste (CSW 6). Stellenbosch. *CSIR Research Report* **415**. 51 pp.

Gründling, M. L. & Largier, J. L. 1991. Physical oceanography of False Bay: a review. *Transactions of the Royal Society of South Africa* **47**: 387-399.

Harding, W. R. 1994. Water quality trends and the influence of salinity in a highly regulated estuary near Cape Town, South Africa. *South African Journal of Science* **90**: 240-6.

Harrison, T. D. & Whitfield, A. K. 1995. Fish community structure in three temporarily open/closed estuaries on the Natal coast. *Ichthyological Bulletin of the J.L.B. Smith Institute of Ichthyology* **64**: 1-80.

Heinecken, T. J. E. 1982a. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 13: Silvermine (CSW 3). Stellenbosch. *CSIR Research Report* **412**. 43 pp.

Heinecken, T. J. E. 1982b. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 8: Rooiels (CSW 10). Stellenbosch. *CSIR Research Report* **407**. 35 pp.

Heinecken, T. J. E., Bickerton, I. B. & Morant, P. D. 1982. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 12: Buffels (Wes) (CW 1), Elsies (CSW 2), Sir Lowry's Pass (CSW 8), Steenbras (CSW 9) and Buffels (Oos) (CSW 11). Stellenbosch. *CSIR Research Report* **411**. 72 pp.

Heydorn, A. E. F. 1991. The conservation status of southern African estuaries. In Huntley, B.J. (Ed) *Biotic Diversity in Southern Africa. Concepts and Conservation.* Oxford University Press, Cape Town. 290-297.

Heydorn, A. E. F. & Tinley, K. L. 1980. Estuaries of the Cape, Part I: Synopsis of the Cape coast. Natural features, dynamics and utilization. Stellenbosch. *CSIR Research Report* **380**: 1-97.

Lamberth, S. J., Bennett, B. A. & Clark. B. M. 1994. Catch composition of the commercial beach-seine fishery in False Bay, South Africa. *South African Journal of Marine Science.* **14**: 69-78.

Lasiak, T. A. 1983. Aspects of the reproductive biology of the southern mullet, *Liza richardsoni*, from Algoa Bay, South Africa. *South African Journal of Zoology* **18**: 89-95.

Melville-Smith, R. & Baird, D. 1980. Abundance, distribution and species composition of fish larvae in the Swartkops estuary. *South African Journal of Zoology* **15**: 72-78.

Morant, P. D. 1991. The estuaries of False Bay. *Transactions of the Royal Society of South Africa* **47**: 629-640.

Morant, P. D. & Grindley, J. R. 1982. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 14: Sand (CSW 4). Stellenbosch. *CSIR Research Report* **413**. 70 pp.

Neira, F. J., Beckley, L. E. & Whitfield, A. K. 1988. Larval development of the Cape silverside, *Atherina breviceps* Cuv. & Val., 1835 (Teleostei, Atherinidae) from southern Africa. *South African Journal of Zoology* **23**: 176-183.

NRIO, 1987. Basic physical geography/hydro data for "estuaries" of the south-western Cape (CW 1-26). CSIR, Stellenbosch. *NRIO Data Report D* **8705**. 13 pp.

Odum, E. P. 1983. *Basic Ecology.* Saunders College Publishing, Holt-Saunders, Japan. 613 pp.

Quick, A. J. R. 1993. An holistic approach to the management of water quality in False Bay, Cape Town, South Africa. *Southern African Journal of Aquatic Sciences.* **19**: 50-73.

Quick, A. J. R. & Harding, W. R. 1994. Management of a shallow estuarine lake for recreation and as a fish nursery: Zandvlei, Cape Town, South Africa. *Water SA.* **20**: 289-297.

Ratte, T. W. 1989. Population structure, production, growth, reproduction and the ecology of *Atherina breviceps* Valenciennes, 1935 (Pisces: Atherinidae) and *Gilchristella aestuaria* (Gilchrist, 1914) (Pisces: Clupeidae), from two southern Cape coastal lakes. PhD. thesis, University of Port Elizabeth, South Africa. 332 pp.

Skelton, P. H. 1993. *A Complete Guide to the Freshwater Fishes of Southern Africa.* Southern Book Publishers, Halfway House. 388 pp.

Smith, M. M. & Heemstra, P. C. 1991. *Smiths' Sea Fishes.* Southern Book Publishers, Johannesburg. 1048 pp.

Talbot, M. M. J-F. 1982. Aspects of the ecology and biology of *Gilchristella aestuarius* (G & T) (Pisces: Clupeidae) in the Swartkops estuary, Port Elizabeth. MSc thesis, University of Port Elizabeth, South Africa. 128 pp.

Van der Horst, G. & Erasmus, T. 1981. Spawning time and spawning grounds of mullet with special reference to *Liza dumerili* (Steindachner, 1869). *South African Journal of Science* **77**: 73-78.

Wallace, J. H. 1975. The estuarine fishes of the east coast of South Africa. III. Reproduction. *Investigational Report of the Oceanographic Research Institute.* **41**: 1-51.

Wallace, J. H. & Van der Elst, R. P. 1975. The estuarine fishes of the east coast of South Africa. IV. Occurrence of juveniles in estuaries. V. Ecology, estuarine dependence and status. *Investigational Report of the Oceanographic Research Institute.* **42**: 1-63.

Wallace, J. H., Kok, H. M., Beckley, L. E., Bennett, B., Blaber, S. J. M. & Whitfield A. K., 1984. South African estuaries and their importance to fishes. *South African Journal of Science* **80**: 203-207.

Whitfield, A. K. 1989. Ichthyoplankton interchange in the mouth region of a southern African estuary. *Marine Ecology Progress Series.* **54**: 25-33.

WHITFIELD, A. K. 1994. An estuary-association classification for the fishes of southern Africa. *South African Journal of Science* **90**: 411-417.

WHITFIELD, A. K. 1995. Available scientific information on individual South African estuarine systems. *Water Research Commission Report*. **577/1/95**. 204 pp.

WHITFIELD, A. K. & KOK, H. M. 1992. Recruitment of juvenile marine fishes into permanently open and seasonally open estuarine systems on the southern coast of South Africa. *Ichthyological Bulletin of the J.L.B. Smith Institute of Ichthyology* **57**: 1-39.