A comparison of the ichthyofaunas in two permanently open eastern Cape estuaries

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The Kowie and Great Fish estuaries are situated less than 30 km apart, yet they differ considerably in terms of riverine inflow, turbidity, food resources and habitat availability. The ichthyofauna of the two estuaries were sampled using plankton, seine and gill nets. A greater ichthyofaunal richness (R) was recorded in the Kowie estuary and this is attributed to the wider range of habitats and greater degree of marine influence in this system. In contrast, all three sampling gears revealed an approximate 3:1 ratio between fish abundance in the Great Fish and Kowie estuaries. The higher abundance of fishes in the Great Fish estuary is partly attributed to the large organic and nutrient inputs into this system when compared with the Kowie system, and the influence of these inputs on estuarine primary and secondary production. Individual fish species are affected differently by turbid water conditions. Indications from this study were that piscivorous fishes (e.g. *Lichia amia*) which rely mainly on visual foraging methods were adversely affected by the high turbidity conditions within the Great Fish estuary, whereas piscivores (e.g. *Argyrosomus hololepidotus*) which rely mainly on non-visual methods were unaffected. Macrobenthic predators (e.g. *Pomadasys commersonnii*) and detritivorous fish species (e.g. *Mugil cephalus*) also appear to be unaffected by high suspensoid levels and were usually more abundant in the Great Fish than in the Kowie estuary. The length-frequency distributions of some of the dominant fish species occurring in both estuaries are presented.

Die Kowie en Groot Vis riviermondings is minder as 30 km van mekaar af geleë, maar verskil aansienlik in terme van varswaterinvloei, watertroebelheid, voedselbronne en beskikbare habitat. Die visfauna van die twee riviermondings was met plankton, trek en kiefnette gemonster. 'n Hoër visspesiesrykheid (R) is in die Kowie riviermond vasgestel en dit word toegeskryf aan die groter habitat verskeidenheid en groter see invloed op die sisteem. In teenstelling het al drie moniteringsmetodes 'n ongeveer 3:1 verhouding tussen visgetalle in die Groot Vis en Kowie riviermondings aangetoon. Die groter aantal visse in die Groot Vis riviermonding word deelteliks toegeskryf aan die groot hoeveelheid organiese en voedingstoevoegings tot hierdie sisteem in vergelyking met die Kowie sisteem, en die invloed van hierdie toevoegings tot primêre en sekondêre produktiwiteit. Sommige visspesies word deur watertroebelheid aangetas. Afleidings van hierdie studie dui daarop dat visvretende visse (b.v. *Lichia amia*), wat hoofsaaklik op visuele metodes aangewys is, meer negatief deur troebelheid in die Groot Vis riviermonding beïnvloed word, terwyl visvreters (b.v. *Argyrosomus hololepidotus*), wat hoofsaaklik nie-visuele metodes gebruik, nie aangetas is nie. Bodemroofvisse (b.v. *Pomadasys commersonnii*) en detritus-vretende visspesies (b.v. *Mugil cephalus*) word klaarblyklik nie deur hoë troebelheid aangetas nie, en was gewoonlik meer talryk in die Groot Vis riviermonding. Die lengte-frekwensie verspreiding van die belangrikste visspesies wat in beide riviermondings voorkom, word ook aangetoon.

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The Great Fish and Kowie estuaries are permanently open systems situated 25 km apart on the eastern Cape coast (Figure 1). The fish communities of both estuaries are not well known, with published information being limited to preliminary lists of fishes which have been caught by anglers. Day (1981) does not document any fishes from the Great Fish estuary and lists only five species (*Rhabdosargus holubi, Lithognathus lithognathus, Pomadasys commersonnii, Gilchristella aestuaria* and *Atherina breviceps*) from the Kowie estuary, with the comment that a scientific survey would reveal many more. In this paper we compare the ichthyofaunas of these two contrasting estuaries using information from three separate but comparable studies. Each study covers a different size component of the fish assemblage, thus providing a more complete understanding of fish community structure in these systems.

Study areas

Great Fish estuary

The permanently open Great Fish estuary (33°30′S; 27°08′E) is about 12 km in length with an absence of extensive sand or mudflats, except in the lower reaches where parts of the delta are exposed at low tide. The estuary channel is narrow (30–100 m wide) and its depth (0,5–3,5 m) is dependent on river flood events. The catchment yields a large fluvial sediment load to the estuary which results in a shallowing of the system, particularly in the upper and middle reaches. During episodic floods these sediments are flushed out to sea but are then gradually replaced during periods of low river discharge by predominantly sand deposits in the upper reaches and mud in the

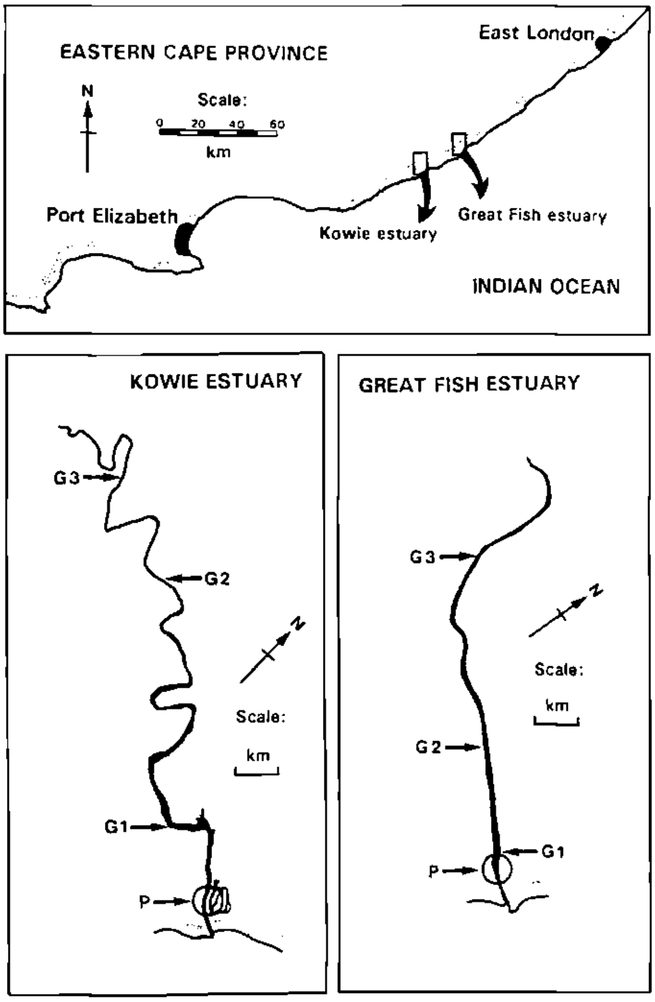

Figure 1 Map showing the locality of the Kowie and Great Fish estuaries on the eastern Cape coast. The gill net (G) and plankton net (P) sampling sites are also indicated.

lower reaches (Reddering & Esterhuysen 1982). Sand deposits predominate in the mouth region of the estuary.

Spring tidal range is between 1 m and 1,5 m in the lower reaches, decreasing up the system. The spring tidal prism averages about $1,6 \times 10^6$ m^3, with the tidal prism volume exceeding river water volume by only six times during an average tidal cycle (Allanson & Read 1987). Water depth in the estuary mouth channel is usually between 2 m and 3,5 m at spring high tide.

The Great Fish River has a high pH (mean = 8,5) and alkalinity (mean = 296 p.p.m. $CaCO_3$), and the water is turbid with a mean Secchi disc transparency ranging from 10–15 cm (Bok 1983). The conductivity of the river water is also high (mean = 3150 μMHOS cm^{-1}) with chlorides (Cl) averaging 500 p.p.m. (Bok 1983). During periods of low river flow the water has a green-brown colour, indicating high phytoplankton concentrations. The mean annual river discharge is about 224×10^6 m^3. Oligohaline conditions (0,5–5 g kg^{-1}) prevail in the upper reaches, mesohaline conditions (5,1–18 g kg^{-1}) in the middle reaches and polyhaline conditions (18,1–35 g kg^{-1}) in the lower reaches. Salinity stratification is often strongly developed in the lower and middle reaches of the estuary. During periods of high river discharge oligohaline conditions extend into the lower reaches of the estuary, with turbid silt-laden waters penetrating many kilometres out to sea. High tide water temperatures (0,5 m below the surface) recorded in the lower estuary channel ranged from 13–21°C and those in the upper reaches from 11–26°C.

Aquatic macrophytic vegetation in the Great Fish estuary comprises mainly *Phragmites australis* beds in the upper and middle reaches, with a total lack of submerged estuarine plants such as *Zostera* or *Ruppia*. Supratidal salt marshes occur in the lower reaches but are only inundated during periods of high river discharge and/or exceptionally high spring tides.

Kowie estuary

The Kowie estuary (33°36'S; 26°54'E) is about 21 km in length and varies in width between 30 m and 150 m. The Kowie River normally carries a low silt load and the estuary channel ranges in depth from 2–8 m (Heinecken & Grindley 1982). The upper reaches have steep banks, often vegetated right down to the water's edge. This section of the estuary has a bottom comprising mainly very fine sand and silt, and has a very narrow intertidal zone (<10 m wide). The middle reaches broaden out (about 100 m in width and 3 m deep in the channel) with an estuary bottom consisting mainly of sand. Intertidal salt marshes and mud banks >50 m wide are found in some areas. The lower reaches consist of an artificial channel about 80 m wide, linked to the Kowie marina which covers an area of 45 ha. The channel and marina canals have walls comprising granite blocks which drop almost vertically to a sandy bottom 2–4 m deep. A large mud flat and salt marsh occur in the 'Bay of Biscay' area of the lower reaches. Intertidal mud banks exceeding 100 m in width are present in the lower reaches.

The permanently open Kowie estuary is tidal for 20,8 km. Spring tidal range in the upper reaches is about 1,1 m, middle reaches 1,5 m and lower reaches 1,7 m (Day 1981). Water depths in the estuary mouth channel are usually between 2,7 m and 6,0 m at spring high tide (Heinecken & Grindley 1982). Strong tidal water currents have been recorded in the Kowie estuary, with ebb current speeds of 12–20 cm s^{-1} recorded in the upper reaches (Day 1981). A very strong flow (>2 m s^{-1}) occurs in the lower reaches of the estuary if river floods coincide with an outgoing spring tide (Heinecken & Grindley 1982). Episodic river floods in excess of 1000 m^3s^{-1} have been recorded at the Wolfscrag gauging station on the Kowie River.

The Kowie River has a high pH (mean = 8,2) and alkalinity (mean = 139–185 p.p.m. $CaCO_3$), and the water is usually clear with a mean Secchi disc transparency ranging from 71–103 cm and maximum values up to 250 cm (Bok 1983). Light penetration is limited however, as the river water is stained a clear brown by dissolved organic material. Algal blooms have not been recorded in the Kowie River system (Bok 1983). The estimated mean annual river discharge, excluding major flood events, is 20×10^6 m^3. River water entering the Kowie estuary during low flow conditions is brackish, ranging in salinity from 2–6 g kg^{-1} (Heinecken & Grindley 1982). Salinities in the estuary are usually above 30 g kg^{-1} and may increase to 40 g kg^{-1} in dry years (Day 1981). During prolonged river floods, the surface water of the whole estuary is almost fresh although sea-water may be present in the mouth region. Salinity stratification, following flood events, is often strongly developed in the lower and middle reaches of the estuary, e.g. after a flood in June 1967; Hill (1967) recorded salinity differences of up to 20 g kg^{-1} between values at the surface and at 2,5 m. Seasonal water temperatures recorded in the mouth region range from 14–22°C, while in the upper reaches it is 11–27°C (Day 1981).

Aquatic macrophytic vegetation in the Kowie estuary comprises mainly *Ruppia* spp. and *Phragmites australis* in the upper reaches, with *Zostera capensis* and various salt marsh plants (e.g. *Spartina maritima*, *Chenolea diffusa* and *Sarcocornia perennis*) dominating in the middle and lower reaches. Filamentous green and red algae are sometimes abundant in littoral areas of the lower estuary.

Materials and Methods

Physical-chemical environment

Monthly surface and bottom salinity, temperature and water transparency were measured at high and low tide at the three gill net sites on the Great Fish and Kowie estuaries (Figure 1). Water temperature was measured with a mercury thermometer, salinity with an optical salinometer and water transparency with a 20-cm diameter Secchi disc. Bottom water samples were obtained using a Hach oxygen sampling bottle. Near surface salinity, temperature and water transparency were also measured at each seine net sampling site.

A minimum of six near surface salinity, temperature and turbidity measurements were conducted on water samples collected during each ichthyoplankton sampling session in the mouth region of the Kowie and Great Fish estuaries (Figure 1). Water turbidity was measured in nephelometric turbidity units (NTU) using a Hach Model 2100A turbidimeter. Details of river flow into each of the estuaries was obtained from the Department of Water Affairs & Forestry gauging stations P4H001 (Kowie River) and Q9H018 (Great Fish River).

Life history categories

For the purposes of this study the fish fauna of the Great Fish and Kowie estuaries is divided into four major categories, viz. marine migrants, marine transients, estuarine spawners and freshwater opportunists. Marine migrants are those euryhaline species which are spawned at sea but use estuaries as nursery and/or foraging areas. Marine transients are usually stenohaline species which are spawned at sea but may enter the lower reaches of some estuaries. Estuarine spawners are euryhaline species of marine origin which breed in estuaries. Freshwater opportunists are euryhaline species which enter estuaries from inflowing rivers and use the systems as nursery and/or foraging areas. All scientific nomenclature in this paper follows that given by Smith & Heemstra (1991).

Plankton net sampling

This method sampled mainly larval and post-larval fishes <20 mm BL. Quarterly sampling (December 1989 – September 1990) of larval and juvenile fishes was conducted at high tide in the mouth region of the Great Fish and Kowie estuaries (Figure 1). The estuaries were sampled on consecutive nights to minimize tidal cycle differences between the estuaries. A 75-cm diameter WP2 plankton net (500-µm aperture mesh) fitted with a calibrated digital flowmeter was used to sample ichthyoplankton in the channel surface waters of each estuary. A minimum of 10 samples was collected from each system, commencing about 30 min after dark and collection was timed to coincide with the high tide wherever possible. The net was attached to a boom fitted on the bow of a flat-bottomed boat equipped with a 35 hp outboard engine. The net was towed alongside the boat for 2–3 min at a speed of about 1–2 knots and the upper 75 cm of the water column was sampled. After each tow, flowmeter readings were recorded and the sample was immediately preserved in 5% buffered formalin. The volume of water filtered by the plankton net ranged between 50 and 100 m^3 per sample. Fish captured in the above net were designated as ichthyoplankton.

Water temperatures were determined *in situ* at the time of sampling using a calibrated electronic thermometer, but salinity and turbidity samples were collected in glass containers for subsequent laboratory analysis. Since all fish were sampled in the upper metre of the water column, all physical-chemical measurements were recorded at 0,5 m below the water surface. In addition, a series of 10 stations (Figure 1) were used to characterize the physical environment in each estuary on each sampling occasion. Once again each system was sampled at a similar phase of the tidal cycle to ensure comparability of the data.

In the laboratory, each ichthyoplankton sample was decanted into a counting tray and sorted using a stereo microscope, following the procedure described by Richards & Berry (1973). All fish were identified to the lowest possible taxon using references given in Harrison & Whitfield (1990). Each fish was measured to the nearest 0,1-mm body length (BL), which represents notochord length in preflexion larvae and standard length in postflexion larvae/juveniles. Densities of ichthyoplankton were standardized to represent the mean number per 100 m^3 of water filtered.

Seine net sampling

This method sampled mainly smaller fishes <200-mm total length (TL). A purse seine net (30 m long × 2 m deep with a 6-mm bar mesh in the bag) was used in the lower, middle and upper reaches of the Great Fish and Kowie estuaries. The gear was selected so that a variety of littoral habitats could be sampled. Netting was conducted quarterly, during daylight hours, between February 1981 and February 1982. The sampling procedure during netting operations was standardized as far as possible and a similar number of seine net samples was collected in each estuary during each season.

Large individuals in the catches were identified and measured to the nearest mm total length (TL) in the field. Small individuals (<50-mm TL) were immediately preserved in 10% formalin for analysis in the laboratory. Catch per unit effort (CPUE) is expressed in terms of the average number of fish captured per 10 purse seine net hauls, and formed the basis of comparisons between the relative abundance of fishes in the Great Fish and Kowie estuaries. The species richness (R) of seine net catches

Table 1 Physical-chemical conditions recorded at gill net sites in the Kowie estuary during 1981

Kowie estuary		Lower reaches Surface	Lower reaches Bottom	Middle reaches Surface	Middle reaches Bottom	Upper reaches Surface	Upper reaches Bottom
Salinity (g kg^{-1})	Mean	25,8	27,5	9,8	13,5	3,5	2,6
	SD	8,7	6,8	7,6	5,8	4,8	1,9
	Range	11–35	15–35	2–30	1–21	1–18	0–5
Temperature (°C)	Mean	18,6	17,3	19,4	18,6	19,1	17,9
	SD	3,3	2,5	4,5	3,8	4,8	4,2
	Range	13–23	14–22	12–25	19–23	11–25	12–24
Secchi (cm)	Mean	110,6		62,6		49,8	
	SD	34,7		32,0		26,7	
	Range	72–175		28–143		9–88	

in each of the estuaries was calculated from the formula R = (s – 1)/log$_e$ N, where s is the number of species and N is the number of individuals in the sample (Margalef 1958).

Gill net sampling

This method sampled mainly larger fishes >100-mm fork length (FL) in the two estuaries. Gill netting sites (Figure 1) were selected such that surface and bottom salinities were normally >20 g kg^{-1} at the lower site, >10 g kg^{-1} at the middle site and <5 g kg^{-1} at the upper site. In the Kowie estuary gill net stations were situated 2 km (lower reaches), 12 km (middle reaches) and 17 km (upper reaches) from the mouth, whereas in the Great Fish system the stations were 0,5 km (lower reaches), 3 km (middle reaches) and 7 km (upper reaches) from the estuary mouth. At each site there was a fleet of gill nets comprising six 10-m sections with stretched mesh sizes of 45, 57, 73, 87, 110 and 150 mm. Nets were set overnight (16:00 – 08:00) on a monthly basis between January 1981 and January 1982.

Captured fish were identified and measured to the nearest mm FL in the field. CPUE is expressed in terms of the average number of fish captured per 100 h of gill netting, and formed the basis of comparisons between the relative abundance of fishes in the Great Fish and Kowie estuaries. The species richness (R) of gill net catches in each of the estuaries was calculated as described above under seine net sampling.

Results

Physical-chemical environment

The physical-chemical environment of the two estuaries between January 1981 and January 1982 is best described by measurements made during the gill net sampling programme. Mean surface and bottom salinities and temperatures in the lower (Station 1), middle (Station 2) and upper (Station 3) reaches of the Kowie and Great Fish estuaries are shown in Tables 1 & 2. The mean surface and bottom salinities for the Kowie estuary during 1981 were 13 and 14,5 g kg^{-1}, respectively, indicating a well-mixed system. Equivalent surface and bottom values for the more stratified Great Fish estuary were 9,6 and 16,1 g kg^{-1}, and are indicative of the influence of higher river inflow on surface salinities. Bottom waters were, on average, 0,7°C cooler than surface waters in the Kowie estuary and 1,3°C cooler in the Great Fish estuary. The mean Secchi disc value for the Kowie and Great Fish estuaries was 74,4 cm and 24,4 cm, respectively (Tables 1 & 2), with the lower water transparency in the latter system being linked to the high suspensoid levels associated with the riverine input.

Between December 1989 and September 1990 mean sali-

Table 2 Physical-chemical conditions recorded at gill net sites in the Great Fish estuary during 1981

Great Fish estuary		Lower reaches Surface	Lower reaches Bottom	Middle reaches Surface	Middle reaches Bottom	Upper reaches Surface	Upper reaches Bottom
Salinity (g kg^{-1})	Mean	16,2	23,8	11,4	20,3	1,2	4,3
	SD	10,6	10,2	7,4	11,2	1,1	6,6
	Range	0–35	0–35	1–26	1–31	1–4	1–17
Temperature (°C)	Mean	18,4	17,3	18,5	17,3	18,8	17,4
	SD	3,9	3,0	4,3	3,2	4,8	4,4
	Range	12–24	12–21	12–25	12–21	11–25	11–23
Secchi (cm)	Mean	46,3		18,4		8,5	
	SD	47,3		9,2		3,3	
	Range	5–175		3–33		2–15	

nity, temperature and turbidity in the Kowie estuary mouth region was 34 g kg^{-1}, 18°C and 5 NTU respectively, compared with 18 g kg^{-1}, 19°C and 21 NTU in the Great Fish estuary mouth region. The lower salinities and higher turbidities recorded in the Great Fish system, when compared with the Kowie estuary, are linked to the higher freshwater input into the former system. Monthly river flow into the two estuaries for the period 1981–1990 are shown in Figure 2.

Plankton net samples

The densities (number per 100 m^3) of estuarine spawners, marine migrants and marine transients in the mouth region of the Kowie and Great Fish estuaries are given in Table 3. The dominant family of estuarine spawners was the Gobiidae with *Caffrogobius* spp. exceeding 10 individuals per 100 m^3 in both estuaries. *Psammogobius knysnaensis* was the second most abundant estuarine spawner in both systems. The dominant family of marine migrants was the Mugilidae, although densities of this taxa were considerably higher in the Great Fish than in the Kowie estuary. Marine transients were dominated by *Engraulis japonicus*, with densities exceeding one individual per 100 m^3 in both systems. Fewer than 3% of the ichthyoplankton catch could not be identified to the family level.

Overall, fish densities in the Kowie estuary were 34% of those recorded in the Great Fish system, with the ratio being highest in the case of estuarine spawners and lowest for the marine transients (Table 3). Where species were present in both estuaries, the size composition of these taxa was very similar, e.g. >95% of the *Caffrogobius* spp. were between 2–4-mm BL.

Seine net samples

Marine migrants dominated seine net catches from both the Kowie and Great Fish estuaries, with the Mugilidae and Sparidae being the two most important families (Table 4). *Rhabdosargus holubi*, *Liza dumerilii* and *Liza tricuspidens* were the three most abundant marine migrants in the Kowie system, and *L. dumerilii*, *L. richardsonii* and *R. holubi* in the Great Fish estuary. *Gilchristella aestuaria* was the most common estuarine spawner in both estuaries.

Altogether, 36 species were captured in the Kowie system (species richness R = 4,1) and 27 species in the Great Fish

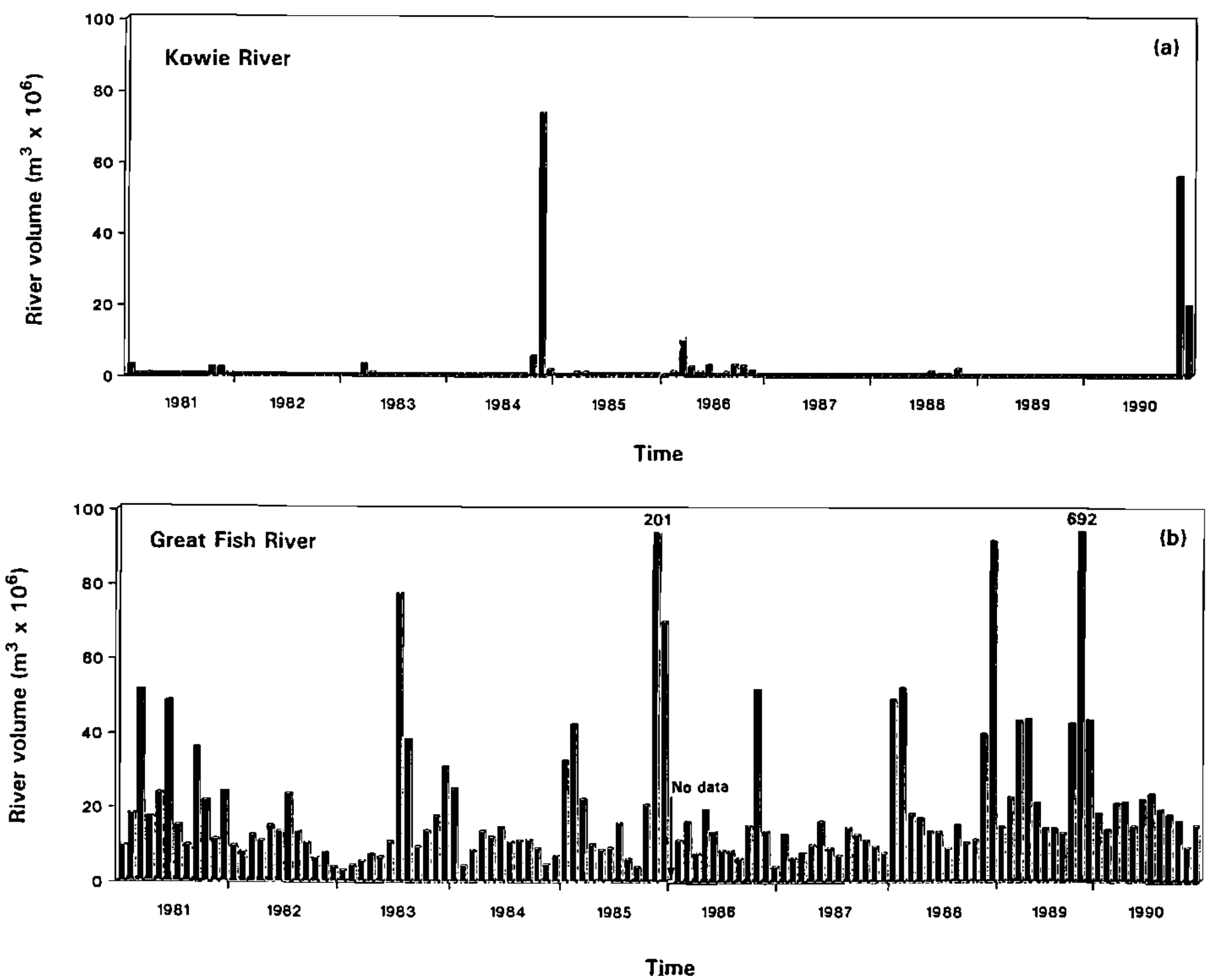

Figure 2 Monthly river flow data from the Kowie (a) and Great Fish (b) systems for the period January 1981 to December 1990.

Table 3 Ichthyoplankton densities (number of fish per 100 m^3) and species ranking in the Kowie and Great Fish estuaries

Fish family: species		Kowie		Great Fish	
		Density	Rank	Density	Rank
Estuarine spawners					
Atherinidae:	*Atherina breviceps*	0,03	14	0,15	13
Blenniidae:	*Omobranchus woodi* + unidentified	0,77	7	0,92	10
Clinidae:	Unidentified	1,04	6	0,04	17
Clupeidae:	*Gilchristella aestuaria*	1,69	5	2,90	6
Gobiidae:	Unidentified			3,27	5
	Caffrogobius spp.	10,54	1	47,95	1
	Psammogobius knysnaensis	3,60	2	4,63	3
Syngnathidae:	*Syngnathus acus*	3,29	3	3,96	4
Marine migrants					
Ambassidae:	*Ambassis gymnocephalus*	0,03	14		
Carangidae:	Unidentified	0,03	14		
Elopidae:	*Elops machnata*	0,03	14	0,04	17
Mugilidae:	Unidentified	0,60	9	6,83	2
Ophichthidae:	*Ophisurus serpens*			0,04	17
Pomatomidae:	*Pomatomus saltatrix*			0,11	14
Sciaenidae:	*Argyrosomus hololepidotus*	0,53	10	0,04	17
Soleidae:	*Heteromycteris capensis*	0,50	11	0,07	15
Sparidae:	*Diplodus sargus capensis*	0,32	12	0,07	15
	Rhabdosargus holubi	0,08	13	0,22	11
Marine transients					
Clupeidae:	*Etremeus whiteheadi*	0,03	14	0,18	12
Engraulidae:	*Engraulis japonicus*	2,20	4	1,87	7
Gobiesocidae:	Unidentified	0,03	14		
Haemulidae:	*Pomadasys olivaceum*			1,76	9
Ostraciidae:	*Lactoria fornasini*	0,03	14		
Scombridae:	*Scomber japonicus*	0,03	14		
Siganidae:	*Siganus sutor*	0,03	14		
Unidentified		0,75	8	1,84	8
Total		26,18		76,89	

Table 4 Catch per unit effort (number of fish per 10 seine net hauls) and species ranking in the Kowie and Great Fish estuaries

Fish family: species		Kowie		Great Fish	
		CPUE	Rank	CPUE	Rank
Estuarine spawners					
Atherinidae:	*Atherina breviceps*	10,5	7	6,0	16
Clupeidae:	*Gilchristella aestuaria*	151,8	2	288,0	2
Gobiidae:	*Glossogobius callidus*	2,5	17	0,7	25
	Psammogobius knysnaensis	0,5	25	2,0	19
Hemiramphidae:	*Hyporhamphus capensis*	3,5	14		
Sygnathidae:	*Syngnathus acus*	0,6	23		
Marine migrants					
Ambassidae:	*Ambassis gymnocephalus*			6,0	16
Ariidae:	*Galeichthys feliceps*	8,2	9	46,0	7
Carangidae:	*Caranx sexfasciatus*	0,1	31		
	Lichia amia	0,8	21	2,0	19
Haemulidae:	*Pomadasys commersonnii*	7,4	10	198,0	4
	Pomadasys olivaceum	24,4	5	28,0	10
Hemiramphidae:	*Hemiramphus far*	0,6	23		
Monodactylidae:	*Monodactylus falciformis*	3,5	14		
Mugilidae:	*Liza dumerilii*	97,0	3	415,3	1
	Liza macrolepis			1,3	22
	Liza richardsonii	11,7	6	233,3	3
	Liza tricuspidens	46,7	4	35,3	9
	Mugil cephalus	3,8	13	22,7	11
	Myxus capensis	0,4	26	3,3	18
	Valamugil buchanani	0,1	31		
Platycephalidae:	*Platycephalus indicus*			1,3	22
Pomatomidae:	*Pomatomus saltatrix*	0,7	22		
Sciaenidae:	*Argyrosomus hololepidotus*	0,4	26	19,3	12
Soleidae:	*Heteromycteris capensis*	0,4	26	6,7	15
	Solea bleekeri	6,0	11	43,3	8
Sparidae:	*Diplodus sargus capensis*	8,7	8		
	Lithognathus lithognathus	1,9	18	59,3	6
	Rhabdosargus globiceps	1,8	19	0,7	25
	Rhabdosargus holubi	164,2	1	88,0	5
	Rhabdosargus sarba	0,3	30		
Marine transients					
Carangidae:	*Trachurus capensis*	0,1	31		
Engraulidae:	*Engraulis capensis*	0,1	31	16,0	13
Fistulariidae:	*Fistularia petimba*	0,1	31		
Monocanthidae:	*Stephanolepis auratus*	1,6	20		
Mugilidae:	*Valamugil seheli*			2,0	19
Siganidae:	*Siganus sutor*	0,4	26		
Sparidae:	*Diplodus cervinus hottentotus*	5,7	12	0,6	27
	Spondyliosoma emarginatum	2,6	16		
Tetraodontidae:	*Amblyrhynchotes honckenii*	0,1	31	1,3	22
Freshwater migrants					
Cyprinidae:	*Cyprinus carpio*			8,0	14
Total		569,2		1534,4	

estuary (species richness R = 3,4), but the relative abundance of fishes in the former system was 37% of that recorded in the latter estuary.

The length-frequency distributions of *R. holubi*, *L. dumerilii* and *L. tricuspidens* in the two estuaries are shown in Figures 3, 4 & 5. The length-frequency distributions were similar between the two estuaries, with *R. holubi* and *L. dumerilii* peaking in the 100-149-mm size class, and *L. tricuspidens* in the 40–59-mm size class.

Marine migrants also dominated gill net catches in the Kowie and Great Fish estuaries, with the Mugilidae being the most important family in both systems (Table 5). The three most abundant species were *Mugil cephalus*, *Liza richardsonii* and *Argyrosomus hololepidotus*. A total of 19 species was recorded in the Kowie estuary (species richness R = 2,8) compared with 16 in the Great Fish system (species richness R = 2,0), with the relative abundance of fishes in the former estuary being 37% of that recorded in the latter system. Two freshwater species, one of which is an exotic (*Cyprinus carpio*), were recorded in the Great Fish estuary and one (*Oreochromis mossambicus*) in the Kowie system. No estuarine spawners were recorded in the gill nets owing to the small size of these species.

The horizontal distribution of the various species is presented in Tables 6 & 7. Species which show a consistent

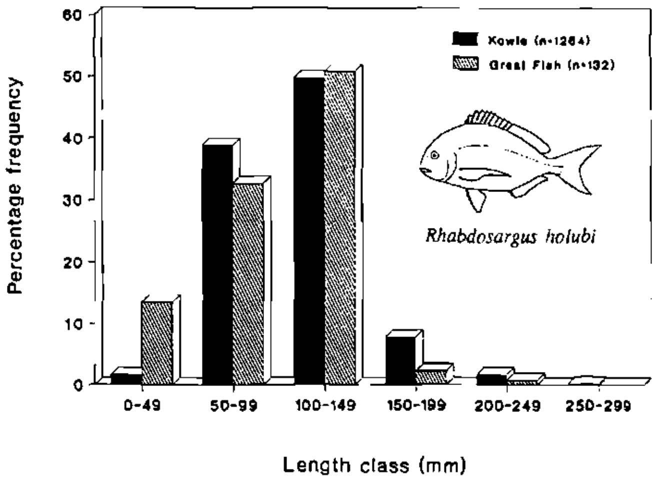

Figure 3 Length-frequency distribution of *Rhabdosargus holubi* captured during seine netting in the Kowie and Great Fish estuaries.

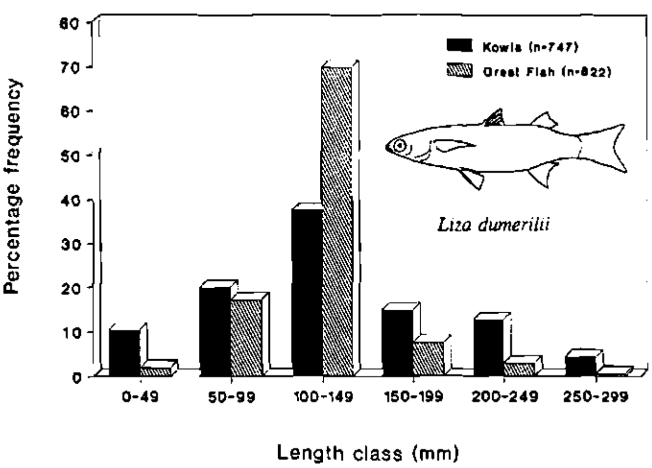

Figure 4 Length-frequency distribution of *Liza dumerilii* captured during seine netting in the Kowie and Great Fish estuaries.

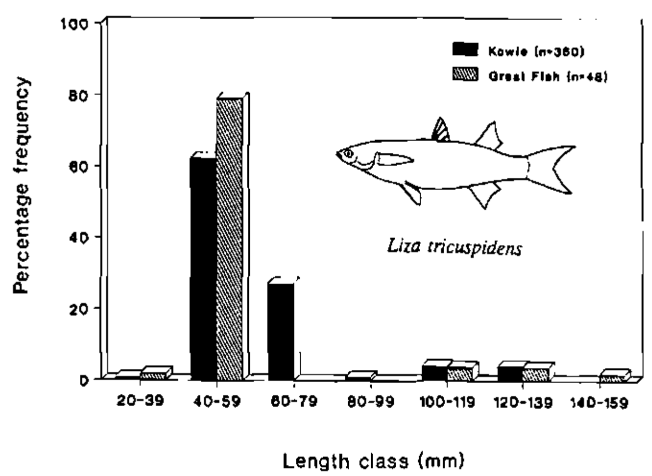

Figure 5 Length-frequency distribution of *Liza tricuspidens* captured during seine netting in the Kowie and Great Fish estuaries.

Table 5 Catch per unit effort (number of fish per 100 gill net hours) and species ranking in the Kowie and Great Fish estuaries

Fish family: species		Kowie CPUE	Kowie Rank	Great Fish CPUE	Great Fish Rank
Marine migrants					
Ariidae:	*Galeichthys feliceps*	9,6	5	27,5	5
Carangidae:	*Caranx sexfasciatus*	0,6	17		
	Lichia amia	15,4	4	5,1	8
Chanidae:	*Chanos chanos*	0,2	19		
Elopidae:	*Elops machnata*	0,8	16	0,5	15
Haemulidae:	*Pomadasys commersonnii*	7,1	6	33,4	3
Hemiramphidae:	*Hemiramphus far*	1,1	14		
Monodactylidae:	*Monodactylus falciformis*	3,2	10	0,8	1
Mugilidae:	*Liza dumerilii*	5,4	8	1,9	11
	Liza richardsonii	20,8	3	109,6	1
	Liza tricuspidens	1,9	11	8,2	7
	Mugil cephalus	25,9	1	101,9	2
	Myxus capensis	6,4	7	28,8	4
	Valamugil buchanani	0,4	18		
Pomatomidae:	*Pomatomus saltatrix*	1,3	13	0,2	16
Sciaenidae:	*Argyrosomus hololepidotus*	22,3	2	25,6	6
Sparidae:	*Lithognathus lithognathus*	1,9	11	0,8	12
	Rhabdosargus holubi	5,1	9	0,8	12
Freshwater migrants					
Cichlidae:	*Oreochromis mossambicus*	0,9	15		
Cyprinidae:	*Cyprinus carpio*			4,2	9
	Labeo umbratus			3,0	10
Total		130,3		352,3	

Table 6 Fish distribution (number of individuals per 100 gill net hours) in the Great Fish estuary

Fish family: species		Great Fish stations 1	2	3
Marine migrants				
Ariidae:	*Galeichthys feliceps*	22,9	4,3	0,3
Carangidae:	*Lichia amia*	1,4	2,6	1,1
Elopidae:	*Elops machnata*		0,2	0,3
Haemulidae:	*Pomadasys commersonnii*	17,6	15,4	0,4
Monodactylidae:	*Monodactylus falciformis*	0,6		0,2
Mugilidae:	*Liza dumerilii*	1,1	0,8	
	Liza richardsonii	21,1	72,0	16,5
	Liza tricuspidens	1,6	6,2	0,4
	Mugil cephalus	0,3	17,9	83,7
	Myxus capensis	1,0	9,0	18,8
Pomatomidae:	*Pomatomus saltatrix*	0,2		
Sciaenidae:	*Argyrosomus hololepidotus*	4,3	11,4	9,9
Sparidae:	*Lithognathus lithognathus*	0,2	0,6	
	Rhabdosargus holubi	0,5	0,3	
Freshwater migrants				
Cyprinidae:	*Cyprinus carpio*		3,1	1,1
	Labeo umbratus			3,0
Total		72,8	143,8	135,7

Table 7 Fish distribution (number of individuals per 100 gill net hours) in the Kowie estuary

Fish family: species		Kowie stations 1	2	3
Marine migrants				
Ariidae:	*Galeichthys feliceps*	6,0	2,4	1,2
Carangidae:	*Caranx sexfasciatus*	0,2	0,2	0,2
	Lichia amia	2,8	4,2	8,4
Chanidae:	*Chanos chanos*			0,2
Elopidae:	*Elops machnata*			0,8
Haemulidae:	*Pomadasys commersonnii*	2,6	2,1	2,4
Hemiramphidae:	*Hemirhamphus far*	1,1		
Monodactylidae:	*Monodactylus falciformis*	0,2	1,3	1,7
Mugilidae:	*Liza dumerilii*	2,4	0,9	2,1
	Liza richardsonii	8,6	5,4	6,8
	Liza tricuspidens	1,9		
	Mugil cephalus	1,9	1,3	22,7
	Myxus capensis			6,4
	Valamugil buchanani	0,2		0,2
Pomatomidae:	*Pomatomus saltatrix*	1,3		
Sciaenidae:	*Argyrosomus hololepidotus*	1,3	6,6	14,4
Sparidae:	*Lithognathus lithognathus*	0,4		1,5
	Rhabdosargus holubi	2,4	0,6	2,1
Freshwater migrants				
Cichlidae:	*Oreochromis mossambicus*			0,9
Total		33,3	25,0	72,0

trend in both estuaries include *Galeichthys feliceps* and *Pomatomus saltatrix* which were most abundant in the lower reaches (Station 1), and *Mugil cephalus* and *Myxus capensis* which were most abundant in the upper reaches (Station 3). Fish abundance was greatest in the upper reaches of the Kowie estuary and in the middle and upper reaches of the Great Fish system.

The length-frequency distributions of some of the dominant species captured in gill nets are shown in Figures 6, 7, 8, 9, 10 & 11. Smaller specimens of *L. richardsonii*, *M. cephalus* and *P. commersonnii* predominated in the Kowie estuary compared with the Great Fish estuary (Figures 6, 7 & 8). Conversely a higher proportion of smaller specimens of *G. feliceps* and *L. amia* were present in the Great Fish estuary (Figures 9 & 10). The size distributions of *A. hololepidotus* in the two estuaries were very similar (Figure 11).

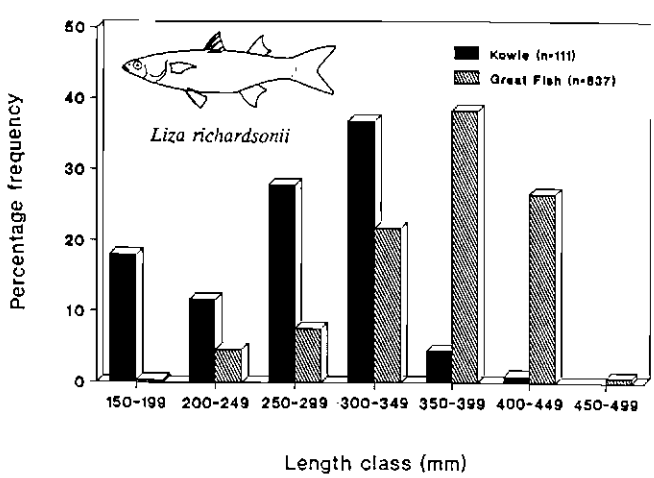

Figure 6 Length-frequency distribution of *Liza richardsonii* captured during gill netting in the Kowie and Great Fish estuaries.

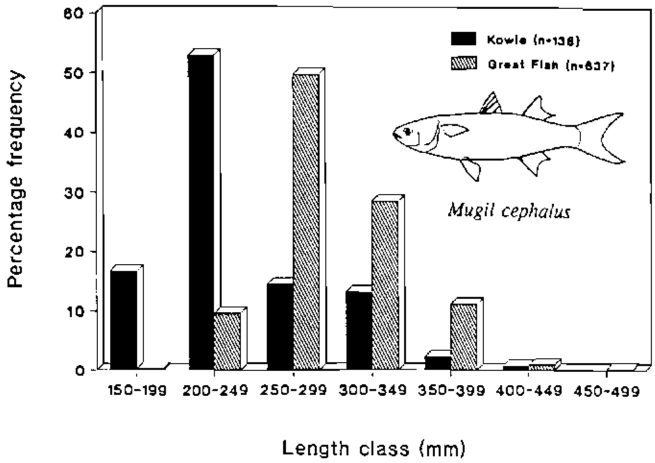

Figure 7 Length-frequency distribution of *Mugil cephalus* captured during gill netting in the Kowie and Great Fish estuaries.

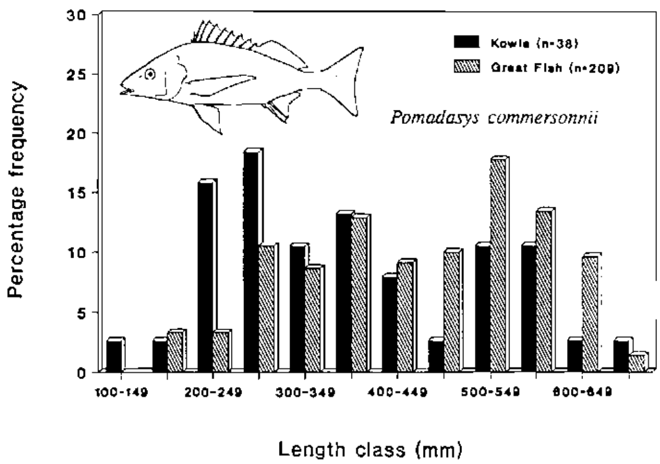

Figure 8 Length-frequency distribution of *Pomadasys commersonnii* captured during gill netting in the Kowie and Great Fish estuaries.

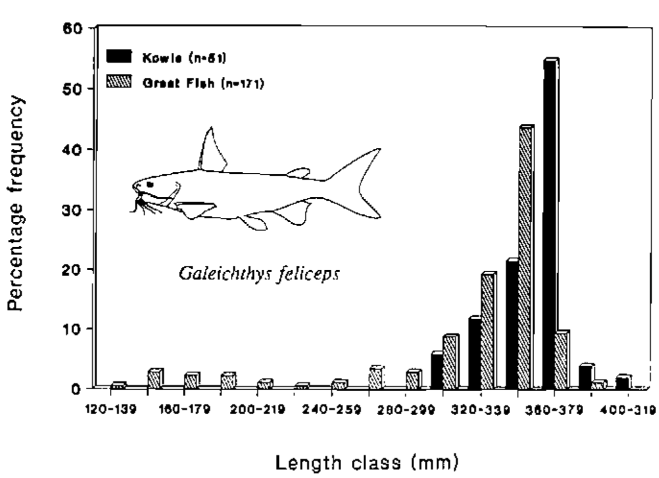

Figure 9 Length-frequency distribution of *Galeichthys feliceps* captured during gill netting in the Kowie and Great Fish estuaries.

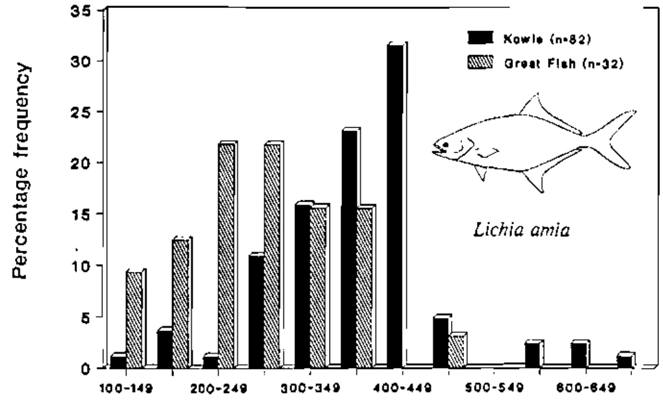

Figure 10 Length-frequency distribution of *Lichia amia* captured during gill netting in the Kowie and Great Fish estuaries.

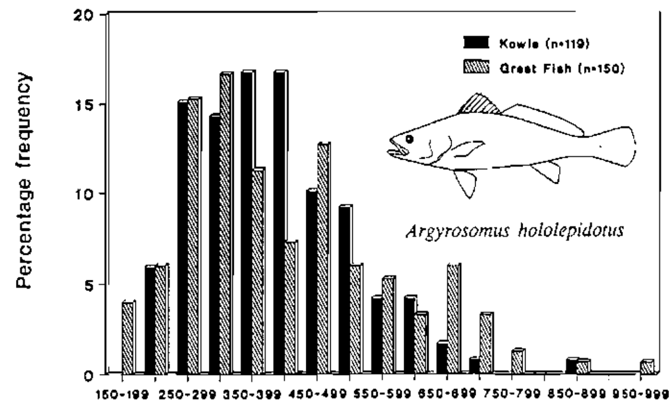

Figure 11 Length-frequency distribution of *Argyrosomus hololepidotus* captured during gill netting in the Kowie and Great Fish estuaries.

Discussion

Numerous factors influence the diversity and abundance of fishes in southern African estuarine systems. These include latitude (Wallace 1975; Blaber 1981), catchment size (Marais 1988), estuary size (Whitfield 1980; 1983), habitat type (Wallace & Van der Elst 1975; Hanekom & Baird 1984; Whitfield 1986), nearshore marine conditions (Whitfield 1989; Potter, Beckley, Whitfield & Lenanton 1990), mouth depth and degree of marine influence (Whitfield & Kok 1992), physical constrictions within estuarine systems (Hall, Whitfield & Allanson 1987), the occurrence and severity of floods (Marais 1982), the presence of catchment dams and weirs (Plumstead 1990), freshwater inflow (Whitfield 1994), whether an estuary is permanently open or temporarily open (Bennett 1989; Kok & Whitfield 1986), timing of the open phase (Wallace & Van der Elst 1975; Whitfield 1980), the ability of species to adjust to salinity and temperature fluctuations (Blaber 1974; Whitfield, Blaber & Cyrus 1981), turbidity (Cyrus & Blaber 1987a; 1987b; 1987c), available food resources (Marais 1984; Whitfield 1988), predation (Blaber 1973; Whitfield & Blaber 1978) and degradation as a result of pollution (Blaber, Hay, Cyrus & Martin 1984). In the following discussion we attempt to identify some of the factors accounting for differences in ichthyofaunal diversity and abundance in the Kowie and Great Fish estuaries.

Although the two estuaries are situated less than 30 km apart, they differ considerably in terms of turbidity, freshwater input, food resources and habitat availability. The greater fish species richness (R) recorded in the Kowie estuary may be partly attributed to the wider range of habitats, and hence, increased variety of food sources, shelter, etc. available to the ichthyofauna of this system. In addition, the greater influence of low turbidity marine waters in the Kowie estuary may account for the presence of certain marine transients in this system (Table 4). The higher abundance of fishes in the Great Fish estuary may be directly and indirectly linked to the large organic and nutrient inputs into this system when compared with the Kowie system, and the influence of these inputs on estuarine primary and secondary production (Grange 1992). All three sampling gears revealed an approximate 3:1 ratio between fish abundance in the Great Fish and Kowie estuaries (Tables 3, 4 & 5).

Marais (1988), working in eastern Cape and Transkei estuaries, found a highly significant ($p < 0,001$) negative correlation between gill net catches and increasing salinity, i.e. both numbers and biomass of captured fish were highest in those estuaries with the largest riverine input. It is perhaps significant that the Great Fish estuary, which had one of the greatest river discharge rates, also had the highest mean number and mass of fish captured in gill nets (Marais 1988). Although the Kowie estuary was not sampled in the above gill net study, indications from the nearby Bushmans estuary (33°42′S; 26°40′E), which also has a highly impounded catchment, revealed that both numbers and mass of fish captured were <30% of values recorded for the Great Fish estuary (Marais 1988). Certain fishes such as the freshwater mullet *Myxus capensis* are known to be attracted to rivers in the eastern Cape (Bok 1979), and this species was considerably more abundant in the Great Fish than in the Kowie estuary (Tables 4 & 5). It is also tempting to speculate that the greater abundance of the larger size groups of detritivorous species such as *Liza richardsonii* and *Mugil cephalus*, which were poorly represented in the Kowie estuary (Table 5, Figures 6 & 7), may be linked to the large riverine-derived organic inputs into the Great Fish estuary.

In many southern African estuaries, freshwater inflow is often associated with high sediment loads (McCormick, Cooper & Mason 1992), which result in these systems having much higher turbidity levels than the adjacent marine environment. Indeed, it has been suggested by Blaber (1981) that the occurrence of many marine species in subtropical south-east African estuaries may be related more to water turbidity than to any other factors. Evidence to support the importance of turbidity as a major factor influencing both juvenile and adult fishes is derived from the positive correlation between fish abundance and turbidity in 14 estuaries along the south and south-east coasts of South Africa (Marais 1988). Detailed studies on juvenile marine fish in Natal estuaries have demonstrated that turbidity may have profound effects on the distribution of fishes (Cyrus & Blaber 1987a). These estuarine-associated fishes can be divided into categories according to the turbidity preference of individual species (Cyrus & Blaber 1987b), with 16 of the 20 species studied by Cyrus & Blaber (1987c) showing a preference for turbid waters. The above results may partially explain the relatively high densities of certain fish species in the turbid Great Fish estuary when compared with the relatively clear Kowie estuary. It is also possible that the higher suspensoid levels in the Great Fish estuary may have contributed to the greater fish catches in this system.

Hecht & Van der Lingen (1992) conducted field and laboratory studies to determine the effect of turbidity on the feeding strategies of fish in eastern Cape estuaries. They found that visual predators are more affected by high turbidity than are macrobenthic feeders. This study has shown that visual piscivores such as *Lichia amia* and *Pomatomus saltatrix* were more abundant in the Kowie than in the Great Fish estuary (Table 5). Also, large *L. amia* (>500-mm FL) were recorded in the Kowie estuary but not in the Great Fish system (Figure 10). Conversely, the piscivore *Argyrosomus hololepidotus*, which hunts mainly by combining olfactory and lateral line senses instead of sight (Van der Elst 1988), was equally abundant in both estuaries (Table 5) and had a similar length-frequency distribution in the two systems (Figure 11). Macrobenthic carnivores such as *Galeichthys feliceps* and *Pomadasys commersonnii*, and benthic detritivores such as *Liza richardsonii* and *Mugil cephalus*, did not appear to be adversely affected by the higher turbidities of the Great Fish estuary and these species were considerably more abundant in this system (Tables 4 & 5). The omnivorous sparid *Rhabdosargus holubi* attained higher densities in the Kowie compared with the Great Fish estuary (Table 4) and this may be attributed to the extensive eelgrass (*Zostera capensis*) habitat available in the former system. Hanekom & Baird (1984) found significantly higher numbers of *R. holubi* in *Zostera* than in non-*Zostera* areas of the Kromme estuary.

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