# A preliminary survey of the estuaries on the south coast of South Africa, Robberg Peninsula – Cape St Francis, with particular reference to the fish fauna

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**A basic ichthyofaunal and physico-chemical survey of the coastal outlets on the south coast of South Africa (Robberg Peninsula to Cape St Francis) was undertaken during November 1994 and September 1995. Some 27 systems were identified along this stretch of coast and of these, 48% (Brak, Helpmekaars, Klip, Witels, Geelhoutbos, Kleinbos, Bruglaagte, Langbos, Sanddrif, Eerste, Boskloof, Kaapsedrif and Klipdrif [Wes]) comprised the inlets of coastal streams that offer little habitat for fishes, 26% (Sout, Bloukrans, Lottering, Elandsbos, Storms, Elands and Groot [Oos]) are located within deeply incised valleys within the Tsitsikamma region and provide limited littoral habitat for estuary-associated fishes; 26% of the systems (Piesang, Keurbooms, Matjies, Groot [Wes], Tsitsikamma, Klipdrif [Oos], Slang) appear to serve some estuarine function for both marine migrant and resident species although some of these may also be limited due to their small size and infrequent connection with the sea. This study serves to emphasize the ecological importance of these latter estuaries within this coastal sector.**

**Key words: ichthyofauna, estuarine survey, fish habitat, Tsitsikamma coast, South Africa.**

## INTRODUCTION

An estimated 300 coastal outlets occur along the South African coastline, which extends some 3000 km from the Orange (Gariep) 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. These outlets range from coastal streams flowing into small estuaries that are periodically closed off from the sea to larger, permanently open systems.

Being formed where rivers meet the sea, estuaries are dynamic environments characterised by large fluctuations in environmental conditions. They are also highly productive areas and act as nursery areas for many species of fishes which are either exploited in estuaries or in coastal fisheries later in their life cycles (Houde & Rutherford, 1993). The role of estuarine nursery areas in southern Africa is particularly important, as the exposed high wave energy coastline is characterised by a widely fluctuating marine intertidal environment (McLachlan *et al.*, 1981; Beckley, 1985). Estuaries by comparison are generally calm, shallow areas, which provide sheltered nursery areas with a variety of habitat types for fishes (Wallace, 1975; Wallace & van der Elst, 1975; Day *et al.*, 1981; Whitfield, 1994a).

While the significance of estuaries as nursery areas for fishes is widely recognised, information on many South African systems is lacking. A review of the available scientific information on 258 South African estuarine systems revealed that the state of information on 68% of estuaries was 'nil' or 'poor'; the state of information on 22% was classified as 'moderate', while only 10% were regarded as 'good' or 'excellent' (Whitfield, 2000).

This paper is a continuation of the published series on the fish assemblages of South African estuaries (Harrison, 1997a,b, 1998, 1999a,b; James & Harrison, 2008) and reports on ichthyofaunal surveys conducted between Robberg Peninsula and Cape St Francis on the south and southeast coast of South Africa. Physico-chemical variables are described along with basic fish community data, and an appraisal of the nursery potential of these systems for fishes is also provided.

## STUDY AREA

Some twenty-seven coastal outlets intersect the south coast of South Africa between Robberg Pensinsula and Cape St Francis (Heydorn & Tinley, 1980). The marine waters of this coast are influenced by the warm, south-flowing Agulhas Current (Heydorn, 1991) although wind-induced coastal upwelling sometimes occurs during summer, which results in cold, nutrient rich waters being brought to the surface (Shannon, 1989). This geographic sector falls within the Tsitsikamma climatic region and receives year-round rainfall, with an annual precipitation of 700–1000 mm that is fairly evenly distributed throughout the year (Heydorn & Tinley, 1980).

## MATERIALS AND METHODS

The coastal outlets between Robberg Peninsula and Cape St Francis (Fig. 1) were sampled during November 1994 (Piesang–Sout) and September 1995 (Groot [Wes] – Slang). Each system was sampled once and, depending on the size, took 1–3 days to survey.

### *Physico-chemical*

Selected physico-chemical parameters were measured at various sites within each system. Water depth and transparency were measured using a 20 cm diameter Secchi disc attached to a weighted shot line graduated at 10 cm intervals. Temperature (°C), salinity (‰), conductivity (mS/cm), pH, dissolved oxygen (mg/l) and turbidity (NTU) were measured using a Horiba U-10 Water Quality Checker. Due to malfunction of the turbidity probe, these measurements were not recorded during the 1995

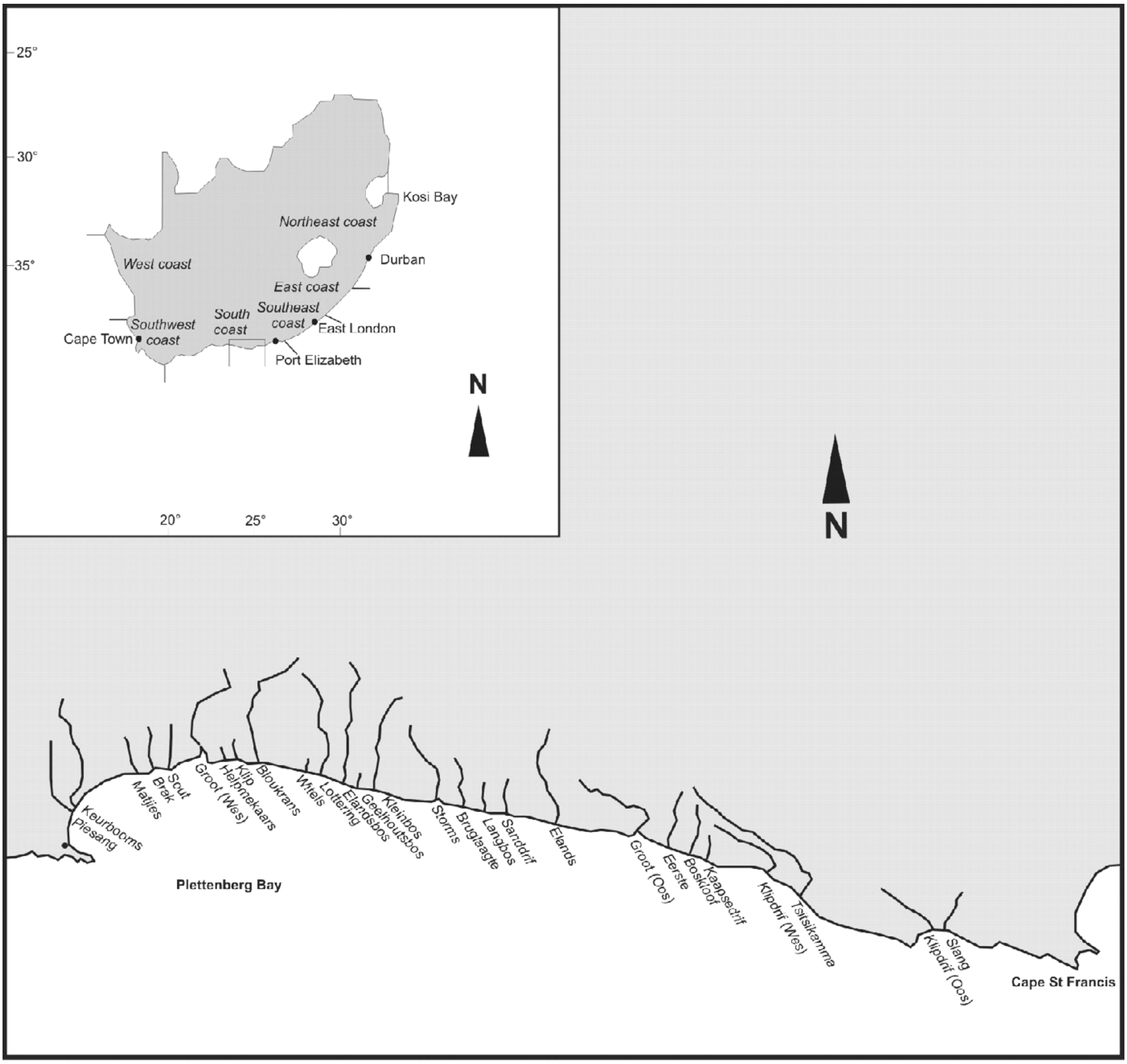


**Figure 1**. Location of study estuaries between the Robberg Penninsula and Cape St Francis on the south coast of South Africa.

survey. Where water depth permitted, both surface and bottom waters were measured. The mouth state of each system at the time of sampling was also noted.

*Ichthyofauna*

Fishes were sampled by means of seine netting and a fleet of multi-mesh gill nets. Details of the sampling approach can be found in Harrison (2005). Where possible all fish caught were identified and measured to the nearest millimetre standard length (SL) in the field before being released alive. Specimens that could not be identified were kept and preserved in 10% formalin for later processing in the laboratory. Where large catches of a particular species were made a sub-sample was also kept. Preserved specimens were identified in the laboratory by reference to Smith & Heemstra (1991) and Skelton (1993). Taxonomic identities were also adjusted using information provided in Heemstra & Heemstra (2004). A minimum of 25 specimens of the abundant species was measured (mm SL) and weighed; the remaining specimens were counted and batch-weighed.

The total species composition, by number and mass, was calculated for each system. The relative biomass contribution of each species was calculated using actual recorded masses as well as masses derived from length–mass relationships presented in Harrison (2001). Where appropriate, the length frequency distribution (in 10 mm size classes) was calculated for the most abundant species within each system. Using information from Whitfield (1998) the species recorded were divided into four estuarine association categories: freshwater species, estuarine-resident species, estuary-associated marine species and marine species. The percentage 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

### Piesang

The Piesang Estuary (34°03′S; 23°23′E) is situated at the coastal town of Plettenberg Bay. The river is approximately

**Table 1**. Physico-chemical parameters measured in south coast estuaries (Robberg Peninsula – Cape St Francis) November 1994 and September 1995 (S, surface; B, bottom; 999, Secchi disc visible on the bed).

| System | Site | Depth (m) | Temperature (°C) | | Salinity (‰) | | pH | | Dissolved oxygen (mg/l) | | Turbidity (NTU) | | Secchi depth (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | S | B | S | B | S | B | S | B | S | B | |
| Piesang | 1 | 0.3 | 24.3 | | 31.6 | | 8.1 | | 5.5 | | 8 | | 999 |
| | 2 | 0.4 | 24.9 | | 28.1 | | 8.1 | | 5.4 | | 13 | | 999 |
| | 3 | 0.4 | 25.6 | | 25.6 | | 8.0 | | 5.1 | | 30 | | 999 |
| Keurbooms | 1 | 2.7 | 19.8 | 19.7 | 35.0 | 35.0 | 8.3 | 8.3 | 5.5 | 5.3 | 0 | 1 | 999 |
| | 2 | 2.3 | 20.0 | 19.8 | 34.9 | 35.0 | 8.3 | 8.3 | 5.6 | 5.4 | 1 | 1 | 999 |
| | 3 | 0.7 | 22.6 | 22.9 | 27.4 | 27.7 | 8.6 | 8.5 | 7.3 | 7.4 | 1 | 0 | 999 |
| | 4 | 2.7 | 20.9 | 20.8 | 31.2 | 33.0 | 8.3 | 8.3 | 5.8 | 5.7 | 1 | 1 | 999 |
| | 5 | 1.2 | 21.2 | 21.2 | 25.4 | 25.4 | 8.0 | 8.0 | 5.0 | 4.8 | 1 | 1 | 999 |
| | 6 | 0.5 | 22.0 | 22.0 | 21.3 | 21.4 | 7.9 | 7.9 | 4.7 | 4.7 | 1 | 1 | 999 |
| | 7 | 1.7 | 22.2 | 22.2 | 20.7 | 23.8 | 7.7 | 7.8 | 4.6 | 4.3 | 0 | 0 | 999 |
| | 8 | 1.2 | 21.8 | 22.7 | 15.3 | 22.6 | 7.3 | 7.5 | 4.5 | 3.0 | 0 | 0 | 999 |
| Matjies | 1 | 0.2 | 26.5 | | 1.4 | | 7.9 | | 6.7 | | 2 | | 999 |
| | 2 | 0.7 | 23.4 | 24.6 | 4.5 | 13.8 | 7.6 | 8.2 | 5.2 | 5.8 | 1 | 1 | 999 |
| Brak | 1 | 0.6 | 22.3 | 26.1 | 3.3 | 10.3 | 7.3 | 7.8 | 3.2 | 3.2 | 2 | 6 | 999 |
| Sout | 1 | 1.0 | 21.7 | 21.7 | 29.8 | 30.2 | 8.2 | 8.2 | 5.8 | 5.7 | 3 | 3 | 999 |
| | 2 | 1.5 | 21.5 | 21.5 | 27.1 | 28.3 | 8.1 | 8.1 | 5.2 | 5.0 | 2 | 3 | 999 |
| Groot (Wes) | 1 | 2.1 | 15.6 | 17.4 | 6.8 | 21.7 | 7.6 | 7.5 | 6.2 | 0.8 | | | 999 |
| | 2 | 2.1 | 15.3 | 17.9 | 6.3 | 23.6 | 7.1 | 7.3 | 6.9 | 3.0 | | | 999 |
| | 3 | 1.7 | 14.5 | 17.0 | 5.7 | 19.5 | 6.7 | 7.0 | 6.2 | 2.8 | | | 999 |
| Bloukrans | 1 | 1.4 | 14.4 | 14.1 | 6.3 | 16.2 | 6.9 | 7.8 | 9.2 | 8.5 | | | 999 |
| | 2 | 3.8 | 13.7 | 14.0 | 3.0 | 19.7 | 6.8 | 7.6 | 9.0 | 7.8 | | | 1.7 |
| | 3 | 2.4 | 13.0 | 13.6 | 1.7 | 13.3 | 6.3 | 6.8 | 9.4 | 8.3 | | | 1.6 |
| Lottering | 1 | 0.3 | 14.5 | | 4.5 | | 6.6 | | 9.6 | | | | 999 |
| | 2 | 0.5 | 12.3 | | 0.2 | | 4.9 | | 10.2 | | | | 999 |
| Elandsbos | 1 | 2.8 | 13.9 | 13.9 | 0.1 | 0.1 | 4.2 | 4.2 | 10.0 | 10.1 | | | 0.7 |
| | 2 | | 13.9 | | 0.0 | | 4.2 | | 10.6 | | | | 999 |
| Storms | 1 | >3.0 | 14.7 | 15.0 | 24.3 | 29.7 | 7.8 | 7.8 | 8.7 | 8.1 | | | >3.0 |
| | 2 | >3.0 | 14.6 | 15.0 | 21.3 | 29.5 | 7.6 | 7.8 | 8.6 | 7.9 | | | >3.0 |
| | 3 | 2.9 | 14.4 | 14.7 | 20.0 | 28.0 | 7.8 | 7.8 | 9.0 | 8.2 | | | 1.5 |
| Elands | 1 | 2 | 13.8 | 13.8 | 0.9 | 1.6 | 5.1 | 5.4 | 10.0 | 10.2 | | | 0.7 |
| | 3 | 4.7 | 13.2 | 13.1 | 0.0 | 0.0 | 4.5 | 4.3 | 10.3 | 10.1 | | | 0.7 |
| Groot (Oos) | 1 | 3.7 | 16.4 | 17.0 | 2.3 | 28.8 | 6.8 | 7.7 | 9.2 | 6.9 | | | 1.2 |
| | 2 | 3.2 | 16 | 16.9 | 0.9 | 29.5 | 6.5 | 7.7 | 9.5 | 6.5 | | | 1.2 |
| | 3 | 1.6 | 15.7 | 16.8 | 1.0 | 29.2 | 6.6 | 7.7 | 9.5 | 6.5 | | | 1.4 |
| Boskloof | 1 | 0.3 | 16.0 | | 0.2 | | 7.6 | | 9.4 | | | | 999 |
| Kaapsedrif | 1 | 0.5 | 15.6 | | 0.2 | | 7.9 | | 9.6 | | | | 999 |
| Tsitsikamma | 1 | 0.9 | 18.1 | 18.1 | 0.7 | 1.0 | 7.2 | 7.2 | 8.6 | 8.0 | | | 0.4 |
| | 3 | 0.4 | 17.0 | | 0.2 | | 7.2 | | 8.8 | | | | 999 |
| Klipdrif (Oos) | 1 | 0.2 | 19.3 | | 0.2 | | 7.6 | | 9.5 | | | | 999 |
| | 2 | 0.3 | 17.4 | | 0.2 | | 7.2 | | 9.6 | | | | 999 |
| Slang | 1 | 0.5 | 18.7 | | 0.3 | | 7.5 | | 9.3 | | | | 999 |

17 km in length with a catchment area of between 35 and 40 $km^2$ (Grindley, 1980; Duvenhage & Morant, 1984). The Piesang River flows through a narrow valley and emerges into a coastal basin approximately 200 m long and 600 m wide where a small lagoon forms behind a sandbar adjoining Beacon Island (Duvenhage & Morant, 1984). The upper reaches of the estuary is demarcated by a road bridge that crosses the system approximately 2.5 km upstream of the mouth. According to Whitfield (2000), the state of information on the Piesang Estuary is moderate.

*Physico-chemical*

Physico-chemical parameters were measured at three sites representing the lower, middle, and upper reaches of the system. The estuary was very shallow, with the depth ranging from 0.3 to 0.4 m (Table 1) and as a result only surface waters were measured. The mouth of the system was closed at time of sampling. The Piesang Estuary enters the sea through a wide, shallow channel that is usually less than 1.0 m deep and 20 m wide. Owing to the shallowness of the channel the mouth closes periodically during dry periods. The sand bar, however, is sometimes artificially breached to prevent flooding of adjacent properties (Duvenhage & Morant, 1984).

Water temperatures increased in an upstream direction from 24.3°C recorded near the mouth to 25.6°C at the uppermost site (Table 1). Temperatures recorded in December 1968, when the mouth was open, measured between 21.8 and 22.6°C (Duvenhage & Morant, 1984). No distinct gradients were observed and this was attributed to the shallowness of the estuary and mixing caused by winds and tidal action.

An axial salinity gradient was also recorded during this survey, with salinity decreasing from 31.6‰ near the mouth to 25.6‰ at the uppermost site (Table 1). The higher salinity is probably a result of seawater washing into the estuary across the sand berm at high tide. Salinities measured in December 1968 ranged from 35‰ at the mouth to 31‰ at the head, while salinities in September 1981 ranged from 0.5 at the head to 35‰ at the mouth (Duvenhage & Morant, 1984).

The pH of the water was close to that of seawater and measured between 8.0 and 8.1 (Table 1). Duvenhage & Morant (1984) reported a mean pH of 7.6 in September 1981.

Dissolved oxygen concentrations were also fairly uniform and measured between 5.1 and 5.5 mg/l (Table 1). In September 1981, higher dissolved oxygen concentrations of between 8.3 and 11.6 mg/l were recorded, with values decreasing towards the head of the estuary (Duvenhage & Morant, 1984).

Turbidity values showed an increase from 8 NTU at the mouth to 30 NTU at the uppermost site (Table 1). This is probably a reflection of more turbid fresh waters entering the upper reaches of the system. However, Duvenhage & Morant (1984) reported an opposite trend in March 1984 where turbidity decreased from the mouth to the head of the estuary.

### *Ichthyofauna*

Four seine net hauls and three gill nets yielded a total of 1266 individuals representing 19 taxa from 10 families (Table 2). Mugilidae (7 species), Sparidae (3 species) and Gobiidae (3 species) dominated the taxa; the remaining families were represented by one species each. *Gilchristella aestuaria* dominated the catches numerically and accounted for 54% of the total abundance. Other numerically important taxa included *Liza richardsonii* (17.2%), *Liza dumerili* (9.9%), *Rhabdosargus holubi* (5.0%), *Mugil cephalus* (4.7%), *Caffrogobius gilchristi* (3.3%), juvenile mugilids (1.5%) and *Psammogobius knysnaensis* (1.1%) (Table 3). A total species mass of over 19 kg was recorded (Table 4). *Liza richardsonii* was the dominant species comprising 42.0% of the total mass, followed by *Argyrosomus japonicus* (16.7%), *L. dumerili* (12.8%), *R. holubi* (6.6%), *M. cephalus* (5.0%), *G. aestuaria* (3.5%), *Pomatomus saltatrix* (3.2%), *Liza tricuspidens* (2.1%), *Pomadasys commersonnii* (2.0%), *Monodactylus falciformis* (1.7%) and *Lithognathus lithognathus* (1.4%) (Table 5).

Whitfield (1994b) provided a list of 11 fish species reported in the Piesang Estuary based on samples collected using a D-net trawl (Duvenhage & Morant, 1984) and a seine net survey. The species reported from the system included *Caffrogobius gilchristi, Caffrogobius nudiceps, Galeichthys feliceps, G. aestuaria, L. dumerili, L. richardsonii, M. falciformis, M. cephalus, P. knysnaensis, R. holubi* and *Solea turbynei.* Nine species were common to those recorded during this survey.

*Liza richardsonii* captured during this survey ranged in size from 36 to 271 mm SL and showed a polymodal length frequency distribution. The smallest individuals were mostly in the 50–80 mm size classes, larger individuals were mostly 100–150 mm, and the largest size group comprised individuals 200–250 mm. *Liza richardsonii* is an estuarine-associated marine species that uses estuaries as nursery areas. Recruitment of postflexion larvae and juveniles into estuaries on the south-western and southern Cape coasts occurs at sizes of between 20 to 50 mm TL (Bennett, 1989; Whitfield & Kok, 1992). The range of size classes captured during this study suggests regular recruitment and utilisation of the system. *Liza dumerili* ranged in size from 46 to 145 mm. Small specimens were mostly 50–60 mm, with larger specimens in the 90–120 mm size classes. *Liza dumerili* is also an estuarine-associated marine species. It spawns at sizes larger than 180 mm SL (van der Horst & Erasmus, 1981) with recruitment into estuaries on the southern Cape coast occurring at <30 mm TL (Whitfield & Kok, 1992). *Rhabdosargus holubi* individuals ranged in size from 16 to 115 mm with most individuals in the 60–120 mm size classes; a few smaller individuals between 10–30 mm were also caught. *Rhabdosargus holubi* is an estuarine-associated marine species that recruits into estuaries at between 9 and 15 mm SL (Cowley *et al.*, 2001) and attains a length of approximately 100 mm SL in the first year (Beckley, 1984). The majority of specimens caught during this survey were less than one year old, indicating good recruitment into the estuary. *Mugil cephalus* is also an estuarine-associated marine species and the catch was dominated by newly recruited juveniles <40 mm. Recruitment into estuaries occurs at sizes below 30 mm TL (Wallace & van der Elst, 1975). A few larger specimens (>190 mm) were also captured suggesting regular utilisation of the system.

*Gilchristella aestuaria* is an estuarine-resident species that matures within seven months at approximately 28 mm SL (Talbot, 1982). Most individuals captured during this study were between 30 and 50 mm. *Psammogobius knysnaensis* ranged in size from 26 to 45 mm with most specimens in the 40–50 mm size class. This species matures at a length of approximately 30 mm SL (Bennett, 1989). *Caffrogobius gilchristi* caught during this survey were between 33 and 73 mm with most specimens in the 30–50 mm size classes. This species matures at a length of approximately 50 mm SL (Bennett, 1989). *Gilchristella aesturia, P. knysnaensis* and *C. gilchristi* are estuarine-resident species and the presence of both mature and immature individuals of these species indicates that the Piesang is also an important habitat for resident species.

Of the species collected in the Piesang during this survey, four (22%) were species which are able to live and breed in estuaries; these included *G. aestuaria, Caffrogobius gilchristi, Caffrogobius natalensis* and *P. knysnaensis.* The remaining 14 species (78%) were estuarine-associated marine species whose juveniles are dependent on estuaries to varying degrees. This group included species such as *A. japonicus, G. feliceps, Heteromycteris capensis, Lithognathus lithognathus, L. dumerili, L. richardsonii, Liza tricuspidens, M. falciformis, M. cephalus, Myxus capensis, P. commersonnii, P. saltatrix, Rhabdosargus globiceps,* and *R. holubi.* Of the species reported by Whitfield (1994b) four (36%) were estuarine species and seven (64%) were estuarine-associated marine species. During this survey estuarine-resident species comprised 58.5% of the total catch numerically and 4.1% of the biomass, while estuarine-associated marine species comprised 41.5% of the catch numerically and 95.9% of the biomass. The high proportion of estuarine and marine species in the Piesang Estuary suggests that it performs an important function as an estuarine nursery area.

## Keurbooms

The Keurbooms Estuary (34°02′S, 23°23′E) is situated near the coastal town of Plettenberg Bay. The system is fed by two major rivers, the smaller Bitou and the larger Keurbooms (Day, 1981) and has a combined catchment area of between 1085 km$^2$ (Day, 1981) and 1188 km$^2$ (Heydorn & Tinley, 1980). The Bitou River is 23 km long and has a wide (1.5 km) floodplain; the system becomes tidal and saline at Wittedrift, 6.7 km from the confluence with the Keurbooms River, which is located approximately 3.5 km from the mouth of the estuary (Day, 1981; Duvenhage & Morant, 1984). The Keurbooms River is 70 km long and flows through a rocky gorge with no floodplain (Day, 1981); the system is tidal and saline at Whiskey Creek, 7 km

**Table 2**. Number of fishes caught in seine (S) and gill (G) nets in south coast estuaries (Robberg Peninsula – Cape St Francis), November 1994 and September 1995.

| Species | Piesang | | Keurbooms | | Matjies | | Sout | | Groot (Wes) | | Bloukrans | | Lottering | | Elandsbos | | Storms | | Elands | | Groot (Oos) | | Tsitsikamma | | Klipdrif (Oos) | | Slang | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G |
| *Argyrosomus japonicus* | | 3 | | 9 | | | | | | | | | | | | | | | | | 0 | 1 | | | | | | |
| *Atherina breviceps* | | | 10 | | | | | | | | | | | | | | | | | | 1 | 0 | | | | | | |
| *Caffrogobius gilchristi* | 42 | | 5 | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Caffrogobius natalensis* | 1 | | 2 | | | | 2 | | | | | | | | | | | | | | | | | | | | | |
| *Caffrogobius nudiceps* | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Clinus superciliosus* | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Diplodus sargus capensis* | | | 189 | | | | 1 | | | | 1 | | | | | | | | | | | | | | | | | |
| *Elops machnata* | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Galeichthys feliceps* | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gilchristella aestuaria* | 684 | | | | | | | | 1 | | | | | | | | | | | | 364 | 0 | 197 | | | | | |
| *Heteromycteris capensis* | 3 | | 4 | | | | | | 4 | | | | | | | | | | 2 | 0 | 4 | 0 | | | | | | |
| *Lichia amia* | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lithognathus lithognathus* | 3 | 1 | 19 | | | | 15 | 1 | 32 | 1 | 1 | 1 | | | 10 | 2 | | 1 | 5 | 2 | 4 | 0 | 66 | 15 | | | | |
| *Liza dumerili* | 125 | | 7 | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Liza richardsonii* | 198 | 20 | 185 | 1 | 18 | | 10 | 5 | 5 | 24 | 32 | | 0 | 1 | 129 | 0 | | 2 | 30 | 0 | 13 | 0 | 31 | 90 | 430 | | 4 | |
| *Liza tricuspidens* | 11 | | 7 | 3 | | | | | | | | | | | | | | 1 | | | | | | | | | | |
| *Monodactylus falciformis* | | 7 | 3 | 1 | | | | 2 | | | | | | | | | | 21 | | | | | | 2 | | | | |
| *Mugil cephalus* | 56 | 3 | 26 | 1 | 200 | | | | | | | | | | | | | | | | | | 1 | 2 | 3 | | 1 | |
| *Myxus capensis* | | 1 | 3 | | | | 1 | | | | 1 | | 42 | 0 | 0 | 0 | | | | | | | 2 | 1 | | | | |
| Mugilidae | 20 | | 565 | | 50 | | 16 | | | | | | | | 14 | 0 | | | 16 | 0 | 33 | 0 | 275 | | 5 | | 197 | |
| *Pomadasys commersonnii* | 2 | 1 | | 1 | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| *Pomatomus saltatrix* | | 4 | | | | | 20 | 3 | | 3 | | | | | | | | 1 | | | | | | | | | | |
| *Psammogobius knysnaensis* | 14 | | 32 | | | | 3 | | 24 | | 3 | | | | 0 | 0 | | | 1 | 0 | 20 | 0 | 22 | | 5 | | | |
| *Rhabdosargus globiceps* | 3 | | 6 | | | | | | | | | | | | | | | | | | 1 | 0 | | | | | | |
| *Rhabdosargus holubi* | 63 | | 952 | | | | 36 | 1 | 3 | | | | | | | | | | 0 | 1 | 0 | 2 | 1 | | | | | |
| *Syngnathus temminckii* | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total individuals | 1225 | 41 | 2030 | 20 | 268 | 0 | 105 | 12 | 69 | 28 | 39 | 1 | 42 | 1 | 153 | 2 | 0 | 26 | 54 | 3 | 440 | 3 | 595 | 110 | 443 | 0 | 202 | 0 |
| Nets | 4 | 3 | 13 | 10 | 3 | 1 | 5 | 3 | 10 | 5 | 7 | 3 | 4 | 3 | 8 | 3 | 0 | 6 | 6 | 3 | 7 | 3 | 7 | 5 | 7 | 0 | 3 | 0 |

**Table 3**. Relative abundance of fishes captured in south coast estuaries (Robberg Peninsula – Cape St Francis), November 1994 and September 1995.

| Species | Piesang | | Keurbooms | | Matjies | | Sout | | Groot (Wes) | | Bloukrans | | Lottering | | Elandsbos | | Storms | | Elands | | Groot (Oos) | | Tsitsikamma | | Klipdrif (Oos) | | Slang | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* | *n* | %*n* |
| *Argyrosomus japonicus* | 3 | 0.2 | 9 | 0.4 | | | | | | | | | | | | | | | | | 1 | 0.2 | | | | | | |
| *Atherina breviceps* | | | 10 | 0.5 | | | | | | | | | | | | | | | | | 1 | 0.2 | | | | | | |
| *Caffrogobius gilchristi* | 42 | 3.3 | 5 | 0.2 | | | 1 | 0.9 | | | | | | | | | | | | | | | | | | | | |
| *Caffrogobius natalensis* | 1 | 0.1 | 2 | 0.1 | | | 2 | 1.7 | | | | | | | | | | | | | | | | | | | | |
| *Caffrogobius nudiceps* | | | 2 | 0.1 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Clinus superciliosus* | | | 10 | 0.5 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Diplodus sargus capensis* | | | 189 | 9.2 | | | 1 | 0.9 | | | 1 | 2.5 | | | | | | | | | | | | | | | | |
| *Elops machnata* | | | 1 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Galeichthys feliceps* | 1 | 0.1 | 1 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gilchristella aestuaria* | 684 | 54.0 | | | | | | | 1 | 1.0 | | | | | | | | | | | 364 | 82.2 | 197 | 27.9 | | | | |
| *Heteromycteris capensis* | 3 | 0.2 | 4 | 0.2 | | | | | 4 | 4.1 | | | | | | | | | 2 | 2.2 | 4 | 1.0 | | | | | | |
| *Lichia amia* | | | 2 | 0.1 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lithognathus lithognathus* | 4 | 0.3 | 19 | 0.9 | | | 16 | 13.7 | 33 | 34.0 | 2 | 5.0 | | | 13 | 7.3 | 1 | 3.8 | 8 | 8.6 | 4 | 1.0 | 81 | 11.5 | | | | |
| *Liza dumerili* | 125 | 9.9 | 7 | 0.3 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Liza richardsonii* | 218 | 17.2 | 186 | 9.1 | 18 | 6.7 | 15 | 12.8 | 29 | 29.9 | 32 | 80.0 | 1 | 2.3 | 129 | 72.1 | 2 | 7.7 | 30 | 32.3 | 13 | 2.9 | 121 | 17.2 | 430 | 97.1 | 4 | 2.0 |
| *Liza tricuspidens* | 11 | 0.9 | 10 | 0.5 | | | | | | | | | | | | | 1 | 3.8 | | | | | | | | | | |
| *Monodactylus falciformis* | 7 | 0.6 | 4 | 0.2 | | | 2 | 1.7 | | | | | | | | | 21 | 80.8 | | | | | 2 | 0.3 | | | | |
| *Mugil cephalus* | 59 | 4.7 | 27 | 1.3 | 200 | 74.6 | | | | | | | | | | | | | | | | | 3 | 0.4 | 3 | 0.7 | 1 | 0.5 |
| *Myxus capensis* | 1 | 0.1 | 3 | 0.1 | | | 1 | 0.9 | | | 1 | 2.5 | 42 | 97.7 | 12 | 6.7 | | | | | | | 3 | 0.4 | | | | |
| Mugilidae | 20 | 1.5 | 565 | 27.5 | 50 | 18.7 | 16 | 13.6 | | | | | | | 7 | 3.9 | | | 51 | 54.9 | 33 | 7.5 | 275 | 39.0 | 5 | 1.1 | 197 | 97.5 |
| *Pomadasys commersonnii* | 3 | 0.2 | 1 | 0.0 | | | | | | | 1 | 2.5 | | | | | | | | | | | | | | | | |
| *Pomatomus saltatrix* | 4 | 0.3 | | | | | 23 | 19.7 | 3 | 3.1 | | | | | | | 1 | 3.8 | | | | | | | | | | |
| *Psammogobius knysnaensis* | 14 | 1.1 | 32 | 1.6 | | | 3 | 2.6 | 24 | 24.7 | 3 | 7.5 | | | 9 | 5.0 | | | 1 | 1.1 | 20 | 4.5 | 22 | 3.1 | 5 | 1.1 | | |
| *Rhabdosargus globiceps* | 3 | 0.2 | 6 | 0.3 | | | | | | | | | | | | | | | | | 1 | 0.2 | | | | | | |
| *Rhabdosargus holubi* | 63 | 5.0 | 952 | 46.4 | | | 37 | 31.6 | 3 | 3.1 | | | | | | | | | 1 | 1.1 | 2 | 0.5 | 1 | 0.1 | | | | |
| *Syngnathus temminckii* | | | 3 | 0.1 | | | | | | | | | | | | | | | | | | | | | | | | |

**Table 4**. Biomass of fishes caught in seine (S) and gill (G) nets in south coast estuaries (Robberg Peninsula – Cape St Francis), November 1994 and September 1995.

| Species | Piesang | | Keurbooms | | Matjies | | Sout | | Groot (Wes) | | Bloukrans | | Lottering | | Elandsbos | | Storms | | Elands | | Groot (Oos) | | Tsitsikamma | | Klipdrif (Oos) | | Slang | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G | S | G |
| *Argyrosomus japonicus* | 0 | 3300 | 0 | 10420 | | | | | | | | | | | | | | | | | 0 | 170 | | | | | | |
| *Atherina breviceps* | | | 2.2 | 0 | | | | | | | | | | | | | | | | | 3.4 | 0 | | | | | | |
| *Caffrogobius gilchristi* | 89.6 | 0 | 4.6 | 0 | | | 1.1 | 0 | | | | | | | | | | | | | | | | | | | | |
| *Caffrogobius natalensis* | 1.7 | 0 | 2.9 | 0 | | | 1.5 | 0 | | | | | | | | | | | | | | | | | | | | |
| *Caffrogobius nudiceps* | | | 7.1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Clinus superciliosus* | | | 22.1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Diplodus sargus capensis* | | | 82.1 | 0 | | | 0.8 | 0 | | | 0.3 | 0 | | | | | | | | | | | | | | | | |
| *Elops machnata* | | | 0 | 2570 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Galeichthys feliceps* | 0 | 300 | 0 | 720 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gilchristella aestuaria* | 699.2 | 0 | | | | | | | 1.1 | 0 | | | | | | | | | | | 898.2 | 0 | 218.6 | 0 | | | | |
| *Heteromycteris capensis* | 1.9 | 0 | 2.9 | 0 | | | | | 5 | 0 | | | | | | | | | 3.7 | 0 | 2.15 | 0 | | | | | | |
| *Lichia amia* | | | 0 | 2570 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lithognathus lithognathus* | 68.8 | 200 | 73.3 | 0 | | | 796.2 | 150 | 2929 | 142 | 0.1 | 223.6 | | | 0.7 | 132.4 | 0 | 348 | 0.68 | 2505 | 0.93 | 0 | 957.2 | 3029 | | | | |
| *Liza dumerili* | 25 | 0 | 1273 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Liza richardsonii* | 32 | 5080 | 9384 | 400 | 1.9 | 0 | 557.3 | 2050 | 1667 | 9909 | 7906 | 0 | 0 | 390 | 711.3 | 0 | 0 | 285.6 | 136.4 | 0 | 4464 | 0 | 173.3 | 25727 | 403.6 | 0 | 3.0 | 0 |
| *Liza tricuspidens* | 417.3 | 0 | 183.8 | 3200 | | | | | | | | | | | | | 0 | 1812 | | | | | | | | | | |
| *Monodactylus falciformis* | 0 | 335.4 | 11.5 | 20.97 | | | 0 | 81.6 | | | | | | | | | 0 | 1352 | | | | | 0 | 52 | | | | |
| *Mugil cephalus* | 31.8 | 950 | 13.8 | 920 | 77.0 | 0 | | | | | | | | | | | | | | | | | 0.3 | 602 | 385.3 | 0 | 0.6 | 0 |
| *Myxus capensis* | 0 | 120 | 1.4 | 0 | | | 0.3 | 0 | | | 0.4 | 0 | 33.3 | 0 | 8.6 | 0 | | | | | | | 1.8 | 382 | | | | |
| Mugilidae | 27.6 | 0 | 172.6 | 0 | 5.8 | 0 | 4.9 | 0 | | | | | | | 14.3 | 0 | | | 40.3 | 0 | 7.2 | 0 | 70.9 | 0 | 1.85 | | | |
| *Pomadasys commersonnii* | 281.8 | 120 | 0 | 550 | | | | | | | 0.2 | 0 | | | | | | | | | | | | | | | | |
| *Pomatomus saltatrix* | 0 | 640 | | | | | 25.6 | 800 | 0 | 3109 | | | | | | | 0 | 196.1 | | | | | | | | | | |
| *Psammogobius knysnaensis* | 15.4 | 0 | 32.6 | 0 | | | 3.7 | 0 | 16.5 | 0 | 1.7 | 0 | | | 3.3 | 0 | | | 1.1 | 0 | 20.0 | 0 | 41.4 | 0 | 13.7 | 0 | | |
| *Rhabdosargus globiceps* | 21.81 | 0 | 3.32 | 0 | | | | | | | | | | | | | | | | | 1.7 | 0 | | | | | | |
| *Rhabdosargus holubi* | 1299 | 0 | 830.3 | 0 | | | 571.9 | 60.78 | 14.37 | 0 | | | | | | | | | 0 | 33 | 0 | 180 | 0.4 | 0 | | | | |
| *Syngnathus temminckii* | | | 5.2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Total individuals | 8686 | 11045 | 12109 | 21371 | 84.74 | 0 | 1963 | 3142 | 4633 | 13160 | 7908 | 223.6 | 33.25 | 390 | 738.1 | 132.4 | 0 | 3993 | 182.1 | 2538 | 5397 | 350 | 1464 | 29792 | 804.3 | 0 | 53.6 | 0 |
| Nets | 4 | 3 | 13 | 10 | 3 | 1 | 5 | 3 | 10 | 5 | 7 | 3 | 4 | 3 | 8 | 3 | 0 | 6 | 6 | 3 | 7 | 3 | 7 | 5 | 7 | 0 | 3 | 0 |

**Table 5**. Relative biomass of fishes captured in south coast estuaries (Robberg Peninsula – Cape St Francis), November 1994 and September 1995.

| Species | Piesang | | Keurbooms | | Matjies | | Sout | | Groot (Wes) | | Bloukrans | | Lottering | | Elandsbos | | Storms | | Elands | | Groot (Oos) | | Tsitsikamma | | Klipdrif (Oos) | | Slang | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g | g | %g |
| *Argyrosomus japonicus* | 3300 | 16.7 | 10420 | 31.1 | | | | | | | | | | | | | | | | | 170 | 3.0 | | | | | | |
| *Atherina breviceps* | | | 2 | 0.0 | | | | | | | | | | | | | | | | | 3 | 0.1 | | | | | | |
| *Caffrogobius gilchristi* | 90 | 0.0 | 5 | 0.0 | | | 1 | 0.0 | | | | | | | | | | | | | | | | | | | | |
| *Caffrogobius natalensis* | 2 | 0.0 | 3 | 0.0 | | | 2 | 0.0 | | | | | | | | | | | | | | | | | | | | |
| *Caffrogobius nudiceps* | | | 7 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Clinus superciliosus* | | | 22 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Diplodus sargus capensis* | | | 82 | 0.0 | | | 1 | 0.0 | | | 0 | 0.0 | | | | | | | | | | | | | | | | |
| *Elops machnata* | | | 2570 | 7.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Galeichthys feliceps* | 300 | 1.5 | 720 | 2.2 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gilchristella aestuaria* | 699 | 3.5 | | | | | | | 1 | 0.0 | | | | | | | | | | | 898 | 15.6 | 219 | 0.7 | | | | |
| *Heteromycteris capensis* | 2 | 0.0 | 3 | 0.0 | | | | | 5 | 0.0 | | | | | | | | | 4 | 0.1 | 2 | 0.0 | | | | | | |
| *Lichia amia* | | | 2570 | 7.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lithognathus lithognathus* | 269 | 1.4 | 73 | 0.0 | | | 946 | 18.5 | 3071 | 17.3 | 224 | 2.8 | | | 133 | 15.3 | 348 | 8.7 | 2506 | 92.1 | 1 | 0.0 | 3986 | 12.8 | | | | |
| *Liza dumerili* | 2521 | 12.8 | 1273 | 3.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Liza richardsonii* | 8289 | 42.0 | 9784 | 29.2 | 2 | 2.2 | 2607 | 51.1 | 11576 | 65.1 | 7906 | 97.2 | 390 | 92.1 | 711 | 81.7 | 286 | 7.2 | 136 | 5.0 | 4464 | 77.7 | 25900 | 82.9 | 404 | 50.2 | 3 | 5.6 |
| *Liza tricuspidens* | 417 | 2 | 3384 | 10.1 | | | | | | | | | | | | | 1812 | 45.4 | | | | | | | | | | |
| *Monodactylus falciformis* | 335 | 2.0 | 32 | 0.0 | | | 82 | 1.6 | | | | | | | | | 1352 | 33.9 | | | | | 52 | 0.2 | | | | |
| *Mugil cephalus* | 982 | 5.0 | 934 | 2.8 | 77 | 90.9 | | | | | | | | | | | | | | | | | 602 | 1.9 | 385 | 47.9 | 1 | 1.1 |
| *Myxus capensis* | 120 | 0.6 | 1 | 0.0 | | | | | | | 0 | 0.0 | 33 | 7.9 | 9 | 1.0 | | | | | | | 384 | 1.2 | | | | |
| Mugilidae | 27 | 0.0 | 173 | 0.5 | 6 | 6.9 | 5 | 0.0 | | | | | | | 14 | 1.7 | | | 40 | 1.5 | 7 | 0.1 | 71 | 0.2 | 2 | 0.2 | 50 | 93.4 |
| *Pomadasys commersonnii* | 402 | 2.0 | 550 | 1.6 | | | | | | | 0 | 0.0 | | | | | | | | | | | | | | | | |
| *Pomatomus saltatrix* | 640 | 3.2 | | | | | 826 | 16.2 | 3109 | 17.5 | | | | | | | 196 | 4.9 | | | | | | | | | | |
| *Psammogobius knysnaensis* | 15 | 0.0 | 33 | 0.0 | | | 4 | 0.0 | 16 | 0.1 | 2 | 0.0 | | | 3 | 0.4 | | | 1 | 0.0 | 20 | 0.4 | 41 | 0.1 | 14 | 1.7 | | |
| *Rhabdosargus globiceps* | 22 | 0.0 | 3 | 0.0 | | | | | | | | | | | | | | | | | 2 | 0.0 | | | | | | |
| *Rhabdosargus holubi* | 1299 | 6.6 | 830 | 2.5 | | | 633 | 12.4 | 14 | 0.1 | | | | | | | | | 33 | 1.2 | 180 | 3.1 | 0 | 0.0 | | | | |
| *Syngnathus temminckii* | | | 5 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | |

from its confluence with the Bitou (Duvenhage & Morant, 1984). Below the confluence of the two rivers, the system forms a 0.5 km wide basin separated from the shore by a ridge of dunes that meet at the narrow estuary mouth (Day, 1981; Duvenhage & Morant, 1984). This region has a well-developed flood-tidal delta and is characterised by extensive intertidal sandflats. The N2 National Road crosses the Bitou and Keurbooms Rivers approximately 1.5 and 3.4 km from the confluence respectively. In the Bitou River, the remains of an older road bridge that was washed away in 1940 lies directly upstream of the N2 road bridge; these remains and re-alignment of the estuary channel restrict the tidal flow upstream of the N2 (Duvenhage & Morant, 1984). Although the state of information on the Keurbooms Estuary is regarded as good (Whitfield, 2000), biological/ecological information on the system is lacking.

### *Physico-chemical*

Physico-chemical parameters were measured at eight sites in the Keurbooms system. Site 1 was situated near the mouth of the estuary, sites 2 and 3 were located in the smaller Bitou arm, and sites 4 to 8 in the larger Keurbooms arm of the system. The mouth of the Keurbooms Estuary is permanently open to the sea and is approximately 200 m wide during high spring tide and attains a maximum depth of 4.5 m (Duvenhage & Morant, 1984). Strong tidal currents serve to prevent the build up of sand at the mouth and maintain a permanent connection with the sea. During this survey a depth of 2.7 m was recorded in the mouth of the system. Depths in the Bitou ranged from 0.7 to 2.3 m, while depths in the Keurbooms measured between 0.5 and 2.7 m (Table 1).

There was little variation between surface and bottom water temperatures, which measured between 19.7 and 22.9°C. A horizontal temperature gradient was evident with both surface and bottom water temperatures increasing from the mouth in an upstream direction along both the Bitou and Keurbooms arms of the estuary (Table 1). In July 1974, Duvenhage & Morant (1984) also measured an increase in water temperature towards the head of the estuary and found that the shallower Bitou was warmer than the deeper Keurbooms. In contrast, in September 1981, following spring rains, temperatures measured 12–19°C and decreased towards the head of the estuary (Duvenhage & Morant, 1984).

Surface water salinities ranged between 35.0 and 15.3‰ and were slightly lower than those recorded at the bottom (35.0–22.6‰).

A horizontal gradient was also evident with salinities decreasing upstream of the mouth (Table 1). Day (1981) recorded salinities of between 13 and 30‰ in the estuary, with variations attributed to rainfall and catchment runoff. Salinities in the shallower Bitou arm during this survey were higher than in the Keurbooms arm (Table 1). Duvenhage & Morant (1984) also found that the Bitou was markedly more saline than the Keurbooms and no vertical salinity gradient was observed at the confluence.

The pH recorded during this survey ranged from 7.3 to 8.6 (Table 1). Both surface and bottom values decreased upstream from the mouth and up the main Keurbooms arm and reflected the decline in salinity. The opposite pattern occurred in the Bitou arm with values increasing upstream of the confluence. This may be a result of extensive plant (*Zostera*) growth within the Bitou, as photosynthetic activity can lead to elevated pH values (Klein, 1959). Duvenhage & Morant (1984) recorded a higher pH in the estuary than in the two arms of the system and this was attributed to the elevated pH of seawater.

Surface water dissolved oxygen concentrations ranged between 4.5 and 7.3 mg/l and were generally higher than those at the bottom (3.0–7.4 mg/l) (Table 1). A horizontal gradient was also apparent in the Keurbooms arm with values declining upstream from the mouth. This is probably a result of both thermal and salinity stratification within the system. In the Bitou arm, however, dissolved oxygen values increased upstream from the mouth (Table 1) and extensive plant growth may account for this pattern. In spring 1981 (September) dissolved oxygen values of between 1.0 and 10.4 mg/l were recorded (Duvenhage & Morant, 1984). The water in the system was very clear and turbidity values did not exceed 1 NTU (Table 1). This may be a reflection of the strong marine influence on the system relative to freshwater inputs, as well as the lack of suspensoids in the inflowing river water.

### *Ichthyofauna*

A total of 2050 individuals representing 23 species and 13 families were caught in thirteen seine net hauls and ten gill nets (Table 2). Mugilidae (five species), Sparidae (four species) and Gobiidae (four species) dominated the taxa. The most abundant species was *R. holubi*, which comprised 46.4% of the total catch numerically followed by juvenile mugilids (27.5%), *Diplodus capensis* (9.2%), *L. richardsonii* (9.1%), *P. knysnaensis* (1.6%) and *M. cephalus* (1.3%) (Table 3). A total species mass of over 33 kg was caught (Table 4) and this was dominated by *A. japonicus* (31.1%), *L. richardsonii* (29.2%), *L. tricuspidens* (10.1%), *Elops machnata* (7.7%), *Lichia amia* (7.7%), *L. dumerili* (3.8%), *M. cephalus* (2.8%), *R. holubi* (2.5%) and *P. commersonnii* (1.6%) (Table 5).

Whitfield (1994b) provides a list of 29 fish species reported in the Keurbooms Estuary based on collections made using a D-net trawl (Duvenhage & Morant, 1984), historical gill net data, and the results of a seine net survey. The species reported from the system included *A. japonicus, Atherina breviceps, C. gilchristi, C. natalensis, C. nudiceps, Clinus superciliosus, D. capensis, Diplodus hottentotus, E. machnata, G. feliceps, H. capensis, Hippocampus capensis, L. amia, L. lithognathus, L. dumerili, L. richardsonii, L. tricuspidens, M. falciformis, M. cephalus, M. capensis, Ophisurus serpens, P. commersonnii, P. saltatrix, P. knysnaensis, R. globiceps, R. holubi, Sarpa salpa, S. turbynei* and *Syngnathus temminckii.* Twenty-three of the above species were recorded during this survey.

Most *R. holubi* captured during this survey were small individuals between 20 and 40 mm, which indicates recent recruitment into the estuary. *Diplodus capensis* is also an estuarine-associated marine species; mature individuals (>220 mm FL, Mann & Buxton, 1993) spawn at sea with recruitment into estuaries occurring at <40 mm TL (Whitfield & Kok, 1992). All specimens captured during this survey were newly recruited individuals and were mostly in the 20–30 mm size class. Several size groups of *L. richardsonii* were represented, suggesting regular utilisation of the system. Small individuals were mostly 50–70 mm with larger individuals in the 110–130 mm, 170–200 mm, and 240–280 mm size classes. The vast majority of the *M. cephalus* specimens recorded were juveniles between 20 and 40 mm; this indicates recent recruitment into the estuary. Both young and mature (>40 mm) specimens of *P. knysnaensis* were captured during this survey with most specimens falling within the 30–40 mm size class.

From this survey, seven estuarine-resident species were recorded and these included *A. breviceps, C. gilchristi, C. natalensis, C. nudiceps, C. superciliosus, P. knysnaensis* and *S. temminckii.* Sixteen species were estuarine-associated marine species and these included *A. japonicus, D. capensis, E. machnata, G. feliceps, H. capensis, L. amia, L. lithognathus, L. dumerili, L. richardsonii,* *L. tricuspidens*, *M. falciformis*, *M. cephalus*, *M. capensis*, *P. commersonnii*, *R. globiceps* and *R. holubi*. Estuarine-associated marine species dominated catches and comprised 96.9% of the total number of fish captured and 99.8% of the biomass. Estuarine species comprised only 3.1% of the abundance and 0.2% of the biomass. Of the species recorded by Whitfield (1994b), nine (30%) were estuarine species and 20 (70%) were estuarine-associated marine species. The large numbers of juvenile marine species captured in the Keurbooms Estuary is a function of the permanently open mouth and highlights the importance of this system as a nursery area (Whitfield, 1994b).

## Matjies

The Matjies (34°00'S; 23°28'E) is a small system situated approximately 13 km northeast of Plettenberg Bay. The river flows through a steep-sided valley and at the coast it is separated from the sea by a wide, low sand barrier. Very little is known about the Matjies and the state of information on the system is poor (Whitfield, 2000).

### *Physico-chemical*

Physico-chemical parameters were measured at two sites in the system. The mouth was open at the time of sampling and comprised a shallow, sinuous outflow channel across the sand barrier. Owing to the shallowness of the mouth (0.2 m), only surface measurements were made at this site. Water depth upstream from the mouth measured 0.7 m (Table 1). Water temperatures ranged between 23.4°C and 26.5°C. Surface salinities were low and did not exceed 5‰, however, there was evidence of vertical salinity stratification at the deeper site with surface values (4.5‰) considerably less than those at the bottom (13.8‰) (Table 1). This indicates some seawater input, which could take place when the system opens or during the closed phase by waves overtopping the sand bar at the mouth. The pH of the waters ranged from 7.6 to 8.2 and dissolved oxygen concentrations were between 5.2 and 6.7 mg/l. The water in the Matjies was very clear, with turbidities below 2 NTU (Table 1).

### *Ichthyofauna*

A total of 116 individuals representing two species from one family was caught in three seine net hauls and one gill net (Table 2). *Mugil cephalus* was the most abundant species and accounted for 74.6% of the catch numerically, followed by juvenile mugilids (18.7%) and *L. richardsonii* (6.7%) (Table 3). A total species mass of over 0.84 kg was recorded (Table 4) with *M. cephalus* accounting for 90.9% of the mass followed by juvenile mugilids (6.9%) and *L. richardsonii* (2.2%) (Table 5).

*Mugil cephalus* and *L. richardsonii* are estuarine-associated marine species and catches of both species comprised newly recruited individuals <30 mm. The presence of recently recruited individuals indicates that the Matjies serves some nursery function for these species. However, the lack of larger size classes, together with the absence of estuarine-resident species, suggests that this may be limited.

## Brak

The Brak (33°59'S; 23°32'E) is a coastal stream situated approximately 19 km northeast of Plettenberg Bay. Owing to its small size the fish fauna of the Brak was not sampled. It is unlikely that this system serves any significant nursery function or provides suitable habitat for either estuarine-resident species or estuarine-associated marine species.

## Sout

The Sout (33°59'S; 23°32'E) is situated approximately 19 km northeast of Plettenberg Bay. The Sout River is about 15 km long with a catchment area of 3360 ha. The river is situated within a steep gorge and approximately 700 m from the coast it emerges from the narrow gorge and widens to about 100 m before entering the sea via a cove, with rocky headlands on either side. A sandy flood-tidal delta is situated within the mouth region of the system; these sandflats are intertidal and are exposed at low tide but are inundated at high tide. The system is undeveloped and the entire estuary falls within the De Vasselot Nature Reserve (Morant & Bickerton, 1983). Although the state of information on the Sout Estuary is regarded as moderate, no published biological/ecological information exists on the system (Whitfield, 2000).

### *Physico-chemical*

Physico-chemical parameters were measured at two sites in the Sout. The mouth of the system remains open throughout the year, largely as a result of tidal scour rather than river runoff (Morant & Bickerton, 1983). Average channel water depth recorded during this survey exceeded 1.0 m. Water temperatures ranged from 21.7 to 21.5°C and there was no variation in bottom and surface values (Table 1). Morant & Bickerton (1983) also recorded fairly homogenous temperatures, both with respect to depth and along the length of the estuary. Both horizontal and vertical salinity gradients were recorded during this survey. Surface salinities ranged from 29.8‰ recorded near the mouth to 27.1‰ further upstream; the equivalent bottom salinities measured between 30.2‰ and 28.3‰ (Table 1). Salinity stratification was also evident in November 1982, with tidal seawater entering the estuary below the outflowing fresh river water (Morant & Bickerton, 1983). The pH of the waters was fairly uniform and measured between 8.1 and 8.2, which is similar to that of seawater (Table 1). According to Morant & Bickerton (1983) the estuary characteristically contains peat-stained acid waters that drain vegetated sandstone catchments. In November 1982 when river flow was stronger than during this study, pH values ranged between 6.6 and 7.4 (Morant & Bickerton, 1983). Dissolved oxygen concentrations during this survey were also fairly uniform and ranged from 5.0 to 5.8 mg/l (Table 1); surface values were slightly higher than those at the bottom. Although the river water entering the Sout Estuary is typically peat-stained, turbidities recorded during this survey were low (<3 NTU) (Table 1) and are probably a reflection of the marine-dominated state of the estuary during sampling.

### *Ichthyofauna*

A total of five seine net hauls and three gill nets caught 117 individuals, representing 10 species from five families (Table 2). Gobiidae and Sparidae were represented by three species each and Mugilidae by two species. *Rhabdosargus holubi* dominated catches numerically and accounted for 31.6% of the total catch (Table 3). *Pomatomus saltatrix* (19.7%) was the next most abundant species recorded, followed by *L. lithognathus* (13.7%), juvenile mugilids (13.6%), *L. richardsonii* (12.8%), *P. knysnaensis* (2.6%), *C. natalensis* (1.7%) and *M. falciformis* (1.7%) (Table 3). A total species mass of over 5 kg was caught (Table 4). Important species, in terms of biomass, included *L. richardsonii* (51.1%), *L. lithognathus* (18.5%), *P. saltatrix* (16.2%), *R. holubi* (12.4%) and *M. falciformis* (1.6%) (Table 5). Morant & Bickerton (1983) reported six fish species from the estuary and these include *L. lithognathus*, *M. falciformis*, *R. holubi*, *L. richardsonii*, *M. cephalus* and *P. knysnaensis*. All of these species were also captured during this survey.

The majority of *R. holubi* individuals captured were represented by new recruits between 20–30 mm; a few larger specimens (60–120 mm) were also captured. A cohort of newly recruited *P. saltatrix* between 30 and 70 mm were also recorded together with a few larger (>200 mm) individuals. *Pomatomus saltatrix* is an estuarine-associated marine species with mature adults (>240 mm TL, van der Elst, 1976) spawning at sea and recruitment of juveniles into estuaries taking place at <40 mm TL (Whitfield & Kok, 1992). *Lithognathus lithognathus* were represented by both small, newly recruited individuals (10–30 mm) as well as larger (100–200 mm) specimens. *Lithognathus lithognathus* is a estuarine-dependent marine species and enters estuaries along the southeastern, southern and southwestern Cape coasts at sizes below 50 mm TL (Bennett, 1993). *Liza richardsonii* were also represented by juveniles (50–70 mm) and larger individuals, mostly >200 mm. The presence of juvenile *L. richardsonii* indicates that the Sout Estuary serves an important nursery function and the presence of larger individuals suggests extended utilisation of the system by this species.

Estuarine-associated marine species were the dominant group, represented by seven species: *R. holubi, D. capensis, L. lithognathus, L. richardsonii, M. falciformis, M. capensis* and *P. saltatrix.* Three estuarine-resident species, *C. gilchristi, C. natalensis* and *P. knysnaesis* were recorded. Of the six fish species recorded in the Sout by Morant & Bicketon (1983) only one (17%) was an estuarine species, while the remaining five (17%) were estuarine-associated marine species. During this survey, estuarine species comprised 5.1% of the total catch numerically and 0.1% of the biomass, while estuarine-associated marine species comprised 94.9% of the catch numerically and 99.9% of the biomass. The presence of both estuarine-resident and estuarine-associated marine species in the Sout Estuary indicates that the system serves as a viable habitat for fishes. However, its location in an incised valley, small size and restricted marginal habitat may limit this function.

### Groot (Wes)

The Groot (Wes) Estuary (33°59'S; 23°34'E) is situated 20 km northeast of Plettenberg Bay and forms the western boundary of the Tsitsikamma National Park. The system has a catchment area of 87.8 km$^2$ and two major tributaries, the Bobbejaans (16 km) and the Groot (14 km) flow into the system (Morant & Bickerton, 1983). The R102 road bridge crosses the estuary approximately 2 km from the mouth. Below the road bridge the estuary widens to a maximum width of approximately 300 to 400 m in the middle reaches and then narrows again at the mouth. The western shore is low lying and has some residential development while the eastern shore is characterised by steep hills that drop sharply to the waters edge (Morant & Bickerton, 1983). The state of information on the Groot (Wes) is moderate; however biological/ecological information is lacking (Whitfield, 2000).

#### *Physico-chemical*

Physico-chemical parameters were measured at three sites in the lower, middle and upper reaches of the estuary. The estuary mouth was closed at the time of sampling. The Groot (Wes) is separated from the sea by a broad dissipative beach. The mouth closes sporadically during dry periods and is sometimes opened artificially on an *ad hoc* basis when the water level threatens properties on the western shore (Morant & Bickerton, 1983).

Channel water depths recorded during this survey ranged from 2.1 m in the lower reaches to 1.7 m in the upper reaches (Table 1). Morant & Bickerton (1983) recorded an average depth of 1 m in November 1982, but depths of over 2 m were recorded in the channel in the middle and upper reaches.

Surface water temperatures recorded during this survey increased from 14.5°C in the upper reaches to 15.6°C in the lower reaches and were generally slightly cooler than those at the bottom, which ranged between 17.0°C and 17.9°C (Table 1). Morant & Bickerton (1983) also recorded a slight gradient in surface water temperatures from the head to the mouth as a result of the influent river water being colder than the seawater; bottom water temperatures were also higher than near the surface and this was attributed to warmer, denser seawater lying beneath the cooler, low salinity surface water.

Both horizontal and vertical salinity gradients were evident during this survey. Surface salinities ranged from 5.7‰ in the upper reaches to 6.8‰ in the lower reaches with the equivalent bottom salinities measuring between 19.5‰ and 23.6‰ (Table 1). Marked salinity stratification was also evident in April 1981 and November 1982, with salinity differentials between surface and bottom waters of 21‰ and 24‰ recorded at the mouth and head, respectively. This was caused by breaching of the mouth and the inflow of dense seawater below the less dense outflowing river water (Morant & Bickerton, 1983).

The pH of surface and bottom waters ranged from 6.7 to 7.6, with the lowest values recorded at the upper site (Site 3) (Table 1). The freshwater entering the Groot Estuary is acidic, peat-stained and dark brown in colour.

Consequently the pH values in the estuary vary depending on the amount of freshwater entering the system (Morant & Bickerton, 1983). Dissolved oxygen concentrations in surface waters ranged from 6.2 to 6.9 mg/l, while dissolved oxygen concentrations in bottom waters were lower and ranged from 0.8 to 3.0 mg/l (Table 1). This is probably a result of a lack of mixing due to salinity stratification. Morant & Bickerton (1983) recorded dissolved oxygen concentrations of between 5.5 mg/l and 9.2 mg/l. Although the freshwater entering the Groot (Wes) was peat-stained at the time of sampling, the estuarine waters were clear and the Secchi disc was visible on the bed of the system (Table 1).

#### *Ichthyofauna*

In this survey 10 seine net hauls and five gill nets caught 97 individuals representing seven species from five families (Table 2). Gobiidae and Sparidae dominated the taxa with two species each. *Lithognathus lithognathus* dominated catches numerically and comprised 34% of the total catch followed by *L. richardsonii* (29.9%), *P. knysnaensis* (24.7%), *H. capensis* (4.1%), *R. holubi* (3.1%), *P. saltatrix* (3.1%) and *G. aestuaria* (1.0%) (Table 3). A total species mass of over 17 kg was caught (Table 4) and this was dominated by *L. richardsonii* (65.1%), *P. saltatrix* (17.5%) and *L. lithognathus* (17.3%) (Table 5).

Beam trawl and gill net sampling in April 1981 and November 1982 recorded a total of 17 species (Morant & Bickerton, 1983). These included *L. amia, L. lithognathus, Lithognathus mormyrus, M. falciformis, R. holubi, P. commersonnii, H. capensis, S. turbynei, L. richardsonii, M. cephalus, L. tricuspidens, M. capensis, P. saltatrix, Hemiramphus far, P. knysnaensis, C. gilchristi* and *Sandelia capensis.* Six species were common to those recorded during this survey.

Three size cohorts of *L. lithognathus* were captured during this survey, which indicates regular recruitment and utilisation of the system. The smallest group comprised individuals between 60 and 90 mm, a second group comprised individuals between 110 and 140 mm and the third group were mostly 160–200 mm. *Liza richardsonii* captured during this survey all exceeded 200 mm with most specimens in the 270–290 mm size classes.

*Psammogobius knysnaensis* were between 20 and 50 mm with most specimens in the 20–30 mm size class. The presence of both young and mature specimens indicates a viable habitat for resident species.

Of the seven species caught during this survey, five were estuarine-associated marine species and two were estuarine-resident species. Estuarine-associated marine species dominated catches comprising 74.2% of the catch numerically and 99.9% of the catch by mass. Estuarine species comprised 25.8% of the catch numerically and only 0.1% of the biomass. The Groot (Wes) Estuary appears to serve as a viable habitat for both estuarine-resident and estuarine-associated marine species.

## Helpmekaars

The Helpmekaars (33°58′S; 23°36′E) is a coastal stream located within the Tsitsikamma National Park. Due to its small size, the system appears to be of little value as a habitat for fishes and was not sampled during this survey.

## Klip

The Klip (33°58′S; 23°37′E) is a coastal stream located within an incised river valley within the Tsitsikamma National Park. The system was not sampled during this survey; its small size suggests that it is unlikely to serve any significant function as a habitat for fishes.

## Bloukrans

The Bloukrans Estuary (33°59′S; 23°39′E) is situated within the Tsitsikamma National Park. The river flows through a narrow bedrock valley and opens to the sea between two rocky headlands. A sandy flood-tidal delta is situated in the mouth region of the estuary that is completely covered during high tide but is exposed at low tide. Little is known about the Bloukrans and the state of information on the system is poor (Whitfield, 2000).

### *Physico-chemical*

Physico-chemical parameters were measured at three sites in the system. The estuary discharges to the sea through rocky headlands that prevent the mouth from closing. At high tide the mouth is 100 m wide and 2 m deep while at low tide the channel is 20–30 m wide and discharges low salinity water into the sea. Channel water depth ranged between 1.4 and 3.8 m during this survey (Table 1). Apart from the mouth area (site 1), surface temperatures were slightly lower than those at the bottom, probably linked to cooler river water entering the estuary. A horizontal temperature gradient was also evident with both surface and bottom temperatures declining upstream from the mouth. Surface temperatures ranged from 14.4°C to 13.0°C, while bottom temperatures measured between 14.1 and 13.6°C (Table 1). This thermal pattern is probably a reflection of the stratified salinity regime within the system. Surface salinities decreased in an upstream direction from 6.3 to 1.7‰, while equivalent bottom salinities decreased from 16.2 to 13.3‰. Vertical stratification in the channel was pronounced throughout the estuary, with bottom salinities higher than those at the surface (Table 1). Surface pH values (6.9–6.3) were lower than those at the bottom (7.8–6.8) and also decreased upstream from the mouth. The Bloukrans is one of several estuaries on the Tsitsikamma coast that are characterised by peat-stained river water of low pH and this accounts for the low pH surface water recorded during this survey. Dissolved oxygen values were high, with surface dissolved oxygen concentrations ranging from 9.0 to 9.4 mg/l and bottom dissolved oxygen concentrations ranging from 7.8 to 8.5 mg/l. This is probably a result of salinity stratification within the system. The waters entering the Bloukrans are typically peat-stained but water transparency in the estuary was good; the Secchi disc was visible on the bed of the system near the mouth and elsewhere Secchi disc measurements exceeded 1.6 m (Table 1).

### *Ichthyofauna*

Seven seine net hauls and three gill nets caught a total of 40 individuals representing six species from four families (Table 2). Mugilidae and Sparidae dominated the taxa. The most abundant species numerically was *L. richardsonii,* which comprised 80% of the catch, followed by *P. knysnaensis* (7.5%), *L. lithognathus* (5.0%), *M. capensis* (2.5%), *P. commersonnii* (2.5%) and *D. capensis* (2.5%) (Table 3). A total species mass of over 8 kg was caught (Table 4); this was dominated by *L. richardsonii* (97.2%) and *L. lithognathus* (2.8%) (Table 5).

Two size classes of *L. richardsonii* were caught; the first comprised individuals between 40 and 80 mm and the second size class, which predominated, consisted of larger individuals between 220–280 mm.

Of the taxa collected, five (*L. richardsonii, M. capensis, P. commersonnii, D. capensis* and *L. lithognathus*) were estuarine-associated marine species and only one estuarine-resident species (*P. knysnaensis*) was recorded. Consequently catches were dominated by estuarine-associated marine species that comprised 92.5% of the catch numerically and over 99.9% of the biomass. Estuarine-resident species only comprised 7.5% of the catch numerically and less than 0.1% of the biomass. The presence of estuarine-resident species and estuarine-dependent marine species suggests that the Bloukrans serves some nursery function for these species. However, this function may be limited due to its location in an incised valley, small size and restricted marginal habitat.

## Witels

The Witels (33°59′S; 23°42′E) comprises a coastal stream situated within the Tsitsikamma National Park. Due to its very small size, the Witels is of limited value as a habitat for fishes and was not sampled during this survey.

## Lottering

The Lottering (33°59′S; 23°44′E) is situated within a narrow bedrock valley within the Tsitsikamma National Park. At the mouth of the system an intertidally exposed flood-tidal delta forms a barrier to incoming wave energy. The state of information on the Lottering is poor (Whitfield, 2000).

### *Physico-chemical*

Physico-chemical parameters were measured at two sites in the Lottering. The system was open to the sea at the time of sampling and was very shallow (channel depth <0.5 m), probably a reflection of the low tide. The mouth of the Lottering is confined between two rocky headlands, which serves to maintain a connection with the sea. At high tide the mouth region is inundated, forming an inlet 50–60 m wide and 2 m deep; at low tide the flood-tidal delta at the mouth is exposed and the system is shallow with an outlet 10 m wide. Water temperatures decreased in an upstream direction and ranged from 14.5 to 12.3°C. Salinities were low and decreased from 4.5 to 0.2‰ in an upstream direction. These conditions also reflect the low tide situation with fresh river inflow predominating and low salinities extending to the mouth. The waters that flow into the Lottering are typically peat-stained and acidic, with pH values of between 6.6 and 4.9 being recorded during this survey. Dissolved oxygen concentrations were high, ranging from 9.6 to 10.2 mg/l (Table 1), probably due to the well-mixed nature of the estuary. Although the waters are peat stained the Secchi disc visible on the bed of the system.

*Ichthyofauna*

Forty-three individuals, all belonging to the family Mugilidae and represented by two species (*M. capensis* and *L. richardsonii*) were caught in four seine nets and three gill nets (Table 2). *Myxus capensis* dominated catches numerically comprising 97.7% of the catch, while *L. richardsonii* comprised 2.3% of the catch (Table 3). A total species mass of over 0.4 kg was caught (Table 4). *Liza richardsonii* dominated catches by mass comprising 92% of the catch (Table 5). The *M. capensis* captured during this survey were all small individuals ranging between 20–50 mm with most specimens in the 30–40 mm size class. This suggests recent recruitment into the system and *M. capensis* is known to be attracted to riverine areas immediately above estuaries. Both *L. richardsonii* and *M. capensis* are estuarine-associated marine species. The absence of other estuarine-associated marine species and resident estuarine species indicates that the Lottering may be of limited value as a habitat for estuary-associated fishes.

**Elandsbos**

The Elandsbos (33°00'S; 23°46'E) is situated in a narrow bedrock valley within the Tsitsikamma National Park. A sandy flood-tidal delta is situated at the mouth, which is completely covered during high tide but is exposed at low tide. Very little information exists on the Elandsbos system (Whitfield, 2000).

*Physico-chemical*

Physico-chemical parameters were measured at two sites in the system. The river was in spate at the time of sampling following heavy rains in the catchment. Due to strong river flow, only surface measurements could be taken at the upper site (site 2). The confinement of the mouth between rocky headlands maintains a permanent connection with the sea. At high tide the inlet is 50 m wide and 2 m deep while at low tide estuarine discharges to the sea are via an outlet 20 m wide and 30 cm deep. A water depth of 2.8 m was recorded in the lower reaches (site 1) during this survey. Water temperatures measured 13.9°C throughout the estuary. As the system was in flood, river flow was sufficiently strong to replace both estuarine and seawater within the estuary (salinities <0.1‰). The pH (4.2) was characteristic of the acidic peat-stained waters that drain the catchment. Dissolved oxygen concentrations were high ranging from 10.0 to 10.6 mg/l. The inflowing river water in the Elandsbos is typically peat-stained with low suspensoid levels. However, the Secchi disc during this survey measured 0.7 m near the mouth (site 1) and this is probably due to high river flow and associated suspensoids at the time of sampling (Table 1).

*Ichthyofauna*

A total of 179 individuals representing four species from three families were sampled in eight seine nets and three gill nets (Table 2). In terms of numbers, catches were dominated by *L. richardsonii* (72.1%), followed by *L. lithognathus* (7.3%), *M. capensis* (6.7%), *P. knysnaensis* (5.0%) and juvenile mugilids (3.9%) (Table 3). A total species mass of 0.87 kg was recorded (Table 4) and this was dominated by *L. richardsonii* (81.7%), *L. lithognathus* (15.3 %), juvenile mugilids (1.7%) and *M. capensis* (1%) (Table 5).

The *L. richardsonii* captured were all small individuals (<80 mm) with most specimens in the 60–70 mm size class. This indicates recent recruitment into the system. Three estuarine-associated marine species were caught and one estuarine-resident species. Estuarine-associated marine species were the dominant group and comprised 95.0% of the catch numerically and 99.6 % of the mass. Estuarine species comprised 5.0% of the catch numerically and only 0.4 % of the mass. The presence of both estuarine-resident species and estuarine-associated marine species indicates that the Elandbos serves some nursery function for these fishes. However, this function may be limited owing to its location in an incised valley, its small size and restricted marginal habitat.

**Geelhoutbos**

The Geelhoutbos (34°00'S; 23°47'E) is the outlet of a coastal stream situated within the Tsitsikamma National Park. Due to its very small size, the Geelhoutbos was not sampled during this survey. This system appears to be of little value as a habitat for fishes.

**Kleinbos**

The Kleinbos (34°00'S; 23°49'E) is a coastal stream located within the Tsitsikamma National Park. Due to its very small size, this system was not sampled during this survey. It is unlikely that the Kleinbos provides any significant habitat for fishes.

**Storms**

The Storms River (34°01'S; 23°54'E) is located within a steep-sided, narrow bedrock valley within the Tsitsikamma National Park. The river flows straight into the sea and although there is no barrier at the mouth, wave energy is dissipated through interaction with the seabed and valley sides. The lack of a flood-tidal delta and the steep sided walls of the estuary severely limit intertidal habitat. The state of information on the Storms is poor (Whitfield, 2000).

*Physico-chemical*

Physico-chemical parameters were measured at three sites from the mouth (site 1) to where the inflowing stream discharges into the system (site 3). Water depth ranged from 2.9 m at the uppermost site to over 3 m at the remaining sites. The estuary is up to 14 m deep in places. Surface temperatures (14.4–14.7°C) were slightly lower than those recorded near the bottom (14.7–15.0°C). Horizontal and vertical salinity stratification was evident, with surface salinities decreasing from 24.3 to 20.0‰ in an upstream direction and the equivalent bottom salinities ranging from 29.7 to 28.0‰. The pH of the water during this survey ranged from 7.6 to 7.8. Dissolved oxygen concentrations of the surface waters (8.6–9.0 mg/l) were slightly higher than those recorded at the bottom (7.9–8.2 mg/l). The inflowing river water of the Storms is typically peat-stained but relatively clear, with Secchi disc readings measuring over 1.5 m in the estuary (Table 1).

*Ichthyofauna*

Because of its morphology, only gill netting could be undertaken in the Storms system. Six gill nets caught a total of 26 individuals representing five species from four families (Table 2). *Monodactylus falciformis* dominated catches numerically, comprising 80.8% of the catch, followed by *L. richardsonii* (7.7%), *L. lithognathus* (3.8%), *L. tricuspidens* (3.8%) and *P. saltatrix* (3.8%) (Table 3). A total species mass of over 3 kg was caught (Table 4) and this was dominated by *L. tricuspidens* (45.4%), *M. falciformis* (33.9%), *L. lithognathus* (8.7%), *L. richardsonii* (7.2%) and *P. saltatrix* (4.9%) (Table 5).

*Monodactylus falciformis* individuals ranged between 115 mm and 148 mm and most individuals were in the 110–130 mm size classes. *Monodactylus falciformis* is an estuarine-associated marine species that recruits into estuaries at a length of 5–10 mm SL, with most recruitment taking place between November and March (Melville-Smith & Baird, 1980). Juveniles remain in estuaries until a length of approximately 120 mm SL after which they return to sea (Whitfield, 1998). Only large specimens were captured during this survey and this is due to sampling being limited to gill netting, which does not capture smaller fishes.

Only estuarine-associated marine species (*L. lithognathus, L. richardsonii, L. tricuspidens, M. falciformis* and *P. saltatrix*) were sampled during this survey suggesting that the Storms serves some nursery function for these species. The lack of estuarine-resident species is probably a reflection of the sampling gear being limited to gill netting only. Estuarine species are typically small and are therefore not susceptible to capture by gill netting. The location of the Storms system in an incised river valley with restricted marginal habitat may also limit its value as a habitat for small fishes.

## Bruglaagte

The Bruglaagte (34°01′S; 23°56′E) is the outlet of a coastal stream located within the Tsitsikamma National Park. Due to its very small size, this system was not sampled during this survey. The Bruglaagte discharges to sea across a rocky foreshore and appears to be of limited value as a habitat for fishes.

## Langbos

The Langbos (34°01′S; 23°58′E) comprises a coastal stream situated within the Tsitsikamma National Park. At the coast the stream flows to the sea across an intertidal rocky shoreline. This system appears to be of limited value as a habitat for fishes and was not sampled during this survey.

## Sanddrif

The Sanddrif Estuary (34°02′S; 24°00′E) is fed by a coastal stream within the Tsitsikamma National Park. The stream discharges to the sea across an intertidal rocky coastline. It is unlikely that the Sanddrif provides suitable habitat for fishes and was not sampled during this survey.

## Elands

The Elands Estuary (34°02′S; 24°04′E) is located in a bedrock valley within the Tsitsikamma National Park. The system discharges to sea between two rocky headlands and a sandy flood-tidal delta, which is exposed at low tide, is situated in the mouth region. The state of information on the Elands system is poor (Whitfield, 2000).

### *Physico-chemical*

Physico-chemical parameters were measured at two sites within the Elands; site 1 was located near the mouth while site 2 was situated approximately 1.4 km upstream of the mouth. The mouth of the Elands is confined between rocky headlands, which serve to maintain a permanent connection with the sea. During high tide the mouth is approximately 150 m wide and 2 m deep while at low tide this is reduced to a narrow channel 20 m wide and 0.5 m deep, which flows through the exposed sand flats at the mouth. Channel water depth ranged from 2.0 m at the mouth to 4.7 m upstream. Surface and bottom water temperatures were uniform, decreasing slightly from 13.8°C at the mouth to 13.2°C further upstream. Both surface and bottom waters at the upper site were fresh (0‰); salinities near the mouth were very low (<2‰) with surface values (0.9‰) slightly lower than those at the bottom (1.6‰). The waters within the Elands are typically peat-stained and acidic and this is reflected in the relatively low pH values recorded during this survey. The pH at the upper site measured 4.3–4.5 and this increased slightly to 5.1–5.4 near the mouth. Dissolved oxygen concentrations were high and generally exceeded 10.0 mg/l (Table 1). The inflowing waters of the Elands are typically dark and Secchi disc values during this survey measured 0.7 m (Table 1).

### *Ichthyofauna*

A total of five species representing four families were caught in the Elands during this survey in six seine nets and three gill nets (Table 2). A total of 93 individuals were captured and numerically catches were dominated by juvenile mugilids (54.9%), followed by *L. richardsonii* (32.3%), *L. lithognathus* (8.6%), *H. capensis* (2.2%), *R. holubi* (1.1%) and *P. knysnaensis* (1.1%) (Table 3). A species mass of over 2.7 kg was caught (Table 4), with *L. lithognathus* (92.1%), *L. richardsonii* (5.0%), juvenile mugilids (1.5%), and *R. holubi* (1.2%) dominating the catch (Table 5).

The predominance of juvenile mugilids (<50 mm) during this survey indicates recent recruitment into the system. *Liza richardsonii* was also represented mainly by juveniles, mostly in the 60–70 mm size class.

Only one estuarine-resident species (*P. knysnaensis*) was caught during this survey; the remaining species (*L. richardsonii, L. lithognathus, H. capensis* and *R. holubi*) were all estuarine-associated marine species. Consequently, estuarine-associated marine species were the dominant group and comprised 98.9% of the catch numerically and over 99.9% of the catch by mass. Estuarine species comprised only 1.1% of the catch numerically and <0.1% of the mass. The occurrence of estuarine-resident species and estuarine-associated marine species in this survey suggests that the Elands provides a viable habitat for fishes; however, this function may be limited owing to its location in an incised valley and the lack of marginal habitat.

## Groot (Oos)

The Groot (Oos) Estuary (34°03′S; 24°11′E) is situated within a steep-sided narrow bedrock valley and forms the eastern boundary of the Tsitsikamma National Park. A sandy intertidally exposed flood-tidal delta, approximately 150 m wide, is situated in the mouth region of the system and is confined between rocky headlands. Very little information exists on the Groot (Oos) system (Whitfield, 2000).

### *Physico-chemical*

Physico-chemical parameters were measured at three sites located near the mouth (site 1), 0.5 km upstream (site 2) and 1.8 km upstream (site 3). The mouth of the estuary is fixed between rocky headlands, which maintain a permanent connection with the sea. During high tide the flood-tidal delta is inundated and the mouth is wide; during low tide the delta is exposed and connection to the sea is restricted to a 20 m wide outflow channel. Water depth ranged from 3.7 m at the mouth to 1.6 m at the uppermost site (Table 1). Both surface and bottom water temperatures decreased in an upstream direction; surface temperatures (16.4–15.7°C) were also slightly cooler than those at the bottom (17.0–16.8°C). This is probably a result of salinity stratification with cooler fresh waters overlying warmer, more saline waters. Vertical salinity stratification was well developed with surface salinities (2.3–1.0‰) lower than those at the bottom (28.8–29.2‰). As with most systems within the Tsitsikamma region, the waters entering the Elands are peat-stained and acidic. The pH of the fresher surface water ranged from 6.5 to 6.8, while the pH of the bottom water was 7.7 at all sites. Salinity stratification probably also accounted for the higher surface water dissolved oxygen concentrations (9.2–9.5 mg/l) than those at the bottom (6.5–6.9 mg/l). Water transparency within the system was high with Secchi disc measurements exceeding 1.2 m (Table 1).

#### *Ichthyofauna*

A total of 441 individuals representing nine species from seven families were caught during this survey in seven seine nets and three gill nets (Table 2). Sparidae was the most important family recorded, represented by three species. In terms of numbers, catches were dominated by *G. aestuaria,* which comprised 82.5 of the catch. Other numerically important taxa included juvenile mugilids (7.5%), *P. knysnaensis* (4.5%), *L. richardsonii* (3.0%), *H. capensis* (1.0%) and *L. lithognathus* (1.0%) (Table 3). A total species mass of over 5.7 kg was recorded (Table 4) and this was dominated by *L. richardsonii* (77.7%), *G. aestuaria* (15.6%), *R. holubi* (3.1%) and *A. japonicus* (3.0%) (Table 5).

Although *L. richardsonii* captured during this survey were large individuals, mostly 230 to 300 mm, the predominance of juvenile mugilids (<30 mm), indicates regular recruitment and utilisation of the Groot (Oos) by this group of fishes. *Gilchristella aestuaria* were all mature individuals with most specimens falling in the 50–60 mm size class. *Psammogobius knysnaensis* were represented by both immature and mature size classes, with most individuals above the size at sexual maturity (>30 mm). This suggests that the Groot (Oos) also supports estuarine-resident species.

Three estuarine-resident species (*A. breviceps, G. aestuaria* and *P. knysnaensis*) were recorded during this survey; the remaining species (*A. japonicus, H. capensis, L. lithognathus, L. richardsonii, R. globiceps* and *R. holubi*) were estuarine-associated marine species. Estuarine-resident species dominated catches numerically, comprising 86.9% of the catch, while estuarine-associated marine species comprised 13.1% of the catch numerically. Catches by mass were dominated by estuarine-associated marine species that comprised 84.0% of the catch, while estuarine species comprised 16.0% of the catch. The occurrence of large numbers of both estuarine-resident species and estuarine-associated marine species indicates that the Groot (Oos) serves as a viable nursery area for these fishes. However, this function may be limited owing to the estuaries location in an incised valley and restricted marginal habitat.

### Eerste

The Eerste Estuary (34°04′S; 24°14′E) lies approximately 2 km east of the coastal town of Eersterivier. The system is fed by a coastal stream and was not surveyed because of its small size and rocky nature. It is unlikely that the system serves any function as a habitat for estuarine-associated fishes.

### Boskloof

The Boskloof Estuary (34°05′S; 24°17′E) is fed by a coastal stream situated approximately 52 km west of Cape St Francis. At the time of this survey, the system was flowing to the sea through rocky outcrops. Physico-chemical parameters were measured at one site. A depth of 0.3 m was recorded and the water temperature measured 16.0°C at the surface. A salinity value of only 0.2‰ was recorded, indicating little seawater input. The pH was 7.6 and dissolved oxygen measured 9.4 mg/l (Table 1).

A single seine net haul caught a recently recruited cohort (<30 mm) of more than 100 mugilids. The lack of larger individuals, as well as the absence of estuarine-resident species, suggests that the system is not regularly utilised and is of limited value as a habitat for fishes.

### Kaapsedrif

The Kaapsedrif Estuary (34°06′S; 24°23′E) is fed by a coastal stream situated approximately 45 km west of Cape St Francis. Physico-chemical measurements were made at one site during this survey. The system was flowing out to sea and a depth of 0.5 m was recorded. The water temperature measured 15.6°C and a salinity of only 0.2‰ was recorded indicating little seawater input. The pH of the water was 7.9 and a dissolved oxygen concentration of 9.5 mg/l was recorded (Table 1).

A cohort of over 17 juvenile mugilids (<25 mm) were caught in three seine net hauls. While this indicated recent recruitment into the system, the lack of larger individuals as well as estuarine-resident species suggests that the Kaapsedrif is of limited value as a habitat for estuary-associated fishes.

### Klipdrif (Wes)

The Klipdrif Estuary (Wes) (34°07′S; 24°44′E) is fed by a coastal stream situated approximately 43 km west of Cape St Francis. At the coast the system flows to the sea through rocky outcrops. The Klipdrif (Wes) was not surveyed because of its small size and rocky nature. It is unlikely that the system serves any viable function for estuary-associated fishes.

### Tsitsikamma

The Tsitsikamma (34°08′S; 24°26′E) is a small estuary situated about 40 km west of Cape St Francis. At the coast the estuary is separated from the sea by a broad dissipative sandy beach. Although the state of information on the Tsitsikamma Estuary is regarded as moderate, there is no published information on the biology/ecology of the system (Whitfield, 2000).

#### *Physico-chemical*

Physico-chemical parameters were measured at two sites in the estuary. The mouth dynamics of the Tsitsikamma Estuary are strongly influenced by the presence of exposed sand dunes in the mouth area and the system may remain closed for much of the year (DWAF, 2002). The mouth was open at the time of sampling as a result of recent rainfall and runoff in the catchment. The opening of the mouth had resulted in a lowering of water levels and water depths ranged between 0.9 m in the lower reaches (site 1) to 0.4 m further upstream at site 2. Owing to the shallowness of site 2 only surface measurements were taken at this site. Water temperatures increased from 17.0 at site 2 to 18.1°C at site 1. Although tidal exchange may occur through the periodically open mouth, salinities during this survey were very low (decreasing from 1.0 to 0.2‰ in an upstream direction), thus indicating that the system was dominated by river inflow. The pH of the water was 7.1 and 7.2. Dissolved oxygen concentrations were high and exceeded 8.0 mg/l. High river flow resulted in a relatively low water transparency, with a Secchi disc reading of 0.4 m at site 1 (Table 1).

#### *Ichthyofauna*

Seven seine net hauls and five gill nets caught a total of 705 individuals representing eight species from five families (Table 2). Mugilidae and Sparidae were the most important families, with three and two species recorded respectively. Numerically catches were dominated by juvenile mugilids (39.0%), *G. aestuaria* (27.9%), *L. richardsonii* (17.2%), *L. lithognathus* (11.5%) and *P. knysnaensis* (3.1%) (Table 3). A total species mass of over 31 kg was sampled (Table 4) and this was dominated by *L. richardsonii* (82.9%), *L. lithognathus* (12.8%), *M. cephalus* (1.9%) and *M. capensis* (1.2%) (Table 5).

Several size cohorts of *L. richardsonii* were captured in the Tsitsikamma during this survey. One group comprised small individuals mostly 30–50 mm while a second group comprised individuals 120–160 mm and a third size class comprised larger specimens mostly >200 mm. Several size groups of *L. lithognathus* were also captured; the smallest individuals were in the 10–30 mm size classes, a second size group comprised individuals mostly between 60 and 100 mm, and larger specimens were mostly >140 mm. The presence of a variety of sizes indicates regular recruitment and possible prolonged use by juvenile fish of this estuary. *Gilchristella aestuaria* captured during this survey ranged in size from 36 to 51 mm and included only mature individuals; most specimens fell within the 40–50 mm size class. *Psammogobius knysnaensis* ranged in size from 27 to 52 mm and most specimens were sexually mature (30–50 mm size classes). This suggests that the Tsitsikamma also serves as a viable habitat for estuarine-resident species.

Estuarine-associated marine species dominated the fishes of the Tsitsikamma Estuary with five species (*L. richardsonii, M. cephalus, M. capensis, L. lithognathus* and *R. holubi*) comprising 68.9% of the catch numerically and 99.2% by mass. Two estuarine-resident species (*G. aestuaria* and *P. knysnaensis*) were recorded and they comprised 31.0% of the catch numerically and only 0.8% by mass. The results of this survey indicate that the Tsitsikamma is an important habitat for fishes that depend on estuaries for all or part of their life cycle.

## Klipdrif (Oos)

The Klipdrif (Oos) Estuary (34°10′S; 24°38′E) is situated approximately 2 km west of the coastal village of Oyster Bay. At the coast the system runs parallel to the sea behind a broad beach before discharging into the sea through a shallow outlet channel. Very little information exists on the Klipdrif (Oos) Estuary (Whitfield, 2000).

### *Physico-chemical*

Physico-chemical parameters were measured at two sites in the system. The Klipdrif (Oos) is a small system and is typically closed to the sea by a broad sand barrier for extended periods. At the time of this survey, however, the mouth was open and this was probably a result of increased rainfall and runoff in the catchment. The breaching of the mouth resulted in the system becoming very shallow and the water depth did not exceed 0.3 m. Water temperature decreased from 19.3°C to 17.4°C in an upstream direction. Salinity was low (0.2‰) as a result of high river inflow and this also indicates little marine penetration during the outflow phase. The pH ranged between 7.2 and 7.6 and dissolved oxygen concentrations were high (>9.5 mg/l). High river inflow usually results in reduced water transparency but the shallowness of the system resulted in the Secchi disc being visible on the estuary bed (Table 1).

### *Ichthyofauna*

A total of seven seine net hauls sampled 443 fish representing three species and two families (Table 2). Numerically, catches were dominated by *L. richardsonii* (97.1%) followed by *P. knysnaensis* (1.1%) and juvenile mugilids (1.1%) (Table 3). A total species mass of 0.8 kg was recorded (Table 4) and this was dominated by *L. richardsonii* (50.2%), *M. cephalus* (47.9%) and *P. knysnaensis* (1.7%) (Table 5).

*Liza richardsonii* sampled in the estuary were juveniles, with most individuals in the 30–40 mm size class indicating recent recruitment into the system. Some large *M. cephalus* (>170 mm) were also caught, thus indicating that the system can be utilised by the subadults of estuarine-associated marine species.

Two of the three species recorded (*L. richardsonii* and *M. cephalus*) were estuarine-associated marine species whose juveniles depend on estuaries to varying degrees. Only one estuarine-resident species (*P. knysnaensis*) was sampled. Consequently estuarine-associated marine species dominated catches comprising 98.9% numerically and 98.3% by mass. Estuarine-resident species comprised only 1.1% numerically and 1.7% of the mass. Although the Klipdrif (Oos) is a small system, the occurrence of both marine migrant species as well as resident species indicates that it serves some function for certain estuary-associated species.

## Slang

The Slang (34°10′S; 24°39′E) is located at the coastal village of Oyster Bay. It is a small, shallow system that is predominantly impounded behind a low sandy beach. Very little information exists on the Slang system (Whitfield, 2000).

### *Physico-chemical*

Physico-chemical measurements were made at one site in the Slang, the mouth of which was open at the time of sampling. The Slang is typically closed to the sea for extended periods and when open it discharges to the sea via an outlet channel that is very narrow (2 m) and only a few centimetres deep. The water depth in the channel measured 0.5 m at the time of sampling. Water temperature was 18.7°C and salinity 0.3‰ thus indicating very little seawater input. The system appears to be dominated by river inflow, with marine water input mostly occurring via barrier overwash, although seawater may enter when the mouth is open. The water had a pH of 7.5 and the dissolved oxygen measured 9.3 mg/l. Being very shallow, the Secchi disc was visible on the bed of the system (Table 1).

### *Ichthyofauna*

A total of three seine hauls caught 202 fish representing two species and one family (Mugilidae) (Table 2). In terms of numbers, juvenile mugilids comprised 97.5% of the catch followed by *L. richardsonii* (2.0%) (Table 3). A total species mass of 0.5 kg was sampled (Table 4), with juvenile mugilids (93.4%) dominating the catch followed by *L. richardsonii* (5.6%) and *M. cephalus* (1.1%) (Table 5).

The Slang appears to serve a nursery function for certain marine species, particularly mugilids. Only newly recruited cohorts were recorded, with juvenile mugilids ranging in size from 18–26 mm and *L. richardsonii* from 30–34 mm. Only estuarine-associated marine species were caught during this survey suggesting that its role for estuarine-resident species may be limited.

## GENERAL DISCUSSION

Of the 27 outlets that intersect the coast between Robberg Penninsula and Cape St Francis, 13 systems, Brak, Helpmekaars, Klip, Witels, Geelhoutbos, Kleinbos, Bruglaagte, Langbos, Sanddrif, Eerste, Boskloof, Kaapsedrif and Klipdrif (Wes) are fed by streams and probably serve little or no function as suitable habitat for estuarine-associated fishes. Seven systems on the Tsitsikamma coast (Sout, Bloukrans, Lottering, Elandsbos, Storms, Elands and Groot [Oos]) are relatively small systems situated within deeply incised valleys. The mouths of these systems are fixed between rocky headlands, which serve to maintain a permanent connection with the sea. An intertidally exposed sandy flood-tidal delta is present in the mouth area of the majority of these systems, the exception being the Storms. During low tide these systems are dominated by peat-stained freshwaters with a low pH while at high tide marine waters flood the valley. This results in a large variability in salinity that may tidally range from fully marine to fresh at the mouth. Both marine migrant and estuarine-resident species were recorded from these systems, indicating a viable habitat for these fishes. However, the nursery function is probably restricted due to their small size and limited amount of intertidal and marginal habitat available.

Three estuaries (Matjies, Klipdrif [Oos] and Slang) are small, shallow sandy systems that are typically closed to the sea for extended periods. When open they form shallow drainage channels for freshwater outflow with minimal tidal inflow. Marine water is mainly introduced via wave overwash events. The presence of estuarine-associated fish species suggests some nursery function although this is probably limited due to their small size and sporadic connection with the sea.

The Piesang, Groot (Wes) and Tsitsikamma are slightly larger systems that are also characterised by temporarily open/closed mouths. These systems appear to function as important estuarine nursery areas as is evident in the large numbers of juvenile marine and estuarine species recorded during this survey. The Keurbooms was the only permanently open system within this group, probably due to the large tidal prism and strong currents that serve to maintain a connection with the sea. The system is characterised by regular fluctuations in salinity and water level, extensive intertidal sand flats and eel-grass beds. Large numbers of juvenile marine species were captured in the Keurbooms Estuary and this highlights the importance of the system as a nursery area for these fishes. Whitfield (1994b) also stressed the importance of the Keurbooms Estuary for fish species noting that it is one of only two permanently open functional estuarine systems between Cape St Francis and Mossel Bay.

Overall, the fish fauna of the surveyed estuaries were dominated by estuarine-associated marine species both numerically and by mass. Mugilidae and Sparidae were represented by the greatest number of species, and also dominated catches numerically and by mass. Dominant species included *L. richardsonii, R. holubi, M. cephalus, L. lithognathus* and *L. tricuspidens. Argyrosomus japonicus* (Family Sciaenidae) and *P. saltatrix* (Pomatomidae) were also well represented in catches by mass. Mugilidae are abundant in South African estuaries (e.g. Marais & Baird, 1980; Marais, 1981, 1983; Kok & Whitfield, 1986; Vorwerk *et al.,* 2001) with a total of 10 species recorded from the cool- and warm-temperate regions (Harrison, 2005). Sparidae are also represented by a large number of taxa in the temperate estuaries of South Africa, with a total of 14 species recorded in these systems (Smith & Heemstra, 1991).

In terms of estuarine-resident species very few taxa were recorded, with catches dominated by *G. aestuaria* and to a much lesser extent *P. knysnaensis* and *C. gilchristi.* This group of fishes was generally not well represented within the estuaries surveyed, which suggests that many systems along this coastal sector are of limited value as a habitat for resident fishes. No freshwater species were recorded during this survey, which also suggests limited value as a habitat for this group of fishes.

In summary, of the coastal outlets between Robberg Peninsula and Cape St Francis, 13 (48%) are little more than coastal streams that provide little or no suitable habitat for fishes; a further 7 (26%) are located within deeply incised valleys and provide a restricted habitat for estuary-associated fishes. Seven systems (26%) appear to serve a viable estuarine function for both marine migrant and resident species although some of these may also be limited due to their small size and infrequent connection with the sea. The results of this survey serves to emphasize the importance of these estuaries within this coastal sector.

In conclusion, of the systems assessed by Whitfield (2000) within this coastal sector, the state of available information on over 64% of the estuaries was regarded as poor. Although the remaining systems were regarded as having moderate (29%) to good (7%) information with unpublished reports available, no published biological/ecological information exists on any of these estuaries. As a result of this survey, basic physico-chemical and biological (fishes) information now exists on most systems.

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