FISHES OF THE MNGAZI AND MNGAZANA ESTUARIES, WITH PARTICULAR EMPHASIS ON THE COMMUNITY STRUCTURE AND PRIMARY CARBON SOURCES

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SEKIWE MBANDE

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ABSTRACT

The fish community structure of two contrasting estuaries, one with a well developed mangrove forest (Mngazana) and the other without mangroves (Mngazi) was compared. Both the Mngazi and Mngazana estuary fish communities were dominated by marine species, reflecting the importance of these systems as nursery areas for marine fishes. The Mngazi Estuary contained 18% more estuarine fishes in terms of catch per unit effort (CPUE) than the Mngazana Estuary. The reduced tidal influence due to the narrow mouth opening is a possible reason for the heightened CPUE of estuarine species in the Mngazi estuary.

The recorded higher diversity of fish species in the Mngazana Estuary when compared with the Mngazi Estuary was attributed to the greater influence of the marine environment due to the wide permanently open mouth, as well as the presence of a variety of habitats in this system. In both estuaries tropical and temperate species were captured, confirming the transitional nature of their biogeographic location which is situated close to the boundary between the subtropical and warm temperate regions of the Southern African coastline.

Contrary to previous studies, which recorded seasonal changes in the proportions of tropical and temperate species, the proportions of tropical species remained unchanged at approximately 70% during the January and June sampling occasions. Global warming as a possible reason for the increased dominance of tropical species is discussed.

Although several studies in southern Africa have investigated estuarine food web structure, none have compared mangrove and non-mangrove estuaries. In this study, the primary sources of carbon utilised by the fish fauna in the Mngazi and Mngazana estuaries was investigated. The carbon isotopic values of fishes in both estuaries displayed a continuum rather than a tight clustering around particular energy sources.

Most detritus feeders of the family Mugilidae (mullets) from both estuaries were relatively more enriched than other fish taxa. The isotopic values of the mullet species suggest a diet derived from relatively enriched carbon sources such as benthic microalgae, the eelgrass *Zostera capensis* and associated epiphytes. Based on the isotopic values, piscivorous fishes from both estuaries could not be linked to specific prey fish taxa, but clearly the mullet species were not their main food source.

The invertebrate feeders that were found in both estuaries showed greater isotopic variations in the Mngazana Estuary than in the Mngazi Estuary, probably reflecting the higher diversity of habitats (carbon sources) and invertebrate prey species in the Mngazana system. Generally the isotopic signatures of fishes from the Mngazi Estuary were more enriched than those from the Mngazana Estuary, thus indicating the possible effect of $\delta^{13}C$ depleted mangrove derived carbon in the latter system.

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CHAPTER 1: GENERAL INTRODUCTION

1.1 REGIONAL CLIMATE

The Mngazi (31°40′S, 29°27′E) and Mngazana (31°41′S, 29°25′E) estuaries are situated to the south of Port St Johns on the east coast of South Africa. According to some authors (e.g. Kopke 1988), the Eastern Cape coast incorporates a transition zone of climatic types. In terms of temperature and rainfall, the area south of East London is a warm temperate region and from East London north-eastwards the climate is predominantly subtropical. The largest part of the Eastern Cape has bimodal rainfall with maximum precipitation occurring during summer in the north and east (Kopke 1988).

Records from the Port St Johns lighthouse indicate that this locality and surrounding areas receive an all year round rainfall, with maximum precipitation recorded during summer and a minimum during winter (Wooldridge 1977). The average annual precipitation in this area is about 1 035 mm along the coast decreasing inland to an average of about 850 mm in the catchment area of Mngazana River (Wooldridge 1977). Most of the Eastern Cape experiences mild winters (average = 10°C) and warm summers (average = 22°C), with air temperatures sometimes rising above 40 °C (Kopke 1988).

1.2 REGIONAL MARINE ENVIRONMENT

The Mngazi and Mngazana estuaries lie within the subtropical region of the Eastern Cape Province. The continental shelf in this area is steep, narrow and extends to a maximum of 30 km offshore (Lutjeharms 1998). The warm Agulhas Current closely follows the edge of the continental shelf flowing in a southwesterly direction and has a major influence on the Eastern Cape coastal waters (Lutjeharms 1998). The Agulhas Current is not known to show any clear seasonal patterns in flow behaviour. Oceanographic data collected from the east coast during 1990/1991 revealed Agulhas Current winter temperatures greater than 22°C and salinities of 35.4 ‰ extending to depths of more than 50 m, as far south as the Mbashe region. Agulhas Current temperatures rose to 24°C in summer with warm shelf water extending as far south as

Port St Johns. From the Mbashe southwards, shelf water was cooler (less than 16°C), with a marked decrease in temperature with depth (Beckley & Van Ballengooyen 1992).

Upwelling inshore of the Agulhas Current is intense and persistent in those areas where the continental shelf width increases along the current path (Lutjeharms *et al*. 2000). This upwelling usually occurs all year round, bringing cold nutrient rich water from central water depths to the surface. These upwellings are not related to local winds but generally occur when a jet of water such as the Agulhas passes from a narrow to a wider shelf. One such upwelling site is off the Port Alfred coast. Data obtained from thermal infrared imagery analysed for a 6-year period revealed that subsurface upwelling at the shelf edge off Port Alfred is substantial and frequent, occurring 45% of the time. The frequency of upwelling decreases up the coast from Port Alfred and is evident about 5% of the time in the Port St Johns region. Surface waters in an upwelling cell may be at least 5°C colder than adjacent shelf water over the Agulhas Bank. Upwelled water has an influence on the physical water characteristics as well as nutrients, biota and biological productivity in the area of upwelling (Lutjeharms *et al*. 2000).

Related to the Agulhas Current are inshore current circulations and counter currents that are characterised by periodic current reversals related to winds and changes in pressure fields, e.g. the arrival of coastal lows and polar fronts. These inshore currents are important in the distribution of larvae of intertidal and subtidal organisms, and transportation of larval fish seeking shelter in estuaries. Inshore current circulations, together with wave-induced currents, play a major role in inshore sediment transportation, i.e. in the coast shaping processes of erosion and accretion. In the continental shelf area between Mbashe River mouth and Cape Morgan, south-going currents predominate within 3 km of the coast (Heydorn & Tinley 1980). Nearshore currents that run parallel to the Agulhas Current carry large quantities of marine sediment and have a significant effect on mouth conditions prevailing in most South African estuaries, including those along the Transkei coast (Lutjeharms 1998).

1.3 REGIONAL ESTUARINE ENVIRONMENT

Since estuaries lie at the interface between land and sea, both river flow and tidal exchange influence their physico-chemical state (Schumann *et al.* 1998). In terms of water temperature, rainfall and river run-off, the east coast estuaries include warm temperate and subtropical systems (Day 1981). According to Day (1981) the boundary between the temperate and subtropical regions is the Great Kei Estuary. The estuaries south of the Great Kei are warm temperate and are characterised by variable rainfall and winter temperatures of 12 – 14°C, while estuaries north of the Great Kei are subtropical, receive most precipitation during summer and have water temperatures above 16°C (Day 1981).

In terms of vegetation, the Transkei estuaries encompass both salt marshes, which are normally associated with temperate systems, and mangroves which favour subtropical conditions (Whitfield 1994). Based on vegetation type and the upwelling regime, Whitfield (1994) shifted the boundary between warm temperate and subtropical regions northwards to the Mbashe Estuary (32°16'5"S; 28°54'8"E). More recently Harrison (2002), based on physico-chemical and fish community analyses, has moved the warm temperate/subtropical boundary even further northwards to the Mdumbi Estuary (31°55'50"S; 29°12'58"E).

The Transkei coast stretches 253 km from the Great Kei Estuary (32°40'S; 28°23'E) in the south to Mntamvuna Estuary (31°04'S; 30°11'E) in the north. This area has 120 water bodies that enter the sea, ranging from small coastal streams, temporarily open/closed systems to large permanently open estuaries. More than 80% of these systems have been poorly studied and limited scientific information is available on these estuaries (Harrison *et al*. 1998).

Geomorphologically, Transkei is characterised by extensive areas of rocky coast with a predominance of hard, erosion resistant substrata. This region has few sandy beaches, mostly found in association with river outlets along the coast. Forty-three of these systems were studied by Harrison *et al*. (1998) and grouped into four broad types according to similarities relating to geomorphology and hydrology. About 37% of these were small temporarily open/closed estuaries due to either a small catchment or limited tidal prism. Moderately sized systems with temporarily open mouths constituted 24%, near permanently open inlets with regular tidal exchange formed 26%, while less than 1% (three estuaries) were river dominated systems with permanently open mouths and a reduced tidal prism (Harrison *et al.* 1998)

1.4 REGIONAL CATCHMENTS

The geological formations over which most Transkei rivers flow include Beaufort group sediments, Ecca shales and mudstones, which are easily erodable resulting in high river silt loads and sedimentation in estuaries e.g. Mbashe and Kei systems (Plumstead *et al.* 1989). Most people in Transkei are historically dependent on subsistence farming as a means of life (E. Spaile pers. comm.). Some of their agricultural practices are not ecologically friendly, including veld burning, overgrazing and poor soil conservation measures (Plumstead *et al*. 1989). As a result, Transkei estuaries are generally very turbid and turbidity usually increases with increasing river catchment area (Branch & Grindley 1979), e.g. some of the highest turbidities have been reported from large Transkei rivers, such as the Mbashe, Mzimvubu and Mzimkulu (Day 1981).

The Mngazana Estuary drains a catchment of 365 km^2 that provides a mean annual runoff (MAR) of 62 x 10^6 m^3 (Colloty *et al*. 1999). Most of the catchment lies in densely forested coastal uplands, with *Acacia* scrub and grasslands predominating on the more gently sloping hills. Fifty-four percent of Mngazana land cover is natural while 24% is degraded grassland. Subsistence livestock and crop farming account for 21% of the total land cover in the catchment. Rural dwellings are scattered throughout the catchment and on the hills surrounding the estuary. There are numerous holiday cottages near the estuary mouth, some with slipways and jetties encroaching beyond the spring low tide level. However, residential development accounts for only 1% of the land cover in the catchment (Harrison *et al*. 1998).

The Mngazi Estuary has a catchment of 591 km^2, which provides a MAR of 87 x 10^6 m^3 (Colloty *et al*. 1999). Sixty-two percent of the land cover in the catchment is natural. Residential development accounts for 7% of the land cover, and this includes the Umngazi River Bungalows Resort, which is situated on the north bank in the mouth region and a few rural dwellings. The resort guests use the estuary as a recreational area, especially for fishing, boating and bird watching. Agriculture utilises 29% of the catchment. Agricultural activities are mainly in the form of subsistence livestock and crop farming, commercial forestry and intermittently irrigated crops (Harrison *et al.* 2001).

1.5 STUDY ESTUARIES

The Mngazi and Mngazana study systems were selected for the following reasons:

- The estuaries are similar in length and size.
- The mouths are situated close to one another but the vegetation types surrounding the two estuaries are different.
- Published information suggests that these estuaries are close to the boundary between the warm temperate and subtropical regions.
- Limited information is available on the fishes of these systems and none has been published on trophic links within the ichthyofaunal assemblages.

The Mngazana Estuary has been classified as a permanently open system (Whitfield 2000) and these estuaries generally have the following characteristics (Whitfield 1992):

- A mouth that is permanently open to the sea.
- A moderate tidal prism ($1 – 10 \times 10^6$ m^3).
- A perennial river flow in the natural state.
- A wetland area surrounding the estuary, usually occupied by salt marshes in temperate regions and mangroves in sub-tropical regions.
- The eelgrass *Zostera capensis* is sometimes found in the intertidal and subtidal areas of the lower reaches.
- A salinity profile that is dependent upon bathymetry, tidal cycle and river flow.
- Tidal currents provide the driving force for most of the water turbulence and mixing.
- Average salinities usually fluctuate between 5 and 35‰, with extremes occurring during times of floods, droughts or reduced river flow.

- Water temperatures are strongly influenced by the sea during most of the year and by riverine conditions during periods of floods or high flows from the catchment.
- The biota is usually dominated by marine and estuarine organisms.

The Mngazi Estuary has some of the physical and chemical characteristics of a permanently open system and may have qualified for this category in its natural state. However, under present day conditions the mouth of Mngazi Estuary sometimes closes when river flow is reduced, but this only happens occasionally and is generally of limited duration. The following temporarily open/closed estuary characteristics now apply to the Mngazi Estuary:

- A mouth that is sometimes blocked off from the sea by a sand bar that develops when river flow is minimal or absent. This bar usually develops as a result of low river flow combined with longshore sand movement in the nearshore marine environment.
- Although large amounts of sediment are scoured from the lower reaches in times of flood, marine and fluvial sediments are deposited in these areas immediately after the floods.
- Hydrodynamics of the water column are driven by both tidal and riverine conditions when the mouth is open and mainly wind driven when it is closed.
- Water temperature is influenced by marine and riverine conditions when the mouth is open, with solar heating and evaporative cooling being the prime determinants of water temperature during the closed mouth phase.

A summary of physical and chemical properties of the study systems is presented in the table below:

Table 1.1. Averages of some physico-chemical properties of the Mngazi and Mngazana systems (after Colloty *et al.* 1999).

VARIABLE	**MNGAZANA**	**MNGAZI**
Catchment size (km)	365	591
MAR x $10^6 m^3$	62	87
Average depth (m)	1.31	1.99
Estuary length (km)	6.0	6.5
Forested area (km^2)	1.0	8.0
Irrigated area (km^2)	0.1	0.2
Temperature (^oC)	24.0	23.8
Salinity (‰)	32.4	20.5
Turbidity (NTU)	11.6	12.4

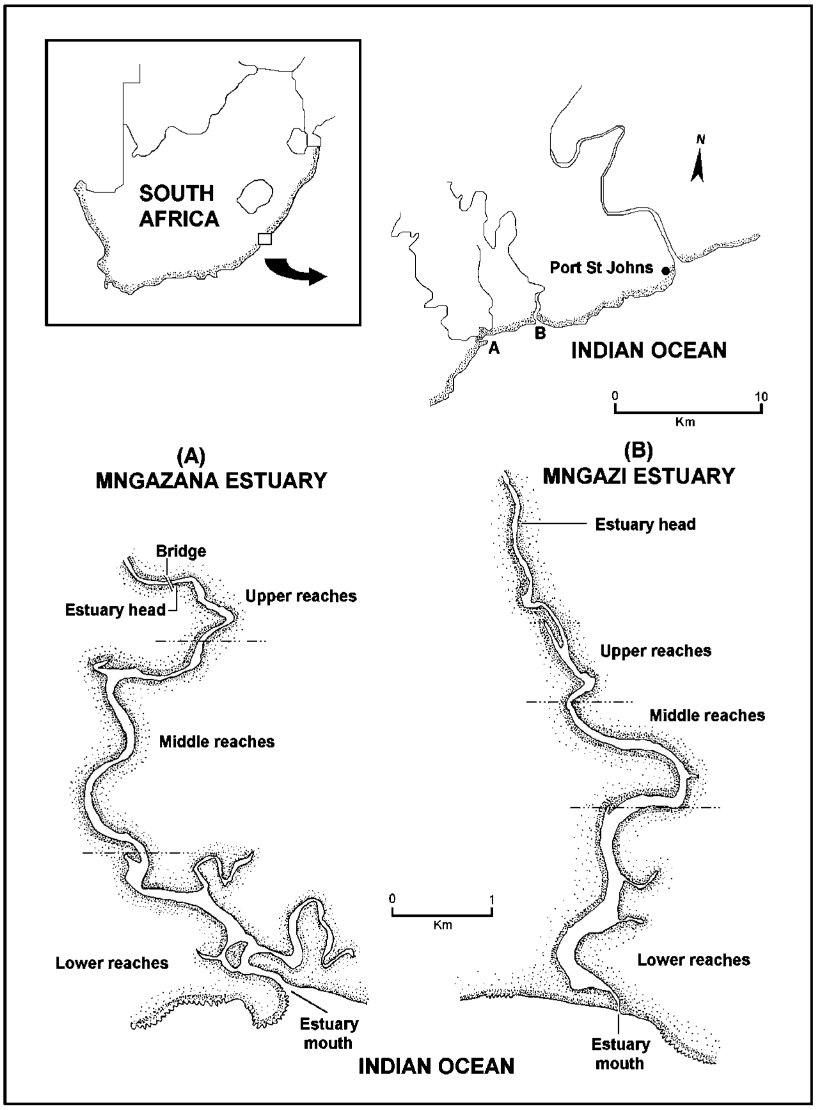

Figure 1.1. Maps showing the location of the study estuaries (A: Mngazana & B: Mngazi) on the South African coastline and the longitudinal divisions within each estuary.

1.5.1 Estuary size and bathymetry

The Mngazana River is about 150 km long but the estuarine portion is only 6 km (Day 1981). A weir built under the bridge that crosses the river (Figure1.1) marks the limit of the estuary and the water above this weir is fresh. Two minor tributaries join the estuary directly, one in the mouth region and the other in the lower reaches (Figure 1.1). Both tributaries are shallow and do not exceed 2 m in depth for most of their length (Branch & Grindley 1979).

The mouth of Mngazana Estuary opens into a broad lagoon with central intertidal sand banks around which channels have formed. The western channel is deep and ranges between 3.5 m and 4 m for most of its course. The low tide depth is about 2.5 m in the lower reaches, increasing to 3 - 4 m in the middle reaches, particularly on the outer bends. The estuary shallows to a low tide depth of about 0.25 m in the upper reaches but increases again to about 1 m at the head region (Wooldridge 1977).

The Mngazi Estuary is about 6.5 km in length (Harrison *et al*. 1998), with the main channel ranging between 50 m and 170 m in width (Day 1981). Depth at mean sea level (MSL), measured at various points from the mouth to the upper reaches, revealed that the Mngazi Estuary is generally shallow (<2 m) with some deeper sections (up to 9 m) in the middle reaches. The mouth region is usually shallow (about 0.5 m) but there are deeper sections (about 1.2 m) depending on the state of the mouth (Harrison *et al*. 1998).

1.5.2 Mouth state

The Mngazana Estuary has extensive sand banks in the lower reaches and mouth region, but because of the large tidal prism the mouth is kept permanently open. The west bank of the estuary has a rocky promontory that prevents further movement of the mouth in a westerly direction and protects the entrance from longshore current sand deposition. The sand dunes on the east bank of the mouth are well vegetated and stable. Branch & Grindley (1979) recorded small seasonal variations in salinity even after river floods and concluded that the tidal prism has a dominant influence on the estuary and mouth state.

The predominantly open Mngazi Estuary is separated from the sea by a wide sand barrier and narrow mouth that limits the influence of the sea on the estuary. In addition, under low river flow conditions, the estuary flows over a rocky sill on the east bank before entering the sea. This sill is perched and as a result tidal amplitude is reduced. During maximum berm development, tidal flows might occasionally fail to reach the estuary even though an outflow channel is present (Harrison *et al*. 1998). The state of the mouth and hence tidal exchange within the estuary is mainly dependent upon river flow. The mouth sometimes closes for short periods when river flow is reduced, with further freshwater abstraction in the catchment likely to increase the frequency and duration of closed mouth conditions (Harrison *et al*. 1998)

1.5.3. Salinity regime

River flow into the Mngazana Estuary results in salinities that are lower in the upper reaches, increasing to a maximum at the mouth (Dye 1979, Branch & Grindley 1979). There is a marked vertical salinity gradient in the upper reaches (especially during summer) where surface salinities are between 5% and 30% lower than bottom salinities. The surface waters experience a wider range of salinity changes than bottom waters (Wooldridge 1977, Branch & Grindley 1979), with surface salinity in the upper reaches being markedly lower during the ebb tide as river flow penetrates further downstream. The surface and bottom waters are relatively well mixed in the middle and lower reaches with relatively uniform salinities throughout these zones (Branch & Grindley 1979).

There is limited information on the salinity regime of the Mngazi Estuary. A winter survey conducted during August, 1996 by the Council for Scientific and Industrial Research (CSIR) showed a high level of vertical salinity stratification over the length of the estuary. The bottom layers had salinities that were close to those of seawater (33‰) decreasing to about 15‰ at the surface. These stratified conditions indicate that tidal mixing of the water column was limited and that the mouth was probably nearly closed during this period. There was no apparent horizontal salinity gradient from the mouth to the upper reaches although salinities at the head of the estuary were 0 – 5‰ (Harrison & Plumstead 2001).

1.5.4 Water temperature

Data collected by Wooldridge (1977) in the Mngazana Estuary revealed a wide seasonal range in water temperature at the upper reaches sites and a narrow range in the mouth region. Water temperatures were generally higher at the mouth (about 19°C) and decreased to about 16°C at the head during winter. The temperatures increased in summer to about 21°C at the mouth and 26°C at the head. The narrow range between summer and winter temperatures in the mouth region may be due to the moderating effect of marine tidal exchanges (Dye 1979).

A slight vertical temperature gradient was evident at the head, with surface temperatures generally lower than bottom temperatures during winter. The winter temperature gradient was attributed to the colder freshwater that flows into the estuary during this season. The temperature gradient at the head was reversed in summer, with warm river water flowing over the cooler more saline bottom waters (Wooldridge 1977).

There is limited data on seasonal changes in water temperature of the Mngazi Estuary. A winter survey conducted by CSIR during August 1996 revealed that there were small changes in temperature along the estuary (Harrison & Plumstead 2001). Temperatures were higher in the upper reaches (mean = 19°C) and gradually decreased to an average of about 17°C at the mouth (Harrison & Plumstead 2001). During summer (January 1998), water temperatures generally increased from the mouth upstream, with surface temperatures higher than bottom temperatures. There was a slight vertical temperature gradient, with surface temperatures ranging between 23.8°C and 25.3°C and bottom temperatures ranging between 23.3°C and 24.5°C, increasing from the mouth to the head (Harrison & Plumstead 2001).

1.5.5 Water quality and dissolved oxygen

A survey conducted by (Harrison *et al*. 1998) revealed that the water quality of the Mngazi and Mngazana estuaries is good. The suitability of the water in both estuaries for aquatic life was slightly impaired in places primarily due to high oxygen absorbed levels and low bottom dissolved oxygen concentrations. The faecal coliform

(*Escherichia coli)* counts in the Mngazana surface waters ranged between 24 and 150 counts per 100 ml, thus indicating that the water was suitable for human contact. *E. coli* counts in the Mngazi surface waters generally increased upstream from the mouth and numbers ranged between 8 and 54 counts per 100 ml (Harrison & Plumstead 2001).

In November 1997, Mngazana surface dissolved oxygen concentrations ranged between 5.4 mg l^{-1} and 8.3 mg l^{-1}. Concentrations of dissolved oxygen in bottom waters were lower, and ranged between 3.1 mg l^{-1} and 6.8 mg l^{-1} (Harrison & Plumstead 2001). In March 1998 concentrations of dissolved oxygen in surface waters increased from the mouth upstream and ranged between 6.5 mg l^{-1} and 7.6 mg l^{-1}, while bottom dissolved oxygen concentrations were lower, ranging from 5.4 mg l^{-1} to 6.5 mg l^{-1}. The overall dissolved oxygen saturation values were between 77 % and 98%.

Nutrient (nitrate and phosphate) concentrations in the surface waters of Mngazana Estuary (measured in March 1998) generally increased upstream from the mouth, thus suggesting a fluvial input. However total ammonia values ranged between zero and 0.4 mg l^{-1}, with the highest value recorded in the surface waters near the mouth. Nitrate values were between 0.48 mg l^{-1} and 0.67 mg l^{-1} in the surface waters. Bottom nitrate values were lower than surface values, and ranged from 0.24 mg l^{-1} to 0.42 mg l^{-1}. Branch & Grindley (1979) recorded relatively high surface nitrate values in the middle reaches, but the highest values were recorded at the bottom near the mouth. They suggested that the influx of marine nitrate might be significant, particularly in view of very low nitrate values in the river. Ortho-phosphate values were between 0.02 mg l^{-1} and 0.04 mg l^{-1} in the surface waters, and between 0.03 mg l^{-1} and 0.04 mg l^{-1}in bottom waters

In November 1997 the concentration of dissolved oxygen in the Mngazi surface waters ranged between 5.5 mg l^{-1} and 7.4 mg l^{-1}. Bottom dissolved oxygen concentrations were lower, ranging between 3.6 mg l^{-1} and 6.8 mg l^{-1}. In March 1998, both surface and bottom dissolved oxygen concentrations were high and increased upstream from the mouth. The surface dissolved oxygen concentrations ranged between 6.9 mg l^{-1} and 7.3 mg l^{-1} and bottom values ranged from 4.9 mg l^{-1} to 7.0 mg l^{-1}. The overall oxygen saturation for Mngazi Estuary water was between 69% and 99% (Harrison & Plumstead 2001).

The nutrient (nitrate and phosphate) values in Mngazi Estuary (measured in March 1998) were generally higher in the surface waters, increasing upstream from the mouth and thus suggesting a fluvial input. Total ammonia concentrations in the surface waters were relatively low, with an average of 0.03 mg l^{-1} while total ammonia concentrations in the bottom waters were considerably higher, ranging from 0.18 mg l^{-1} to 0.31 mg l^{-1}. This was attributed to denitrification where nitrate is converted into ammonia or nitrogen. Nitrate values were between 0.19 mg l^{-1} and 0.56 mg l^{-1} in surface waters and increased upstream from the mouth. Bottom water nitrate values were generally lower than surface values and ranged between 0.16 mg l^{-1} and 0.25 mg l^{-1}. Ortho-phosphate values in the surface waters ranged between 0.02 mg l^{-1} and 0.04 mg $l^{-1}$and increased upstream from the mouth, thus indicating a fluvial input. Bottom water values were generally lower than those at the surface and ranged between 0.03 mg l^{-1} and 0.03 mg l^{-1} (Harrison & Plumstead 2001).

1.5.6 Sediment characteristics

Samples taken during the course of this study revealed that the sediment particle size decreased from the Mngazana Estuary head to the lower reaches. The head sediments were mainly composed of gravel (46%) and coarse sand (35%). The percentage silt content also decreased from the head to the lower reaches. The lower reaches consisted almost exclusively of fine sand (99%) (S. Mbande unpublished), while the mouth region was mainly composed of medium sand (P. Huzinga pers. comm.). The percent organic content increased from the estuary head to the middle reaches and then declined towards the mouth (S. Mbande unpublished).

The sediment particle size also decreased from the head to the middle reaches in the Mngazi Estuary. The lower reaches did not conform to this trend, as their coarse sand component was higher than in the middle reaches (Mbande unpublished). The sediment at the estuary head was mainly composed of gravel (43%) and coarse sand (49%) while fine sand (57%) and coarse sand (35%) were the main components in the lower reaches (Mbande unpublished). In the mouth region, the sediment was mainly composed of medium sand (P. Huzinga pers. comm.). The percent organic content of the sediment generally increased from the head to the lower reaches, with the exception of the upper reaches, where the sediment contained slightly less organic material than at the estuary head (Mbande unpublished).

1.6 ESTUARINE BIOTA

Estuary macrophytes

An extensive mangrove forest made up of *Avicennia marina*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata* dominates the vegetation along the banks of Mngazana Estuary. The roots and pneumatophores of these mangroves act as a natural silt trap and stabilize the banks of the estuary (Branch & Grindley 1979). Recent studies indicate that the mangroves, especially *R. mucronata* are threatened by harvesting. Approximately 11% of the total mangrove area of 154 ha was destroyed between 1961 and 1995 (Dayimani & Adams 2002).

In addition to the Mngazana mangroves, salt marsh plants such as *Sarcocornia perennis*, *Sarcocornia natalensis*, *Chenolea diffusa*, *Triglochin striata*, *Cotula filifolia*, *Salicornia meyeriana*, *Limonium scabrum* and the sedge *Juncus kraussii* are also present in the lower and middle reaches (Colloty 2000). Beds of the eelgrass, *Zostera capensis* are present in the lower reaches, especially in the tributary closest to the mouth (Figure 1.1). The gradient of the estuary bottom increases sharply (i.e. depth decreases rapidly) about 4 km from the mouth and this marks the limit of mangrove penetration, with only a few stunted *Avicennia* and *Bruguiera* found on the banks above this point.

The following plant species were found in the intertidal and supratidal regions of the Mngazi Estuary: *Scheenoplectyus scirpoides*, *Syzygium cordatum*, *Stenotephrum secundatum*, *Phragmites australis*, *Juncus kraussii*, *Cynodon dactylidon*, *Sporobolus virginicus*, *Cyperus textiles* and *Scirpus maritimus*. Typical salt marsh and mangrove plants were absent from the Mngazi estuary.

Estuary invertebrates

Wooldridge (1977) recorded 115 zooplanktonic taxa in the Mngazana Estuary, including copepods, mysids, cumaceans, isopods, amphipods and larval decapods. Marine associated copepods, including *Acartia danae*, *Acartia negligens* and *Oithona* *fallax*, were dominant in the mouth and lower reaches, with typical estuarine zooplankton (e.g. *Oithona brevicornis*) found in large numbers in the lower and middle reaches (Wooldridge 1977). The bed fauna of the estuary head was dominated by typically estuarine species such as *Exosphaeroma estuarium* (isopod), *Melita zeylanica* (amphipod), *Ficopomatus enigmatica* (polychaete) and *Musculus virgiliae* (bivalve) (Branch & Grindley 1979).

Dye (1979) reported a peak in meiofaunal abundance in the mouth region of Mngazana Estuary during the autumn and winter months. Nematodes represented more than 83% of the meiofauna and this dominance persisted during both summer and winter. Also present, in association with rocky habitats in the mouth region were the polychaete (*Pomatoleios* sp.), crabs (*Grapsus grapsus tenuicrustatus* and *Grapsus fairmanoiri*), bivalve and isopod species that are commonly found in association with rocky shores (Branch & Grindley 1979).

The amphipod *Urothoe pulchella* and isopods *Eurydice longicornis* and *Pontogeloides latipes* dominated the lower shore fauna in the Mngazana lower reaches. The gastropod *Assiminea bifasciata* was abundant on the mangrove mud surface in the lower reaches. The infaunal polychaetes, *Ceratonereis keiskamma* and *Orbinia angrapaquensis*, the crab *Cleistostoma algoense* and the swimming prawn *Upogebia africana* dominated the lower reach LWS fauna. Other species that inhabited muddy surfaces in the lower reaches were *Nassarius kraussianus* (Gastropoda) and *Clibanarius longitarsus* (Anomura). *Upogebia africana* is the only species that extended its distribution from the LWS into the mangroves, where oxygen levels in the mud were low (Branch & Grindley 1979).

Crab species of the genus *Uca* and swimming prawns of the genus *Penaeus* were common in the middle reaches, with the mudprawn *Upogebia africana* the dominant species on steep outer banks. The amphipods *Orchestia nectipalma* and the polychaetes *Perinereis nuntia vallata* and *Perinereis falsovariegata* were found on the algae that covered pneumatophores. A total of 34 species of crabs was found associated with various habitats in the Mngazana Estuary (Branch & Grindley 1979). The following crab species were found in association with either mangroves or salt marsh vegetation:

Neosarmatium meinerti, Neosarmatium smithii, Sesarma catenata, Sesarma eulimene, Sesarma guttatum, Uca annulipes, Uca urvillei, and *Uca chlorophthalmus* (Dye 1979).

Mngazi Estuary had a high abundance of zooplankton, represented mainly by copepods and mysids. Copepods were most abundant and were dominated by *Acartia longipatella* in the lower reaches and *Acartia natalensis* in the upper reaches. Mysids were represented by *Rhapolophthalmus terranatalis* and *Mesopodopsis wooldridgei* and were most abundant in the lower reaches (Wooldridge pers. comm.). The marine euryhaline amphipod *Corophium triaenonyx* and the crab *Rhynchoplax bovis* were confined to the lower reaches of Mngazi Estuary, while the same species were abundant in the lower reaches of Mngazana Estuary (Branch & Grindley 1979).

The hyperbenthos in the lower Mngazi Estuary was dominated by *M. wooldridgei* and *R. terranatalis* whereas in the upper estuary *Mesopodopsis africana* was most abundant. Polychaete worms of the genera *Prionospio* and *Cossura* dominated the benthic community. Crustaceans were also common and were dominated by *Grandidierella chelata* in sandy substrata and *Grandidierella lignorum* in muddy areas (Wooldridge pers. comm.).

Ichthyofauna

A total of 62 fish species, including estuarine residents, marine and freshwater species was collected from the Mngazana Estuary by Branch & Grindley (1979). The composition of the fish community showed seasonal changes, with tropical species appearing in large numbers during summer, and species of temperate origin increasing in numbers during winter. Several species of mullet (e.g. *Mugil cephalus*, *Liza dumerili*, *Myxus capensis* and *Liza macrolepis*) predominated in winter and some species (e.g. *Liza richardsonii*, *Lichia amia* and *Valamugil buchanani*) that were common during winter disappeared in summer. Species that only appeared during summer include *Lutjanus fulviflamma*, *Lutjanus argentimaculatus*, *Pomadasys commersonii* and *Pomadasys kakaan*. Several species, including *Terapon jarbua*, *Rhabdosargus holubi* and *Diplodus sargus* occurred throughout the year.

Certain species showed preferences for particular habitats within the Mngazana Estuary e.g. *Psammogobius knysnaensis* occurred in sandy areas near the mouth while

Glossogobius giuris preferred muddy substrata. Also, *Gilchristella aestuaria* and *Ambassis ambassis* were limited to the upper reaches and predominated in the estuary head region. Juvenile marine fish appeared to be diverse and were found in large numbers in *Zostera* beds and surrounding areas.

A CSIR survey conducted in the Mngazi Estuary reported 31 species of fish, which included 22 marine and eight estuarine species. A similar survey conducted in the Mngazana Estuary reported 38 species and these included one freshwater species (*Glossogobius giuris*) in addition to the eight estuarine and 29 marine species (Harrison *et al.* 1998).

Avifauna

Birds play an important ecological role in the cycling and transfer of energy within estuaries. Of particular importance are birds that feed on aquatic vegetation (e.g. coot), invertebrates (e.g. waders) and fish (e.g. cormorants). South African estuaries have a high taxonomic diversity of birds (162 species) and this is attributed to the variety of habitat types that are part of estuarine ecosystems (Hockey & Turpie 1999). Estuarine habitats include mudflats, sandflats, saltmarshes, reedbeds and mangroves, and are utilised by birds for breeding, roosting and feeding. The numbers of birds found in South African estuaries vary with season, e.g. most migrants arrive in estuaries during the austral summer and leave at the onset of winter. Some bird species breed in estuaries and migrate to the tropics during their non-breeding season (Hockey & Turpie 1999).

The following aquatic bird species were seen at the study estuaries during the fish sampling programme: African fish eagle (*Haliaeetus vocifer*), giant kingfisher (*Megaceryle maxima*), pied kingfisher (*Ceryle rudis*), half-collard kingfisher (*Alcedo semitorquata*), malachite kingfisher (*Corythornis leucogaster*), reed cormorant (*Phalacrocorax africanus*), white-breasted cormorant (*Phalacrocorax carbo*), darter (*Anhinga melanogaster*), goliath heron (*Ardea goliath*), grey heron (*Ardea cineria*), great white egret (*Egretta alba*) and little egret (*Egretta garzetta*).

Mammals

Most mammals that might have naturally occurred on the Mngazi and Mngazana estuaries and surrounding areas have become locally extinct. Ellerman *et al.* (1953) and

Plug & Badenhorst (2001) suggested that the following estuary associated mammals used to occur in the Eastern Cape (including the Transkei), viz. hippopotamus (*Hippopotamus amphibius*) and water mongoose (*Atilax paludinosus*). Foot prints of the nocturnal Cape clawless otter (*Aonyx capensis*) were found in the lower reaches of the Mngazana Estuary, and due to the close proximity of the two estuaries, this animal is expected to also occur in the Mngazi Estuary. The Mzimvubu River, the mouth of which lies about 10 km north of the Mngazana Estuary is named after the hippopotamus which suggests that hippos used to occur in this system before becoming locally extinct. It is therefore probable that hippos occurred in both Mngazi and Mngazana estuaries.

CHAPTER 2: THE ICHTHYOFAUNAL COMMUNITIES

2.1 INTRODUCTION

Ichthyological research in the Eastern Cape has been conducted largely on systems between the Kromme and Great Fish estuaries, which excluded the Ciskei and Transkei regions of this province. The availability of published fish information on most estuaries in the Transkei region ranges from limited to none at all (Whitfield 2000). Branch & Grindley (1979) conducted a preliminary investigation into the overall ecology, including that of the fish community, of the Mngazana Estuary. Other more focused studies on the biota of the Mngazana included the zooplankton (Wooldridge 1977), meiofauna (Dye 1979, Dye 1983a, 1983b, 1983c) and mangrove crabs (Emmerson 1990, Emmerson & McGwynne 1992).

The composition and distribution of fishes in estuaries is determined by physical and chemical conditions, as well as biological interactions (Whitfield 1996). In Eastern Cape estuaries, the fish community composition is determined primarily by the response of individual species to the physico-chemical conditions such as salinity, temperature, turbidity and mouth phase (Vorwerk *et al.* 2003). The longitudinal distribution of species within an estuary is indicative of the habitat occupied and the differing physico-chemical conditions along the length of each system.

Hanekom & Baird (1984) found that juveniles of some marine migrants had a preference for eelgrass habitats in the Kromme Estuary. It has been suggested that submerged macrophytes offer these juveniles protection from predators as well as a reliable source of food (Russell 1996, Paterson & Whitfield 2000a). Whitfield (1986) recorded a decline in the catch per unit effort of plant associated fish species in the Swartvlei Estuary and this was attributed to the loss of extensive submerged macrophyte habitats. Thus alterations in the physical conditions such as habitat structure would be expected to result in changes in the fish community structure owing to the effect that this change would have on the abundance and composition of species associated with it. The interactions between the various physical, chemical and biological properties are therefore the reason why the ecology of estuaries display changes in time and space. A good understanding of these interactions is important if estuarine functioning and the conservation of estuarine biodiversity are to be ensured.

The distribution of fish in estuaries is often linked to the salinity regime prevailing in different parts of a system (Whitfield 1998). There is usually a direct relationship between salinity and fish species richness and diversity, with both species richness and diversity decreasing with salinity from the mouth region to the estuary head (Marais 1988). Water temperature also affects fish communities within estuaries. For example, a sudden decline in temperature caused extensive fish mortalities in the St Lucia Estuary (Cyrus & Mclean 1996), while a previous fish kill in the same system was attributed to a combination of extremely low salinities and temperatures (Blaber & Whitfield 1976). Conversely, salinity was not an overriding factor in the Kariega Estuary where no significant longitudinal changes were apparent in the fish communities associated with eelgrass beds, despite a reversed salinity gradient being present in the system at the time of sampling (Ter Morshuizen & Whitfield 1994). In a subsequent Kariega study when a reversed salinity gradient was absent, Whitfield & Paterson (2003) found that a combination of salinity, temperature and percentage vegetation cover influenced the fish community structure. Therefore, while some individual factors do not have a significant effect on the structuring of fish communities in certain systems, a combination of such factors may determine the structure of ichthyofaunal assemblages within these estuaries.

Juveniles of estuary-associated marine species are attracted to shallow turbid waters and along the east coast of Africa such areas are only found in estuaries (Blaber & Blaber 1980). It has been suggested that turbidity provides juvenile fish with protection from visual predators such as certain piscivorous fish and birds, as well as increased feeding success (Blaber & Blaber 1980, Paterson & Whitfield 2000a, 2000b). In Eastern Cape estuaries, visual predators are adversely affected by high turbidity while non-visual predators are relatively unaffected (Cyrus & Blaber 1987a). This reduces inter-specific competition in that different types of predators then forage in different parts of the estuary, based on turbidity gradients that usually exist between the estuary mouth and the head. In the St Lucia system, juveniles of marine species showed preferences for different turbidity levels which resulted in differential distribution patterns (Cyrus & Blaber 1987a, 1987b). In the case of piscivorous species such as *Caranx sexfasciatus,* juveniles and adults have different turbidity preferences and therefore forage in different parts of the estuary, thus reducing intra-specific predation (Blaber & Cyrus 1983).

Estuarine fish communities also display seasonal changes (Whitfield 1998). Seasonal variations in species composition are primarily due to the breeding cycles of estuarine residents and the movements of marine migrant species, with both fish groups being strongly influenced by seasonal changes in environmental conditions (Whitfield 1998).

Information on fish species composition, distribution and seasonal changes is important to better understand the dynamics of these communities. This also has an important bearing on the management, conservation and utilization of natural resources in estuaries. The primary aims of this study were to:

- Compare the fish assemblages of two adjacent estuaries, one containing an extensive mangrove forest (Mngazana) and the other devoid of any mangrove trees (Mngazi).
- Undertake a preliminary investigation into temporal changes in species composition within the two estuaries.
- Compare the distribution and habitat preferences of the ichthyofauna within the two estuaries.
- Compare the fish assemblages in terms of the species biogeographic origins.

2.2 MATERIALS AND METHODS

2.2.1 Physico-chemical properties

Water temperature was measured at each fish sampling site, approximately 0.5 m below the surface, using a mercury thermometer. Water samples were also collected at the same sites (and depth) for subsequent analysis of salinity and turbidity in the laboratory. Salinity (‰) was assessed using a Reichert optical refractometer and turbidity (NTU) was measured with a Hach 2100A turbidimeter.

2.2.2 Ichthyofaunal sampling

Fish were sampled during summer (January) 2001, winter (June) 2001 and summer (January) 2002. Sampling was conducted over three to four consecutive days at each estuary during each field trip. Sampling sites were located throughout the estuary covering the upper, middle and lower reaches and were selected depending on accessibility, with a bias towards sampling as many different habitats as possible. The location of the sampled areas in each estuary is shown in Figure 1.1. Whenever possible, captured fish were identified, counted and returned live to the water. Specimens that could not be identified in the field were preserved for later identification using Smith & Heemstra (1986). In addition representative samples were kept as voucher specimens.

Monofilament gill nets were used during the summer and winter of 2001. These nets, targeting adults or large individuals of marine spawning and freshwater species, were set in the evening (18h00 – 19h00) and lifted at dawn (05h00 – 06h00) on the following day. A total of nine gill nets was used in each estuary on each sampling occasion, with three nets set in the lower, middle and upper reaches respectively. Each net was 10 m long, 2 m in depth and comprised three equal panels of 45 mm, 75 mm and 100 mm stretch mesh. Catch per unit effort (CPUE), as a measure of relative abundance, was defined as the number of fish captured per two nets per night.

A large mesh seine net (50 m long, 2 m deep, with a 3 cm stretch mesh in the wings and a 1 cm stretch mesh bag) was used to target juvenile marine and freshwater fishes (>40 mm SL). Netting was conducted in gently sloping unobstructed areas over a range of habitats. The net was laid in a semicircle from the bank using a motorised boat and hauled ashore by four people. Sampling was carried out between 09h00 and 17h00 at each estuary during January and June 2001. A total of 22 sites was sampled in each estuary during each sampling occasion. The total number of selected sites in each estuarine region (i.e. upper, middle and lower reaches), during a sampling occasion ranged between four and ten. CPUE was defined as the number of fish captured per seine net haul.

A small mesh seine net (30 m long, 2 m deep, with a 1 cm stretch mesh in the wings and bag) was used to target mainly estuarine spawning species. The general sampling procedure and site selection were the same as with the large mesh seine net. A total of 11 sites in each estuary was sampled during January and June 2001. The total number of selected sites in each estuarine region during a sampling occasion ranged between three and five. Because of the large number of fish captured in this net, most specimens were preserved on site for later identification in the laboratory. CPUE was defined as the number of fish captured per seine net haul.

A fry seine net (15 m long, 2 m deep with a stretch mesh of 0.5 cm) was used to sample mainly juveniles of estuarine residents, post-flexion larvae and 0+ juveniles of marine spawning and freshwater species. A total of three hauls was conducted at each of eight sites (upper reaches = 3 sites, middle reaches = 2 sites, lower reaches = 3 sites) in each estuary during January 2002. The net was laid in a semicircle from the bank and hauled onshore by two people. All captured fish were preserved in 10% formalin for later identification and counting in the laboratory. CPUE was defined as the number of fish captured per seine net haul.

Two cast (throw) nets were used to target juveniles of marine spawning and freshwater species, particularly in areas not covered by the seine nets. These nets included one multifilament net with a radius of 1.8 m and a stretch mesh of 2.5 cm, and one monofilament cast net with a radius of 1.3 m and stretch mesh of 2.5 cm. A total of 400 throws was hauled in eight sites (25 throws per site per cast net) within each estuary during January 2002. A total of 50 throws was hauled from each of the eight sites (upper reaches = 3 sites, middle reaches = 2 sites, lower reaches = 3 sites) in each estuary during January 2002. The sampling sites were selected to cover the length of the estuary as well as the full range of habitats within each system. Fish caught were identified, counted and returned live to the water. CPUE was defined as the number of fish captured per 50 (25 + 25) cast net hauls.

2.2.3 Data analysis

All sampled fish were allocated an estuary-dependency category using the descriptions given in Table 1. Longitudinal distribution and seasonal changes in the fish assemblages of Mngazi and Mngazana estuaries were investigated using non-parametric multivariate analyses from the PRIMER version 5.0 package (Clarke & Gorley 2001). A cluster analysis of the fish assemblages in each estuary was created, first on a site basis and then each estuary was geographically divided into three regions, viz. upper, middle and lower reaches. The seine net data consisted of numbers of each species captured at each sampling site. All data were converted into catch per unit effort (CPUE) and root transformed to weigh out the contribution of common and rare species. An association matrix was produced using the Bray-Curtis similarity measure, from which classification and ordination procedures were conducted. The similarity matrix was produced using hierarchical agglomeration with group average linkages (Clarke & Warwick 1994). The longitudinal composition relationships between the estuarine regions, based on their sampled fish assemblages, were examined using hierarchical classification and multi-dimensional scaling (MDS) in two dimensions. Hierarchical clustering and MDS were based on Bray-Curtis similarities of the abundance data. The goodness of fit for the data points in the MDS was measured by the stress coefficient, where stress tends to zero when data are perfectly represented. Stress values <0.2 give a potentially useful 2-dimensional picture, stress <0.1 corresponds to a good ordination and stress <0.05 gives an excellent representation.

A one-way layout ANOSIM (analysis of similarity) was carried out to compare similarities of fish species composition between samples and to determine if there were significant differences between samples. ANOSIM determines the Global value R, which indicates the degree of similarity between the tested groups. Values of R range between –1 and 1, e.g. if all replicates within a site are more similar to each other than any replicates from different sites, then the value of R is 1. Where significant differences ($P < 0.05$) were found, SIMPER (from the Primer package) was used to identify the species that were primarily responsible for those differences.

BIOENV, also from the Primer package, was used to investigate the linkage of driving physico-chemical variables with fish assemblages. This procedure calculates rank correlations between a similarity matrix derived from the species composition and matrices derived from various subsets of the physico-chemical variables measured from the same sites, thereby defining suites of variables that best explain the fish community structure.

Seasonal comparisons between the overall fish assemblages were carried out by combining catches from each gear type for each estuary during summer and winter, and then comparing between seasons as described above.

Table 2.1. The estuary-association categories of fishes that utilise southern African estuaries (after Whitfield 1998).

Categories	Description of categories
I	Estuarine species that breed in southern African estuaries. Further divided into: Ia. Resident species that have not been recorded spawning in marine or freshwater environments. Ib. Resident species that also have marine or freshwater breeding populations.
II	Euryhaline marine species that usually breed at sea with the juveniles showing varying degrees of dependence on southern African estuaries. Further divided into: IIa. Juveniles dependent on estuaries as nursery areas. IIb. Juveniles occur mainly in estuaries, but are also found at sea. IIc. Juveniles occur in estuaries but are usually more abundant at sea.
III	Marine species that occur in estuaries in small numbers but are not dependent on these systems.
IV	Freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. This category includes some species that may breed in both freshwater and estuarine systems.
V	Catadromous species that use estuaries as transit routes between the marine and freshwater environments but may also occupy estuaries in certain regions. Further subdivided into: Va. Obligate catadromous species that require a freshwater phase in their development. Vb. Facultative catadromous species that do not require a freshwater phase in their development.

2.3 RESULTS

2.3.1 Physico-chemical properties

Salinity

Salinity increased from the upper reaches towards the lower reaches during both summer and winter in the Mngazana Estuary. The summer mean salinity was 20.9‰, 29.2‰ and 36.7‰ while in winter mean salinity was 31.4‰, 33.2‰ and 35.3‰ in the upper, middle and lower reaches respectively. There were significant differences between the mean salinity in the upper, middle and lower reaches during summer and winter (ANOVA, $p < 0.05$ in both cases). The difference in the mean salinity between adjacent estuarine regions was not more than 2‰ during winter but increased to 8‰ between reaches during summer (Figure 2.1).

In the Mngazi Estuary salinity also increased from the upper to the lower reaches during both summer and winter. The mean salinity was 15.2‰, 28.0‰ and 27.0‰ during summer; and 14.2‰, 16.5‰ and 20.1‰ during winter in the upper, middle and lower reaches respectively. There were significant differences in salinity between the estuarine regions during summer ($p < 0.002$) but not during winter ($p > 0.05$). The differences in the mean salinity between adjacent estuarine regions were greater in summer (≥ 6‰) than during winter (2‰) (Figure 2.2).

Temperature

The mean summer water temperature in the Mngazana Estuary was 28.7ºC; 27.2ºC and 27.8ºC in the upper; middle and lower reaches respectively. During winter the mean summer temperature was 21.2ºC, 20.7ºC and 20.3ºC in the upper, middle and lower reaches, respectively (Figure 2.1).

The mean summer water temperature in the Mngazi Estuary was 29.6ºC, 28.5ºC and 24.4ºC the upper, middle and lower reaches respectively. During winter, the mean temperature was 22.1ºC, 20.6ºC and 18.7ºC in the upper, middle and lower reaches respectively (Figure 2.2). As expected the mean water temperatures were lower during winter than in summer.

Turbidity

In the Mngazana Estuary, turbidity decreased from the upper reaches to the lower reaches during both summer and winter. During summer, the lower reaches experienced the lowest mean turbidity (9.6 NTU), while the mean turbidity was 14.3 NTU in the middle reaches and 14.1 NTU in the upper reaches. During winter turbidity was 14.0 NTU, 13.7 NTU and 9.7 NTU in the upper, middle and lower reaches, respectively (Figure 2.1).

Turbidity in the Mngazi Estuary was 12.8 NTU, 14.0 NTU and 17.1 NTU during summer while in winter it was 9.9 NTU, 13.2 NTU and 7.9 NTU in the upper middle and lower reaches respectively (Figure 2.2). There were significant differences in the mean turbidity in the three estuarine regions during winter ($p < 0.04$), but this was not the case during summer.

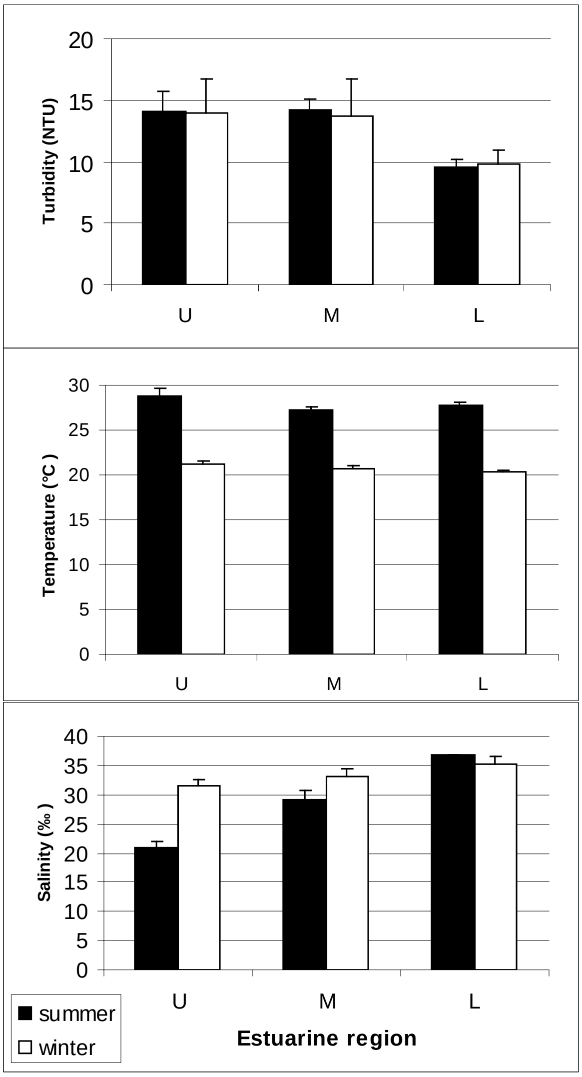

Figure 2.1. Mean (± S.E.) summer/winter turbidity (NTU), temperature (ºC) and salinity (‰) values recorded at the sites in the upper (U), middle (M) and lower (L) reaches of the Mngazana Estuary.

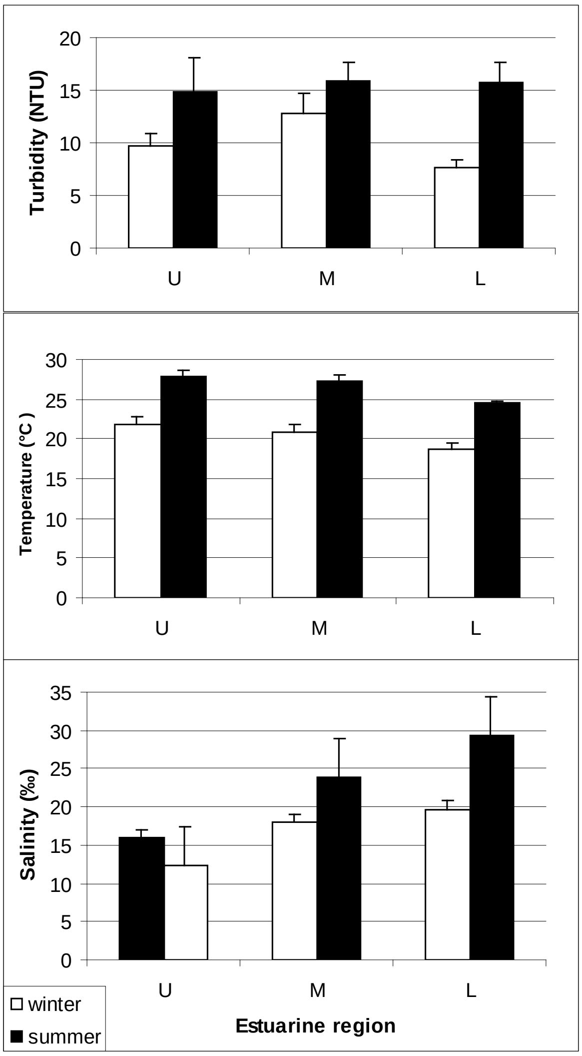

Figure 2.2. Mean (±S.E.) summer/winter turbidity (NTU), temperature (^{o}C) and salinity (‰) values recorded at the sites in the upper (U), middle (M) and lower (L) reaches of the Mngazi Estuary.

2.3.2. Fish species composition

A total of 3 832 fishes representing 31 families and 66 species was captured from the Mngazana Estuary (Table 2.2). The families Gobiidae (14 species) and Mugilidae (11 species) were represented by the most number of species, followed by Carangidae (4 species), Ambassidae (3 species) and Sparidae (3 species). The rest of the families were represented by either single or two species. In terms of the estuary-dependency categories, euryhaline marine species (Category II) dominated the catch composition and constituted 48% (31 species) of the total number of taxa. Categories IIa, IIb and IIc constituted 17% (11 species), 19% (12 species) and 12% (8 species), respectively. The estuarine spawning species (Category I) constituted 28% (18 species) and marine species that are not dependent on estuaries (Category III) comprised 17% (12 species). The freshwater species (Category IV) constituted 5% (3 species) of the total catch composition, while catadromous species (Category V) were represented by a single (2%) facultative catadromous species (Vb) (Figure 2.3). The most abundant species were *Gilchristella aestuaria* (27%), *Atherina breviceps* (19%), *Ambassis dussumieri* (12%), *Leiognathus equulus* (5%), *Glossogobius callidus* (4%), *Rhabdosargus holubi* (4%), *Valamugil cunnesius* (4%) and *Liza dumerili* (3%).

A total of 14 157 individuals representing 24 families and 49 species was captured from the Mngazi Estuary (Table 2.3). The families that dominated the catch composition were Mugilidae (11 species), Gobiidae (8 species), Carangidae (4 species) and Sparidae (4 species). Some families (e.g. Ambassidae and Sphyraenidae) were represented by two species while the rest were represented by single species. Euryhaline marine species (Category II) constituted 57% (28 species) of the catch composition. Marine species that are dependent on estuaries as nursery areas (IIa) constituted 24% (12 species), followed by categories IIb (22%) and IIc (10%). Estuarine species that spawn in estuaries (Category I) constituted 24% (12 species), while marine species that are not dependent on estuaries (Category III) constituted 10% (5 species) and freshwater species 4% (2 species) (Figure 2.3). Both obligate and facultative catadromous species constituted 2% (1 species) each to the total catch composition. The estuarine resident *Gilchristella aestuaria* was the most dominant species and comprised 77 %; other important species included *G. callidus* (5%), *V. cunnesius* (4%), *L. dumerili* (3%), *A. breviceps* (3%), *Thryssa vitrirostris* (2%) and *L. equulus* (1%).

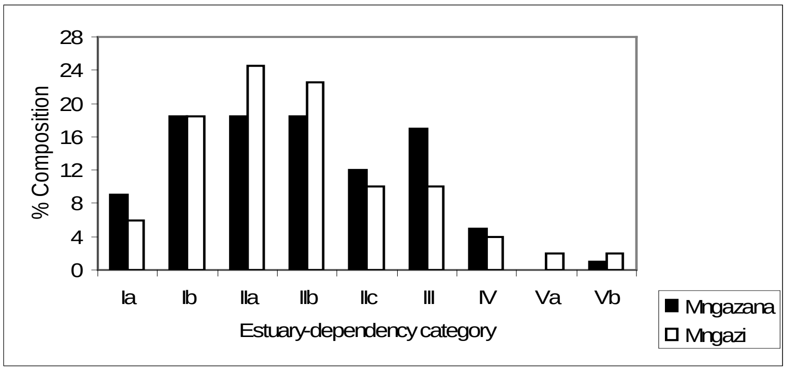

Figure 2.3. Fish species contribution (% of total species) to estuary-dependency categories in the Mngazi and Mngazana estuaries.

2.3.3 Longitudinal distribution

The results of the similarity analysis on a per site basis indicated no longitudinal grouping of fish assemblages in either estuary, although the large seine net summer data from both systems and the Mngazi in winter did show some weak clustering. A geographic division of the estuaries into upper, middle and lower reaches was therefore used in the analysis of data.

In both the Mngazi and Mngazana estuaries, the highest CPUE was in the middle reaches followed by the lower reaches, with the upper reaches having the least catch per unit effort (Tables 2.2 and 2.3). Similarly, in terms of the number of species, the middle and lower reaches had the highest numbers with the upper reaches having the least recorded taxa in both estuaries. A total of 29 fish species was recorded from the Mngazana upper reaches while the middle and lower reaches had a total of 47 species each (Table 2.2). A total of 27 species was captured from the Mngazi upper reaches while the middle and lower reaches contained 32 and 35 species, respectively (Table 2.3).

Gill nets

The gill nets sampled a total of 15 species from the Mngazana Estuary and 16 species from the Mngazi system (Tables 2.2 and 2.3). The dominant species in the Mngazana Estuary were *Hilsa kelee, Liza macrolepis, Mugil cephalus* and *Valamugil buchanani. H. kelee* and *V. buchanani* occurred throughout the estuary, but both had the highest CPUE in the middle reaches. The gill nets captured *Mugil cephalus* in the middle and lower reaches while *L. macrolepis* was only sampled in the lower reaches of the Mngazana Estuary (Table 2.2). The dominant species in the Mngazi Estuary were *Caranx sexfasciatus*, *Pomadasys commersonnii*, *Liza alata*, *L. macrolepis*, *M. cephalus, M. capensis, V. cunnesius* and *Argyrosomus japonicus* (Table 2.3). *Caranx sexfasciatus, L. alata* and *Myxus capensis* were caught in the upper and middle reaches, with the first two taxa dominant in the upper reaches while *M. capensis* was dominant in the middle reaches. *Pomadasys commersonnii*, *M. cephalus*, *L. macrolepis* and *V. cunnesius* were caught in all three Mngazi Estuary regions with the highest CPUE recorded in the middle reaches. *Argyrosomus japonicus* was also sampled in all three estuarine regions but was most dominant in the lower reaches (Tables 2.2 and 2.3).

Large seine

A total of 38 species was captured with the large seine net from the Mngazana Estuary. The following species had the highest abundances and were present in all three estuarine regions: *L. equulus*, *M. argenteus*, *L. dumerili*, *V. cunnesius* and *R. holubi*. *Monodactylus argenteus* and *V. cunnesius* were most abundant in the middle reaches while *L. dumerili* and *R. holubi* had the highest CPUE in the lower reaches. *Leiognathus equulus* catches were well distributed throughout the estuary but the upper reaches yielded higher catches than the other two regions (Table 2.2).

A total of 27 species was captured from the Mngazi Estuary with the large seine net. The most abundant species were *Thryssa vitrirostris*, *L. equulus*, *L. dumerili*, *M. capensis*, *V. cunnesius* and *R. holubi*. *Thryssa vitrirostris* had a high CPUE in the middle reaches and was also caught in the lower reaches. *Valamugil cunnesius* occurred throughout the estuary with the highest CPUE in the middle reaches. *Leiognathus equulus* and *M. capensis* were also caught in all the estuarine regions but the highest

CPUE was recorded in the upper reaches. *Liza dumerili* and *R. holubi* occurred throughout the estuary with highest catches recorded in the lower reaches (Table 2.3).

Small seine

The small seine net captured a total of 15 species from the Mngazana Estuary and the following species had the highest CPUE: *A. dussumieri*, *A. breviceps*, *G. callidus* and *Oligolepis keiensis*. *Ambassis dussumieri* was well represented in all the estuarine regions and had the highest CPUE in the lower reaches. Although *A. breviceps* was present in the upper reaches, it was more abundant in the lower reaches. *Gilchristella aestuaria* was present throughout the estuary but had a high CPUE in the middle reaches. *Glossogobius callidus* was concentrated in the middle reaches, with some representatives in the upper reaches. *Oligolepis keiensis* was caught in both the middle and lower reaches with highest catches in the middle reaches (Table 2.2).

A total of 11 fish species was captured from the Mngazi Estuary with the small seine net. The following species had a high CPUE: *A. breviceps*, *G. aestuaria*, *G. callidus* and *Solea bleekeri*. *Atherina breviceps* was well presented in the middle reaches but the highest catch was recorded in the lower reaches. *Gilchristella aestuaria* was caught in the upper reaches but highest catches were made in the middle reaches. *Glossogobius callidus* was caught in all the estuarine regions, with the highest densities recorded in the middle reaches. *Solea bleekeri* was only found in the middle reaches (Table 2.3).

Fry seine

The fry seine net sampled 32 species from the Mngazana Estuary and these included marine, freshwater and estuarine resident species (Table 2.2). The CPUE of the following species was high: *A. dussumieri*, *G. aestuaria*, *C. natalensis*, *G. callidus*, *M. capensis* and *R. holubi*. *Ambassis dussumieri* was caught throughout the estuary and had a high CPUE in the middle and lower reaches. *Gilchristella aestuaria* had the highest CPUE and although sampled in the middle and lower reaches it was most abundant in the upper reaches. *Glossogobius callidus* also was caught throughout the estuary with highest catches recorded from the upper reaches. *Caffrogobius gilchristi* and *M. capensis* were only found in the middle reaches. *Rhabdosargus holubi* had the highest CPUE in the middle reaches but was also sampled in the upper reaches (Table 2.2).

A total of 18 species was captured with the fry seine net from the Mngazi Estuary and the following species dominated the CPUE: *A. dussumieri, G. aestuaria* and *G. callidus. A. dussumieri* were caught in the middle and lower reaches, had the highest CPUE in the lower reaches. *Gilchristella aestuaria* were caught throughout the estuary with highest CPUE in the lower reaches. *Glossogobius callidus* also occurred in all three estuarine regions but had a high CPUE in the middle and upper reaches (Table 2.3).

Cast nets

The cast nets captured a total of 13 fish species from the Mngazana Estuary, one of which (*Glossogobius giuris*) was a freshwater species. The dominant species were *V. cunnesius, L. dumerili, L. equulus, R. holubi* and *A. berda*. *Valamugil cunnesius* and *R. holubi* were caught in all three estuarine reaches with the former having the highest CPUE in the upper reaches while the latter had the highest CPUE in the middle reaches. *Leiognathus equulus* and *L. dumerili* were caught in the middle and lower reaches. The highest CPUE for *L. equulus* was recorded in the upper reaches while *L. dumerili* had the highest CPUE in the middle reaches. *Acanthopagrus berda* was only caught in the upper reaches (Table 2.2).

A total of 15 species was captured with cast nets in the Mngazi Estuary, with *V. robustus* having the highest CPUE in this system. Although this taxon was sampled in the lower reaches it was more abundant in the middle reaches (Tables 2.3). Other dominant species included L. *dumerili, L. macrolepis* and *A. berda. Liza dumerili* was only caught in the lower reaches whereas *A. berda* was only caught in the upper reaches. *Liza macrolepis* was caught in the middle and lower reaches of the Mngazi Estuary.

Table 2. 2. Catch per unit effort (using five different gear types) of fish species sampled from the upper (UR), middle (MR) and lower (LR) reaches of the Mngazana Estuary.

FAMILY	SPECIES	EST.ASSOC. CAT.	GILL NETS			LARGE SEINE			SMALL SEINE			FRY SEINE			CAST NETS			OVERALL CPUE		
			UR	MR	LR	UR	MR	LR	UR	MR	LR	UR	MR	LR	UR	MR	LR	UR	MR	LR
Ambassidae	Ambassis dussumieri	Ib							11.3	15.7	59.3	6.3	14	10.8	0.7	0.5		18.3	30.2	70.1
	Ambassis natalensis	Ib							0.7									0.7	0	0
	Ambassis producta	Ia							0.7	0.3								0.7	0.3	0
Atherinidae	*Atherina breviceps*	Ib							0.3		171.8	0.2		4.8				0.5	0	176.6
Bothidae	*Bothus pantherinus*	III						0.1			0.3							0	0	0.4
Carangidae	*Caranx ignobilis*	IIb				0.4		0.2					1				0.3	0.4	1	0.5
	Caranx sexfasciatus	IIb	1.4	0.6		0.8	0.4	0.1				0.8	0.3					3	1.3	0.1
	Scomberoides commersonnianus	III					0.2											0	0.2	0
	Scomberoides tol	III				0.8		0.4					0.3					0.8	0.3	0.4
Cichlidae	*Oreochromis massambicus*	IV										0.8						0.8	0	0
Clupeidae	*Gilchristella aestuaria*	Ia							113.6	136.5	0.3	36.8	2.7	9.2				150.4	139.2	9.5
	Hilsa kelee	IIc	2.6	5			0.4											2.6	5.4	0
Elopidae	*Elops machnatha*	IIa	1	1.4								2.3		0.5				3.3	1.4	0.5
Engrualidae	*Thryssa vitrirostris*	III	6.6	10			1.8											6.6	11.8	0
Fistulariidae	*Fistularia petimba*	III						0.2										0	0	0.2
Gerreidae	*Gerres filamentosus*	IIb						0.2										0	0	0.2
	Gerres metheuni	IIb						0.4										0	0	0.4
Gobiidae	*Caffrogobius gilchristi*	Ib								1.3			0.3					0	1.6	0
	Caffrogobius natalensis	Ib								0.3			15					0	15.3	0
	Caffropgobius nudiceps	Ib									0.5		1					0	1	0.5
	Favonigobius melanobranchus	Ib															0.7	0	0	0.7
	Favonigobius reichei	Ib							0.3	0.3	0.5		0.3					03	0.6	0.5
	Glossogobius biocellatus	Ia									0.3			0.2				0	0	0.5

	Glossogobius callidus	Ib							1	8.2		17.3	3	3.3				18.3	11.2	3.3
	Glossogobius gyuris	IV													1.7			1.7	0	0
	Oligolepis acutipennis	Ia											1.7	1.3				0	1.7	1.3
	Oligolepis keiensis	Ia								8.3	2.3		5.3					0	13.6	2.3
	Oxyurichthys ophthalmonema	Ib								0.3	0.3							0	0.3	0.3
	Periophthalmus argentilineatus	Ia								0.5								0	0.5	0
	Psammogobius knysnaensis	Ib											0.7	2.7				0	0.7	2.7
	Stenogobius polyzona	IIb										0.2						0.2	0	0
Haemulidae	*Pomadasys commersonnii*	IIc	0.6	0.4		0.8		0.3				3.5	3.7	1.7				4.9	4.1	2
	Pomadasys kaakan	IIa				0.3	0.1											0.3	0.1	0
Labridae	*Labrid sp.*	III											0.3					0	0.3	0
Leiognathidae	*Leiognathus equulus*	IIb		0.4		9.2	7.8	7.3						0.2		3	1.7	9.2	11.2	9.2
Lutjanidae	*Lutjanus fulviflamma*	IIc											2.7					0	2.7	0
Monacanthidae	*Canthirhines dumerilii*	III						0.1										0	0	0.1
Monodactylidae	*Monodactylus argenteus*	IIb				0.5	12.6	0.7										0.5	12.6	0.7
	Monodactylus falciformis	IIa										0.7	0.7	0.2	0.3			1	0.7	0.2
Mugilidae	*Liza alata*	IIb	0.6				0.4	0.1										0.6	0.4	0.1
	Liza dumerili	IIb				3.6	3.8	7.8								3	4.3	3.6	6.8	12.1
	Liza macrolepis	IIa	0.4	1	2.3	2	0.3	2.3										2.4	1.3	4.6
	Liza richardsonii	IIc						0.3								0.5		0	0.5	0.3
	Liza tricuspidens	IIb			0.2			0.2										0	0	0.4
	Liza subviridis	IIb						0.1										0	0	0.1
	Mugil cephalus	IIa		1	1.5	1.3	1	1				0.2			1			2.5	2	2.5
	Myxus capensis	Vb				0.4		3.5					11.3			0.5		0.4	11.8	3.5
	Valamugil buchanani	IIc	2.4	2.4			0.1	0.1										2.4	2.5	0.1
	Valamugil cunnesius	IIa		0.6		0.6	17.8	0.3					0.3		3.7	1	0.3	4.3	19.7	0.6
	Valamugil robustus	IIa	0.4				0.5	0.2										0.4	0.5	0.2
Paralichthyidae	*Pseudorhombus arsius*	III						0.4										0	0	0.4
Platycephalidae	*Platycephalus indicus*	IIc				0.8	0.3											0.8	0.3	0

Sciaenidae	*Argyrosomus japonicus*	IIa	0.4	0.4		0.3	0.2											0.7	0.6	0
Serranidae	*Epinephelus marginatus*	III											0.7					0	0.7	0
Siganidae	*Siganus sutor*	III						0.3										0	0	0.3
Soleidae	*Solea bleekeri*	IIb								0.3	0.5	0.2	2.7					0.2	3	0.5
Sparidae	*Acanthopagrus berda*	IIa		0.4	0.4	1.7	0.6								2.3			4	1	0.4
	Rhabdosargus holubi	IIa				4.7	2.4	8.7				0.5	11.7		0.3	3	0.3	5.5	17.1	9
	Rhabdosargus sarba	IIb				0.3		0.2										0.3	0	0.2
Sphyraenidae	*Sphyraena jello*	IIc				0.6	0.2	0.7										0.6	0.2	0.7
Syngnathidae	*Hippichthys spicifer*	Ib					0.3											0	0.3	0
Synodontidae	*Saurida gracilis*	III							0.7		0.3							0.7	0	0.3
Teraponidae	*Terapon jarbua*	IIa					0.2	0.2				0.2	0.3					0.2	0.5	0.2
Tetreodontidae	*Arothron immaculatus*	III						0.2				0.2	0.3					0.2	0.3	0.2
	Arothron hispidus	III						0.7					1.3					0	1.3	0.7
Torpenidae	*Torpedo fuscomaculata*	IIc					0.1											0	0.1	0
																		254.3	340.2	320.6

Table 2. 3. Catch per unit effort, using five different gear types, of fish species sampled from the upper (UR), middle (MR) and lower (LR) reaches of the Mngazi Estuary.

FAMILY	SPECIES	EST.ASSOC. CAT.	GILL NETS			LARGE SEINE			SMALL SEINE			FRY SEINE			CAST NETS			TOTAL CPUE		
			UR	MR	LR	UR	MR	LR	UR	MR	LR	UR	MR	LR	UR	MR	LR	UR	MR	LR
Ambassidae	*Ambassis dussumieri*	Ib											0.2	9.1				0	0.2	9.1
	Ambassis natalensis	Ib								0.3	0.4							0	0.3	0.4
Anguillidae	*Anguilla marmorata*	Va													0.3			0.3	0	0
Atherinidae	*Atherina breviceps*	Ib								28.7	52.1			4				0	28.7	56.1
Bothidae	*Bothus pantherinus*	III												0.1				0	0	0.1
Carangidae	*Caranx ignobilis*	IIb	2			0.2	0.3											2.2	0.3	0
	Caranx sexfasciatus	IIb	6.6	1		1.7	0.7											8.3	1.7	0
	Lichia amia	IIa	2															2	0	0
	Scomberoides tol	III														0.5		0	0.5	0
Chanidae	*Chanos Chanos*	IIc				0.2		`										0.2	0	0
Cichlidae	*Oreochromis massambicus*	IV										2	0.8				0.3	2	0.8	0.3
Clupeidae	*Gilchristella aestuaria*	Ia							14.3	1572.2	1123.2	1.3	9.8	36.7				15.6	1582	1159.9
Dasyatidae	*Gymnura natalensis*	III					0.2											0	0.2	0
Elopidae	*Elops machnatha*	IIa	1.4	0.6	0.6							3.6	0.3	0.1				5	0.9	0.7
Engraulidae	*Thryssa vitrirostris*	IIb					34	1.1										0	34	1.1
Gerreidae	*Gerres filamentosus*	IIb						0.3										0	0	0.3
Gobiidae	*Caffrogobius gilchristi*	Ib									0.5		0.5	0.1				0	0.5	0.6
	Favonigobius reichei	Ib							0.3					0.1				0.3	0	0.1
	Glossogobius callidus	Ib							2.7	4.5	1.9	34.9	44.2	3.3				37.6	48.7	5.2
	Glossogobius gyuris	IV														0.5		0	0.5	0
	Oligolepis acutipennis	Ia								1			3.2	0.3				0	4.2	0.3
	Oligolepis keiensis	Ia								3.1				0.2				0	3.1	0.2

	Oxyurichthys ophthalmonema	Ib								0.3								0	0.3	0
	Psammogobius knysnaensis	Ib									0.3							0	0	0.3
Haemulidae	*Pomadasys commersonnii*	IIa	0.6	3.4	2.6		0.8	3.3						0.1			0.7	0.6	4.2	6.7
Leiognathidae	*Leignathus equulus*	IIb		1.4	0.6	8.2	7.4	3.2									1	8.2	8.8	4.8
Mugilidae	*Liza alata*	IIb	6.6	2		1.7									0.7			9	2	0
	Liza dumerili	IIb				0.2	0.4	41.3									3	0.2	0.4	44.3
	Liza macrolepis	IIa	0.6	7.2	3.2	0.2	2.9	1.6								0.5	0.7	0.8	10.6	5.5
	Liza richardsonii	IIc						0.5										0	0	0.5
	Liza tricuspidens	IIb			2		1.1	1.1										0	1.1	3.1
	Liza subviridis	IIb															1	0	0	1
	Mugil cephalus	IIa	5.6	6	4.6	1	0.1	1.6								0.5	0.3	6.6	6.6	6.5
	Myxus capensis	Vb	1.4	2.6		8.1	02.2	0.8				0.1	0.2		1			10.6	5	0.8
	Valamugil buchanani	IIc	1.6	2		0.4												2	2	0
	Valamugil cunnesius	IIa	0.6	2.6	1.2	4.4	77.3	2.4							0.7			5.7	79.9	3.6
	Valamugil robustus	IIa	0.6		2	0.4		1.2								14.5	1	1	14.5	4.2
Paralichthyidae	*Pseudorhombus arsius*	III						0.9						0.1				0	0	1
Aciaenidae	*Argyrosomus japonicus*	IIa	1.6	2.2	4.6		0.7	0.2										1.6	2.9	4.8
Soleidae	*Solea bleekeri*	IIb								8.9		0.3	0.5	0.1				0.3	9.4	0.1
Sparidae	*Acanthopagrus berda*	IIa					1	0.8							1.3			1.3	1	0.8
	Diplodus sargus	IIc						0.1										0	0	0.1
	Rhabdosargus holubi	IIa				0.3	2.4	8.9					0.8	0.1				0.3	3.2	9
	Rhabdosargus sarba	IIb						1										0	0	1
Sphyraenidae	*Sphyraena baraccuda*	IIb	0.6															0.6	0	0
	Sphyraena jello	IIc				0.2												0.2	0	0
Syngnathidae	*Hippichthys spicifer*	Ib												0.1				0	0	0.1
Teraponidae	*Terapon jarbua*	IIa					0.1	1				0.1	0.5	0.4				0.1	0.6	1.4
	Arothron hispidus	III						0.2										0	0	0.2
Zanclidae	*Zanclus canescens*	III						0.1										0	0	0.1
																		122.6	1858.9	1334.3

2.3.4 Temporal changes

Data from the fry seine net and cast nets were not included in the analysis of temporal changes in the fish community structure as these gears were only used during the January 2002 sampling.

The contributions of the various estuary-dependency categories to the total catch composition and the percent contribution of each species to the total number of fish captured from the two estuaries during January and June are presented in Tables 2.4, 2.5 and 2.6.

A total 1 775 specimens comprising 21 families and 41 species was caught (gill, large seine and small seine combined) from the Mngazana Estuary during the January sampling occasion. The fish assemblage was dominated by euryhaline marine species (Category II), which contributed 56% to the total number of species collected. Estuarine species that breed in estuaries (Category I) constituted 23% of the total number of species, while marine species that are not dependent on estuaries (Category III) constituted 13.5%. The following species were numerically abundant during summer in the Mngazana Estuary: *A. breviceps* (39%), *G. aestuaria* (17%), *A. dussumieri* (13%), *V. cunnesius* (7%) and *L. equulus* (6%).

The total number of fish caught, using the same combination of gears, from the Mngazana Estuary during the June sampling occasion was 1 106, representing 20 families and 45 species. In terms of the estuary-dependency categories, the assemblage was dominated by marine migrant species that constituted 56% (26 species) of the total number of species, while estuarine taxa that breed in estuaries constituted 23% (11 species). Marine species that are not dependent on estuaries constituted 14% (6 species) of the total number of species captured during winter in the Mngazana Estuary. The most abundant species were *G. aestuaria* (43%), *A dussumieri* (7%), *Monodactylus argenteus* (7%), *L. equulus* (6%), and *L. dumerili* (5%).

A total of 10 977 fish, representing 17 families and 31 species was caught (gill, large seine and small seine combined) from the Mngazi Estuary during the January sampling occasion. Euryhaline marine species were the most dominant species and constituted 68% (25 species) of the species sampled during this season. Estuarine species that breed in estuaries constituted 24% (9 species) of the species captured. *Gilchristella aestuaria* (88%) and *V. cunnesius* (5%) were the most numerically abundant taxa.

A total of 1 863 fish, representing 17 families and 35 species was sampled with the same combination of gears from the Mngazi Estuary during the June sampling occasion. The fish assemblage was dominated by euryhaline marine species, which constituted 67% (23 species) of the catch composition, followed by estuarine species that breed in estuaries, which constituted 21 % (7 species). The most numerically abundant species were *G. aestuaria* (44%), *T. vitrirostris* (13%), *L. dumerili* (13%), *R. holubi* (5%) and *V. cunnesius* (4%).

Table 2.4. The percent species composition of fishes in each estuary-dependency category sampled during January and June 2001 from the Mngazi and Mngazana estuaries.

	Mngazi Estuary		**Mngazana Estuary**	
Estuary-association category	% Contribution January	% Contribution June	% Contribution January	% Contribution June
Ia	8	6	9	6
Ib	16	15	14	17
IIa	30	32	22	26
IIb	27	23	22	17
IIc	11	12	18	13
III	5	9	14	19
Vb	3	3	2	2

Table 2.5. Percentage contribution (per gear type) of fish species sampled during January and June in the Mngazana Estuary, together with an indication of the geographic affinity of each species.

FAMILY	SPECIES	ORIGIN	GILL NET		LARGE SEINE		SMALL SEINE	
			January	June	January	June	January	June
Ambassidae	Ambassis dussumieri	Tropical					19.2	12.5
	Ambassis natalensis	Tropical						0.3
	Ambassis ambassis	Tropical						0.5
Atherinidae	*Atherina breviceps*	Endemic					55.3	
Bothidae	*Bothus pantherinus*	Tropical				0.3		0.2
Carangidae	*Caranx ignobilis*	Tropical			0.4	0.5		
	Caranx sexfasciatus	Tropical	5.0	3.6	0.2	1.6		
	Scomberoides commersonnianus	Tropical				0.5		
	Scomberoides tol	Tropical			0.8	1.1		
Clupeidae	*Gilchristella aestuaria*	Endemic					24.4	73.8
	Hilsa kelee	Tropical	25	9.5	0.6			
Elopidae	*Elops machnatha*	Tropical	5.0	4.8				
Engraulidae	*Thryssa vitrirostris*	Tropical	13.3	50	1.7	1.1		
Fistulairidae	*Fistularia petimba*	Tropical				0.5		
Grrreidae	*Gerres filamentosus*	Tropical			0.4			
	Gerres metheuni	Endemic			0.8			
Gobiidae	*Caffrogobius gilchristi*	Endemic						0.6
	Caffrogobius natalensis	Endemic						0.2
	Caffropgobius nudiceps	Endemic					0.2	
	Favonigobius reichei	Tropical					0.1	0.5
	Glossogobius biocellatus	Tropical					0.1	
	Glossogobius callidus	Endemic					0.2	3.9
	Oligolepis keiensis	Tropical						3.9
	Oxyurichthys ophthalmonema	Tropical						0.3
	Periophthalmus argentilineatus	Tropical					0.2	
	Psammogobius knysnaensis	Endemic						1.4
Haemulidae	*Pomadasys commersonii*	Tropical	1.7	2.4		1.6		
	Pomadasys kaakan	Tropical			0.2	0.3		
Leiognathidae	*Leiognathus equulus*	Tropical	1.7		23.3	16.1		
Monacanthidae	*Canthirhines dumerilii*	Tropical			0.2			
Monodactylidae	*Monodactylus argenteus*	Tropical			1.7	20.3		
Mugilidae	*Liza alata*	Tropical		2.4	0.6	0.3		
	Liza dumerilii	Endemic			12.3	15.6		
	Liza macrolepis	Tropical	11.7	13.1	6.6	1.1		
	Liza richardsonii	Endemic			0.2	0.5		
	Liza tricuspidens	Endemic	1.7		0.4			
	Liza subviridis	Tropical				0.3		
	Mugil cephalus	Cosmopolitan	11.7	6.0	2.5	2.6		
	Myxus capensis	Endemic			0.6	7.3		

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	Valamugil buchanani	Tropical	15	6.0	0.4			
Platycephalidae	*Valamugil cunnesius*	Tropical	1.7	1.2	27.1	0.5		
	Valamugil robustus	Endemic		1.2	0.4	7.4		
Paralichthyidae	*Pseudorhombus arsius*	Tropical			0.2	0.8	0.1	
Platycephalidae	*Platycephalus indicus*	Tropical			0.4	0.8		
Sciaenidae	*Argyrosomus japonicus*	Tropical	3.3			0.5		
Siganidae	*Siganus sutor*	Tropical				0.8		
Soleidae	*Solea bleekeri*	Endemic				0.3	0.2	2.0
Sparidae	*Acanthopagrus berda*	Tropical	3.3		1.5	1.6		
	Rhabdosargus holubi	Endemic			13.1	12.4		
	Rhabdosargus sarba	Tropical			0.4	0.3		
Sphyraenidae	*Sphyraena jello*	Tropical			0.6	2.1		
Synodontidae	*Saurida gracilis*	Tropical					0.1	0.6
Teraponidae	*Terapon jarbua*	Tropical			0.4	0.3		
Tetraodontidae	*Arothron hispidus*	Tropical			1.5			
	Arothron immaculatus	Tropical				0.5		
Torpedinidae	*Torpedo fuscomaculata*	Tropical			0.2			

Table 2.6. Percent contribution (per gear type) of fish taxa sampled during January and June in the Mngazi Estuary, together with an indication of the geographic affinity of each species.

FAMILY	SPECIES	ORIGIN	GILL NET		LARGE SEINE		SMALL SEINE	
			January	June	January	June	January	June
Ambassidae	Ambassis dussumieri	Tropical						
	Ambassis natalensis	Tropical					0.02	0.1
Atherinidae	*Atherina breviceps*	Endemic					2.5	8.1
Carangidae	*Caranx ignobilis*	Tropical	1.5	2.7		0.4		
	Caranx sexfasciatus	Tropical	10.4	8.2	0.2	1.4		
	Lichia amia	Temperate		4.1				
Chanidae	*Chanos chanos*	Tropical			0.1			
Clupeidae	*Gilchristella aestuaria*	Endemic					97.0	86.7
Dasyatidae	*Gymnura natalensis*	Endemic			0.1			
Elopidae	*Elops machnatha*	Tropical	1.5	4.1				
Engraulidae	*Thryssa vitrirostris*	Tropical				29.3		0.2
Gerreidae	*Gerres filamentosus*	Tropical			0.3			
Gobiidae	*Caffrogobius gilchristi*	Endemic						0.2
	Favonigobius reichei	Tropical					0.1	
	Glossogobius callidus	Endemic					0.1	2.9
	Oligolepis acutipennis	Tropical					0.03	
	Oligolepis keiensis	Tropical					0.04	0.7
	Oxhyurichthys ophthalmonema	Tropical						0.1
	Psammogobius knysnaensis	Endemic						0.1
Haemulidae	*Pomadasys commersonii*	Tropical	9.0	6.8	3.0	1.2		
Leioganathidae	*Leignathus equulus*	Tropical	3.0	1.4	8.4	7.0		
Mugilidae	*Liza alata*	Tropical	9.0	10.9		1.2		
	Liza dumerili	Endemic		0	16.5	27.8		
	Liza macrolepis	Tropical	3.0	20.6	2.0	2.0		
	Liza richardsonii	Endemic		0	0.5			
	Liza tricuspidens	Endemic	1.4	2.7	0.9	1.2		
	Mugil cephalus	Cosmopolitan	23.9	16.4	0.8	2.7		
	Myxus capensis	Endemic	1.5	6.8	4.0	5.7		
	Valamugil buchanani	Tropical	9.0	1.4	0.1	0.1		
	Valamugil cunnesius	Tropical	3.0	6.8	54.6	7.9		
	Valamugil robustus	Endemic	6.0	1.4	1.7	0.7		
Paralichthyidae	*Pseudorhombus arsius*	Tropical			0.5	0.5		
Sciaenidae	*Argyrosomus japonicus*	Tropical	16.4	5.5	0.2			
Soleidae	*Solea bleekeri*	Endemic					0.2	0.8
Sparidae	*Acanthopagrus berda*	Tropical			1.5	0.1		
	Diplodus sargus	Temperate				0.1		
	Rhabdosargus holubi	Endemic			3.4	9.8		
	Rhabdosargus sarba	Tropical			0.2			
Sphyraenidae	***Sphyraena barracuda***	Tropical	1.5					
	Sphyraena jello	Tropical				0.1		
Teraponidae	*Terapon jarbua*	Tropical			0.8	0.4		
Tetraodontidae	*Arothron hispidus*	Tropical				0.2		
Zanclidae	*Zanclus canescens*	Tropical				0.1		

2.3.5 Similarity analysis

The BIOENV procedure indicated no significant correlations between the fish community structure and the physical and chemical properties that were investigated (Table 2.7). The highest correlations were found in the Mngazi Estuary where estuarine resident species had a positive correlation (R) of 0.31 with salinity, R = 0.27 for salinity and temperature combined, and R = 0.22 for salinity and turbidity. However, none of these correlations were significant (P > 0.05).

Table 2.7. Summary statistics for the Spearman correlation between environmental variables and the fish community composition. Data from January and June has been combined.

Variable	**Mngazana Estuary**				**Mngazi Estuary**			
	Marine species		Estuarine species		Marine species		Estuarine species	
	R	P	R	P	R	P	R	P
Temperature	0.02	> 0.05	0.08	> 0.05	0.12	> 0.05	-0.03	> 0.05
Salinity	0.12	> 0.05	-0.09	> 0.05	0.08	> 0.05	0.31	> 0.05
Turbidity	-0.00	> 0.05	0.03	> 0.05	0.00	> 0.05	-0.10	> 0.05
Temperature/Salinity	0.10	> 0.05	0.01	> 0.05	0.15	> 0.05	0.27	> 0.05
Salinity/Turbidity	0.05	> 0.05	-0.01	> 0.05	0.07	> 0.05	0.22	> 0.05
Temperature/Turbidity	-0.02	> 0.05	-0.00	> 0.05	0.08	> 0.05	-0.05	> 0.05

Longitudinal distribution

Analysis of data from the small and large seine nets portrayed different fish community structural trends within and between the two estuarine systems.

(a) Large seine net

The large seine net data indicated a degree of similarity between the fish communities in corresponding regions of the two estuaries (Figures 2.4 & 2.5). The cluster analysis indicated a 61% similarity between the fish assemblages in the lower reaches of Mngazi and Mngazana estuaries. The middle reaches of the two systems were 54% similar and the two upper reaches less than 50% similar. The ANOSIM procedure indicated no significant differences between the fish assemblages in the Mngazi and Mngazana estuaries (P > 0.05 in all cases) (Table 2.8).

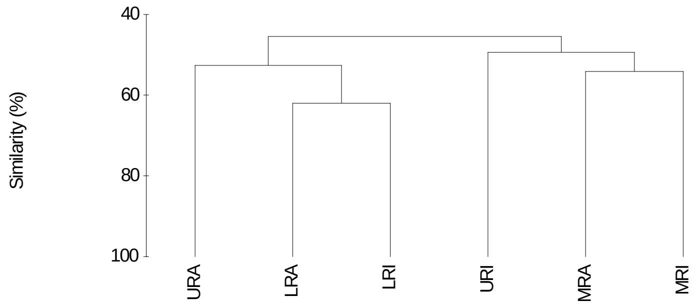

Figure 2.4. CPUE (catch per unit effort) dendrogram of the longitudinal distribution of Mngazi and Mngazana fish assemblages (data from large seine net). The first two letters refer to the estuarine region (UR = upper reach, MR = middle reach, LR = lower reach) and the last letter refers to the estuary name (A = Mngazana, I = Mngazi).

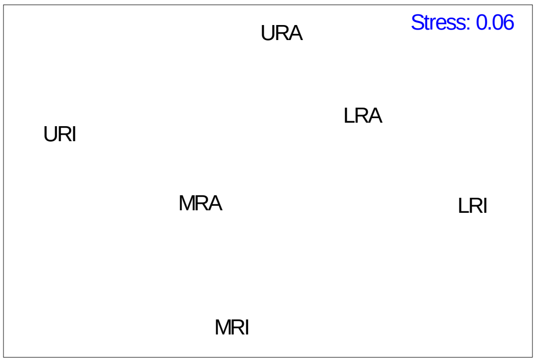

Figure 2.5. MDS (multidimensional scaling) plot of the longitudinal distribution of Mngazi and Mngazana fish assemblages (data from large seine net). The first two letters refer to the estuarine region (UR = upper reach, MR = middle reach, LR = lower reach) and the last letter refers to the estuary name (A = Mngazana, I = Mngazi).

(b) Small seine net

Similarities between fish assemblages in different regions within the same estuary were strong, with both Mngazi and Mngazana showing regional similarities greater than 70% except for the Mngazana lower reaches which was an outlier (Figures 2.6 & 2.7). In addition, the equivalent estuarine regions of both estuaries were more than 60% similar, except the Mngazana lower reaches, which was dissimilar. ANOSIM confirmed these results with significant differences ($P < 0.05$) between the Mngazana lower reaches and the other regions from either estuary (Table 2.8).

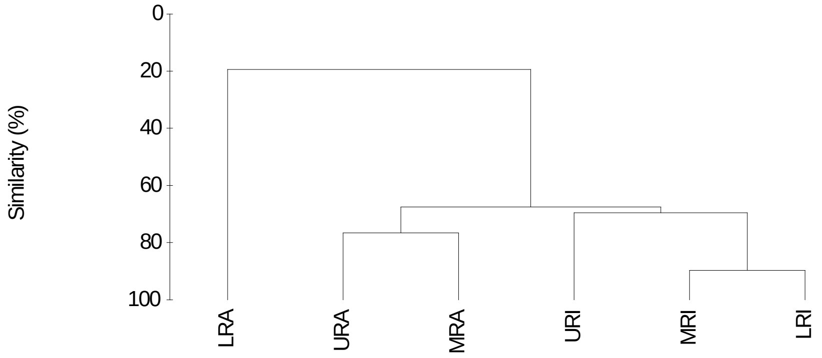

Figure 2.6. Percent similarity dendrogram of the longitudinal distribution of Mngazi and Mngazana fish assemblages (data from small seine net). The first two letters refer to the estuarine region (UR = upper reach, MR = middle reach, LR = lower reach) and the last letter refers to the estuary name (A = Mngazana, I = Mngazi).

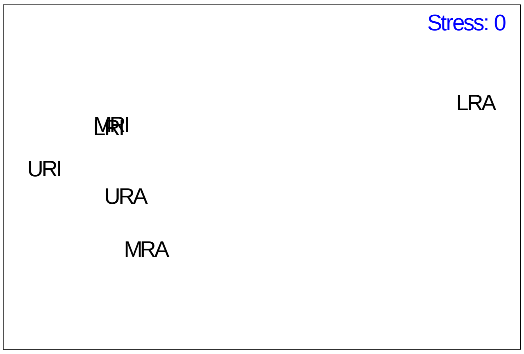

Figure 2.7. MDS plot of the longitudinal distribution of Mngazi and Mngazana fish assemblages (data from small seine net). The first two letters refer to the estuarine region (UR = upper reach, MR = middle reach, LR = lower reach) and the last letter refers to the estuary name (A = Mngazana, I = Mngazi).

The SIMPER routine for the small seine net catches showed that the following species were responsible for approximately 60% of the differences between the Mngazana lower and middle reaches: *G. aestuaria* (27%), *S. bleekeri* (10%), *G. callidus* (10%) and *A. breviceps* (9%). The differences between the Mngazana upper and lower reaches were accounted for by *G. aestuaria* (38%), *A. dussumieri* (14%) and *A. breviceps* (10%). SIMPER also showed that approximately 60% of the dissimilarities between the lower reaches of Mngazi and Mngazana estuaries were accounted for by *G. aestuaria* (34%), *A. breviceps* (17%) and *G. callidus* (7%).

Table 2.8. Regional analysis of similarities (ANOSIM) between the Mngazi and Mngazana small and large seine nets fish assemblages. The first two letters refer to the estuarine region (UR = upper reach, MR = middle reach, LR = lower reach) and the last letter refers to the estuary name (A = Mngazana, I = Mngazi).

	Small seine net		Large seine net	
Estuarine region	R statistic	Significance level P	R statistic	Significance level P
LRA, MRA	0.21	0.025	0.09	9.0
LRA, URA	0.25	0.018	0.18	1.8
MRA, URA	-0.12	0.879	-0.01	50.5
LRI, MRI	-0.04	0.633	0.20	0.1
LRI, URI	0.23	0.127	0.53	0.1
MRI, URI	0.39	0.067	0.14	1.5
LRA, LRI	0.38	0.001	0.05	6.9
MRA, MRI	-0.02	0.541	0.23	0.1
URA, URI	0.24	0.125	0.16	2.9

Temporal changes

The small and large seine net data from Mngazi and Mngazana estuaries indicated no significant temporal changes in the fish assemblages within each system (ANOSIM, $P > 0.05$). The large seine net data indicated a clear area effect, with the January and June samples more similar within an estuary than between the samples collected during the same time period in different estuaries. The Mngazi January and June samples were 67% similar and those of Mngazana were 70% similar (Figures 2.8 & 2.9). The small seine net data indicated an 80% similarity between the Mngazi January and June samples while those of Mngazana were less than 50% similar (Figures 2.10 & 2.11).

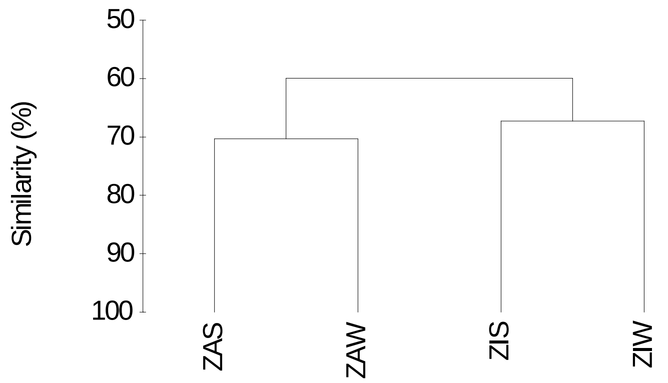

Figure 2.8. Similarity (%) dendrogram of fish assemblages collected during January and June (large seine net) from the Mngazi and Mngazana estuaries (S = January, W = June, ZA = Mngazana, ZI = Mngazi).

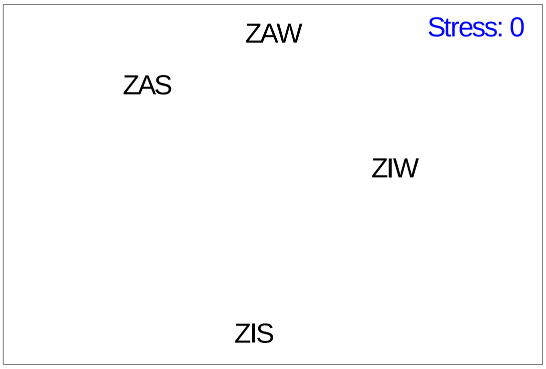

Figure 2.9. MDS plot between fish assemblages collected during January and June (large seine net) from the Mngazi and Mngazana estuaries (S = January, W = June, ZA = Mngazana, ZI = Mngazi).

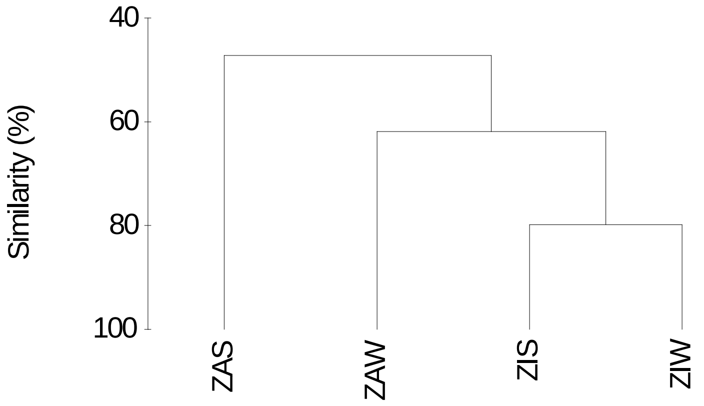

Figure 2.10. Similarity (%) dendrogram of fish assemblages collected during January and June (small seine net) from the Mngazi and Mngazana estuaries (S = January, W = June, ZA = Mngazana, ZI = Mngazi).

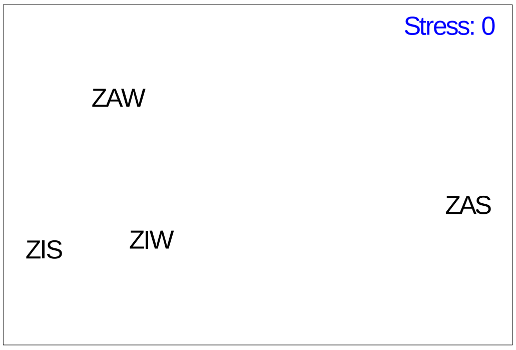

Figure 2.11. MDS plot of fish assemblages collected during January and June (small seine net) in the Mngazi and Mngazana estuaries (S = January, W = June, ZA = Mngazana, ZI = Mngazi).

Biogeography

For the purposes of this study, endemic species together with other species of temperate origin will be referred to as temperate species, as the centre of distribution of South African endemics lies within the temperate region. In both the Mngazi and Mngazana estuaries tropical species dominated the fish fauna during summer and winter, while the contribution of temperate and cosmopolitan species attained a maximum of 38% in the Mngazi Estuary during winter but was less than 30% on all other sampling occasions (Figure 2.12). There was an increase in the contribution of temperate species during June in both systems, but these temporal changes were not statistically significant in both the Mngazi (ANOVA, $P > 0.06$) and Mngazana (ANOVA, $P > 0.95$). This increase in the diversity of temperate species during June was coupled with a decline in the contribution of tropical species in the Mngazi Estuary but not in the Mngazana Estuary. When the January and June data from the Mngazana Estuary were pooled, tropical species contributed 71% while temperate species comprised 26% and cosmopolitan species 3%. The overall contribution of tropical species in the Mngazi Estuary was 63% while temperate and cosmopolitan species contributed 34% and 3% respectively.

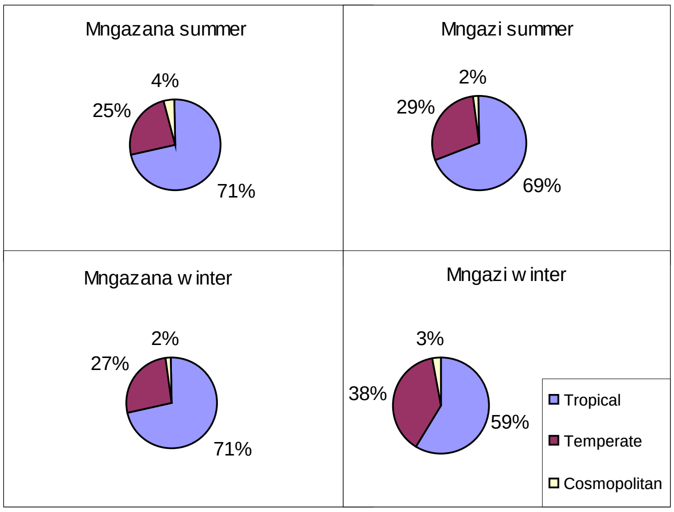

Figure 2.12. Fish species contribution from each biogeographic category to the total number of species captured during January (referred to as summer) and June (referred to as winter) in the Mngazana and Mngazi estuaries.

2.4. DISCUSSION

Marine taxa (Category II and III) comprised the bulk of recorded fish species in both the Mngazana (66%) and Mngazi (67%) estuaries, thus indicating the considerable influence exerted by the sea, as opposed to the river, on these systems. Similar findings have been recorded by several authors. For example, marine species were the most important component of the fish community in the permanently open Palmiet (Bennett 1989), Kowie and Great Fish estuaries (Whitfield *et al*. 1994) in South Africa. Marine species also dominated the fish taxa in the Elbe Estuary (Germany) in the Northern Hemisphere (Thiel & Potter 2001). The same group was less important and only comprised 36% of the total number of species in the predominantly closed Bot Estuary (Bennett 1989). The low representation of marine taxa in the Bot Estuary was attributed to the infrequent opening of the estuary mouth, which blocks the recruitment of marine fishes into the system. Similar results were obtained from Ciskei estuaries where permanently open systems had more marine species than those that opened intermittently (Vorwerk *et al*.2001). The degree of connection between the estuary and the adjacent marine environment is known to affect the structure of fish communities in estuaries (Kok & Whitfield 1986, Bennett 1989, Whitfield *et al*. 1994). Since marine species make an important contribution to the fish communities in estuaries (Day *et al*. 1981), a permanently open mouth allows continuous access to an estuary, resulting in a higher species diversity of marine taxa when compared with intermittently open estuaries.

Beckley (1984) also found marine species to be the dominant taxa in the Sundays Estuary and concluded that the dominance of juvenile marine fishes in estuaries, together with their absence from other coastal environments, illustrates the importance of estuaries as nursery areas. Previous studies have explained the utilisation of estuaries by juvenile marine fish with respect to the availability of calm waters, shelter, suitable food and protection from piscivorous predators (Blaber & Blaber 1980, Cyrus & Blabber 1987a, 1987b, Paterson & Whitfield 2000a, 2000b). The dominance of marine species in the Mngazi and Mngazana estuaries is probably related to the considerable marine influence on these systems and also indicates that the study estuaries provide suitable nursery conditions for the juveniles of these marine-spawned fishes.

Although marine taxa were dominant in terms of the number of species, their contribution to the total number of fish caught was low (32% at Mngazana and 14% in the Mngazi estuaries). This result contradicts the findings of some other studies conducted in some permanently open estuaries in South Africa. For example, marine species dominated the catch in terms of abundance in the Kowie and Great Fish estuaries (Whitfield *et al.* 1994) and Palmiet Estuary (Bennett 1989). Cowley & Whitfield (2001) reported a significant increase in the abundance of selected marine fishes following an extended open mouth phase in the intermittently open East Kleinemonde Estuary. The increase in percent contribution of marine species with an increase in the degree of marine influence illustrates the importance of marine connectivity in determining fish species composition in estuaries. While the estuary mouth status influences species composition, fish abundance is possibly influenced by both mouth status as well as the size differences between marine and estuarine taxa. These factors might partially explain the numerical dominance by estuarine species of the study systems.

Although the Mngazi Estuary contained fewer species, the total number of fish captured in this system was greater than that in the Mngazana Estuary. The planktivorous estuarine species, *Gilchristella aestuaria*, was primarily responsible for this difference as its CPUE in the Mngazi Estuary was more than nine times that recorded in the Mngazana Estuary. The goby *Glossogobius callidus* and juveniles of the mugilid, *Valamugil cunnesius* also contributed to the elevated abundance of fishes in the Mngazi Estuary, with the CPUE of these species in the Mngazi Estuary being more than twice that recorded in the Mngazana Estuary. Vorwerk *et al*. (2003) found that the main difference between fish communities in permanently open and intermittently open Ciskei estuaries was that the former had higher species diversity while the latter had greater fish abundance (CPUE). Estuarine species also accounted for the increased abundance of fishes in the Ciskei intermittently open estuaries (Vorwerk *et al*. 2003). Results from the current study revealed a similar trend. The Mngazi Estuary with its shallow (and occasionally closed) mouth had a higher proportion and abundance of estuarine species when compared with the Mngazana Estuary with its well developed permanently open mouth. The results of this study support Bennett's (1989) suggestion that the greater abundance of estuarine fishes in intermittently open estuaries is a result of these systems being more physically stable (when closed) compared with permanently open estuaries, thus facilitating greater reproductive success for resident taxa.

The resident *G. aestuaria* was the most abundant estuarine species in both systems and contributed 27% to the total number of fish captured from the Mngazana Estuary and 77% in the Mngazi Estuary. The success of *G. aestuaria* in these estuaries may be attributed to its eurytopic traits such as broad habitat tolerance range and prolonged breeding period. The differences in the abundance of this species in the Mngazi and Mngazana estuaries may be related to various factors including the freshwater residence time and tidal influence. There is no data on tidal flux in either of the study systems, but clearly the narrow (and shallow) mouth of the Mngazi Estuary would restrict tidal interchange between this estuary and the adjacent marine environment. Furthermore, freshwater flowing into the Mngazi Estuary would remain within the system for longer periods thus possibly sustaining zooplanktonic production upon which *G. aestuaria* depends. Estuary mouth closure can also increase foraging areas due to prolonged (not only at high tide) inundation of intertidal and supratidal habitats, (Kok & Whitfield 1986). The long residence time of estuarine water also allows the development of high plankton densities for zooplankton feeders such as *G. aestuaria* (Day *et al.* 1981). In contrast, the strong marine exchange in the permanently open Mngazana Estuary reduces water residence time in this system. The freshwater dominated Great Fish Estuary yielded lower catches of larval and juvenile *G. aestuaria* than the freshwater deprived Kariega Estuary, possibly a result of high river flows that flushed early life stages of this species into the sea (Strydom *et al*. 2002). A similar situation can be hypothesized for the Mngazana Estuary with its strong tidal action.

In both estuaries, fishes belonging to the family Mugilidae and Gobiidae were represented by the most number of species. Mugilids are among the most diverse and abundant marine species in South African estuaries, including the East Kleinemonde (Cowley & Whitfield 2001), Sundays (Beckley 1984), Mhlanga, Zotsha and Damba (Harrison & Whitfield 1995), as well as the Wilderness and Swartvlei lake systems (Russell 1996). The dominance of mullet species in South African estuaries may be related to a number of factors including the year-round availability of large amounts of detritus (their primary food source), as well as the fact that most of these species are euryhaline (Whitfield 1996) and have extended spawning seasons that facilitate recruitment during most seasons of the year (Whitfield & Kok 1992). The success of mugilids in intermittently open estuaries is also ascribed to their ability to recruit during overwash condition while the estuary mouth is closed (Cowley *et al*. 2001). The diversity of gobiids in the study estuaries may be linked to the colonisation of these systems by species from both the marine and freshwater environments. In addition, there are also estuarine goby species that have become resident in these environments (Whitfield 1998).

In the following sections, samples that were collected during January 2001 will be referred to as summer samples and those collected in June 2001 will be referred to as winter samples. In both the Mngazi and Mngazana estuaries the highest number of species were recorded during June, primarily due to an increased contribution of marine stragglers (Category III) (Table 2.4). The increase in marine stragglers during June is possibly a function of the more stable salinity regime in the estuaries during this winter period (Figures 2.1 & 2.2).

The recorded increase in fish abundance during summer and decrease in winter is not unique to the study estuaries. Using gill nets, Marais (1983) and Plumstead *et al*. (1989) recorded higher CPUE values during summer months in other Eastern Cape estuaries. These results are similar to other studies in the Northern Hemisphere where an increase in abundance of larvae, juveniles and adult fishes was recorded during summer with low fish numbers being found during winter (Kennish 1990). The increase in fish abundance in South African estuaries during the summer months can be attributed to peak recruitment during spring for most species (Whitfield & Kok 1992, Whitfield 1998) together with the seasonal abundance of primary and secondary food sources (Campbell *et al*. 1991). Some authors (e.g. Blaber & Blaber 1980, Cyrus & Blaber 1987a) have found a positive correlation between water turbidity and the distribution (and abundance) of juvenile marine fishes. Since the Mngazi and Mngazana estuaries lie in a summer rainfall region, the expected increase in turbidity could also be the reason for increased fish abundances during this season. During this study the turbidity in the Mngazi Estuary (but not in the Mngazana) was higher during summer than in winter (Figures 2.1 and 2.2).

The reasons for the decrease in the number of fishes during winter are unclear, but predation possibly played a major role, as a number of piscivorous birds were sighted in both estuaries during the sampling occasions. There is no available data on fish predation and its seasonal changes in intensity in the study estuaries. Although predation possibly occurred during both seasons, its effects would be masked by recruitment during summer and be more pronounced in winter.

The Mngazi and Mngazana estuaries had more species when compared with the Western Cape permanently open Palmiet (18 species) and the predominantly open Kleinmond (15 species) estuaries. The fish species diversity in estuaries is known to increase from the west to the east coast of South Africa (Whitfield 1998, Harrison 2002). Because of their geographic position, the Mngazi and Mngazana estuaries would be expected to have more species than similar systems further south. According to Harrison (2003), South African estuaries may be grouped into three biogeographic regions, with the study estuaries located within the subtropical region, approximately 25km north of the warm temperate boundary at the Mdumbi Estuary (31º55′50″S; 29º12′58″E). Because the Mngazi and Mngazana estuaries lie within a transitional zone, the study sites were expected to be dominated by tropical species but to also contain moderate numbers of temperate taxa.

Both temperate and tropical species were present in the study estuaries with their proportions displaying some temporal changes (Figure 2.12). Although tropical species dominated the ichthyofauna during summer and winter, temperate species showed a trend of increased diversity and abundance during winter (Figure 2.12). Branch & Grindley (1979) suggested that seasonal changes in the Mngazana Estuary fish species composition were linked to tropical species extending their ranges southwards during summer and temperate species extending their distribution northwards during the winter months. The results from this study indicate that although the species composition in the Mngazana Estuary support this hypothesis, there were some changes, viz. there was a larger proportion of tropical species and fewer temperate species during both summer and winter when compared with the summer and winter fish data reported by Branch & Grindley (1979). Although tropical species dominated the Mngazana ichthyofauna during both January and June, Branch & Grindley’s (1979) winter data indicated a slight decrease (4%) in the percentage tropical species, accompanied by an increase (6%) in the percentage temperate species. During this study the percentage of tropical species (71%) showed no temporal changes while temperate species showed only a slight increase (2%) during winter (Figure 2.12). Although this difference was not statistically significant ($P > 0.05$), it may be biologically important. The increased variety of tropical species and decreased numbers of temperate species in the Mngazana Estuary during both summer and winter could be an indication of climate change (increased average water temperatures in the marine and estuarine environments). Such temperature changes affect the seasonal migrations of both tropical and temperate species (Kennish 1986)

The average Mngazana Estuary water temperature was 2^{o}C higher in winter and 5^{o}C higher in summer during this study than the winter and summer temperatures reported by Branch & Grindley (1979). Consequently, it is tempting to associate the observed temporal changes in the fish community structure during 1975-1977 and 2001-2002 to longer term changes in water temperature. Similar changes in the species composition of fauna in marine and estuarine environments have been reported in the Northern Hemisphere. Attrill & Power (2002) found climatic variability to have a principal controlling influence on the fish community structure and abundance of many marine species found in the Thames Estuary (United Kingdom). In the Thames, the increase in species diversity during warm winter years was found to be due to the increase in the number of warm water species, which normally do not penetrate this cool-temperate estuary (Attrill & Power 2002). An ecosystem response consistent with the increasing Northern Hemisphere temperatures was observed in terrestrial ecosystems, suggesting that common atmospheric processes have influenced both the marine (including estuaries) and terrestrial faunal communities. In the North Sea, the increase in the average minimum and maximum temperatures over the past decade has been paralleled by a decline in the abundance of cold water species such as the cod (*Gadus morhua*) (O'Brien *et al*. 2000). Therefore, the changes in fish community structure in the Mngazana Estuary and faunal structures of other systems in the Northern Hemisphere may reflect an ecosystem shift towards a warmer global dynamic equilibrium, an ecological modification expected under climatic warming.

Climatic conditions such as the North Atlantic Oscillation (NAO) have been used to explain the variation in composition of juvenile marine fish during their estuarine residency period, primarily due to temperature differences between the marine environment and the estuary (Attrill & Power 2002). Higher fish species diversity has been reported during high NAO (warm winter) events, thus allowing more species with a preference for warm waters to enter the estuarine environments. Although differences in the sampling effort cannot be discounted as a possible reason for the increase in the number of species recorded in the Mngazana Estuary during this study when compared with numbers recorded by Branch & Grindley (1979), the influence of higher water temperatures cannot be discredited.

It has been suggested that salinity influences the longitudinal distribution of fishes in estuaries, with species diversity and richness increasing with an increase in salinity from the estuary head to the mouth (Marais 1988, Henderson 1989, Whitfield 1998). The BIOENV results of this study indicated no correlations between salinity and the fish community structure in both the Mngazi and Mngazana estuaries (Table 2.7). However the middle and lower reaches contained the most species and higher fish abundances, while the upper reaches contained the least in both estuaries. The physico-chemical data indicated that in both estuaries, salinity was lower in the upper reaches than in the middle and lower reaches. Other studies reported no direct relationship between the salinity regime and the distribution of fishes in estuaries. For example, there were no significant longitudinal changes in the fish community structure of the Kariega Estuary even though there was a reversed salinity gradient in this system (Ter Morshuizen & Whitfield 1994). Vorwerk *et al.* (2003) also found no clear relationship between salinity and the fish assemblage structure in some permanently open and intermittently open Eastern Cape estuaries. Although salinity may have influenced the fish community structure in the Mngazi and Mngazana estuaries, the results of this study indicate that it was not the primary factor determining the longitudinal distribution of fish in these systems.

Analysis of the longitudinal distribution of fish in relation to the water temperature along each of the study estuaries did not show any significant patterns (Table 2.7). Combinations of extreme temperatures and salinities have been shown to have devastating effects on fish communities in estuaries (Blaber & Whitfield 1976, Cyrus & Mclean 1996). The combination of temperature and salinity in the Mngazi Estuary showed a positive correlation (R = 0.3) with the longitudinal distribution of estuarine fishes but this was not significant (P > 0.5) (Table 2.7). There were also no significant correlations between the distribution of fish and the prevailing turbidity regime in either the Mngazi or Mngazana estuaries. Turbidity influences the fish communities in various ways, including protecting juveniles from visual predators (Blaber & Blaber 1980) and reducing intra-specific predation (Blaber & Cyrus 1983). The lack of a significant influence of turbidity during this study may be related to the fact that turbidity was generally low (< 20 NTU) throughout both estuaries (Figures 2.1 & 2.2).

In spite of the differences in their mouth dynamics and dominant fringing vegetation, there were no significant differences in the longitudinal distribution of both marine and estuarine fishes between the two systems (Table 2.8), with the exception of the Mngazana lower reach estuarine assemblage. The two tributaries that bring freshwater into the Mngazana Estuary lower reaches are a possible reason for the separation of this estuarine fish assemblage. The species that accounted for these differences were *Gilchristella aestuaria*, *Atherina breviceps*, *Glossogobius callidus* and *Ambassis dussumieri*. *Gilchristella aestuaria* and *G. callidus* were more abundant in the Mngazi lower reach, while *A. dussumieri* and *A. breviceps* were more abundant in the lower Mngazana Estuary.

Differences between estuarine fish communities usually arise from a number of factors, including the geographic location, catchment size, estuary size and mouth dynamics (Whitfield 1996). With the exception of catchment size and mouth status, these factors were comparable between the two estuaries. One way in which the catchment size affects estuaries is by influencing the amount of runoff that reaches the estuary. Data on the total runoff reaching the Mngazi and Mngazana estuaries is not available. Although the Mngazi Estuary has a larger catchment, the amount of runoff reaching this system cannot be directly linked to the catchment size as some water is abstracted from the river for irrigation purposes. The timing of the sand bar development in the Mngazi Estuary mouth (in winter) is not synchronised with the recruitment period of most marine fishes (spring and early summer), and this may partly explain the lack of differences in the distribution of juvenile marine fishes in the Mngazi and Mngazana estuaries. The lack of significant differences in the community structure of both estuarine and juvenile marine fishes between the two estuaries suggests that the functioning of these systems is perceived as being similar by the fishes that utilise them.

CHAPTER 3: ICHTHYOFAUNAL ISOTOPES

3.1. INTRODUCTION

Estuaries are regarded as among the most productive aquatic ecosystems, matching that of coral reefs and mangrove swamps in terms of their carbon production per unit area (Whitfield 1999). Estuarine ecosystems are characterised by complex food webs that include components from terrestrial, freshwater and marine environments (Haines & Montague 1979, Stephenson & Lyon 1982). Information on the feeding relationships, nutrient and energy pathways within estuarine animal communities is vital for the management and conservation of these systems (Stephenson & Lyon 1982). However, linking an animal to its primary food source and the subsequent role played by that animal in the diet of higher consumers is not always easy to evaluate. Direct observations of the feeding behaviour of an animal can be impractical and, due to the difficulty of identifying highly degraded organic material, and the presence of large quantities of non-recognisable organic matter, indirect methods such as gut content analysis may be misleading (Rau *et al*. 1983, Creach *et al.* 1997). Another shortcoming of gut content analysis is that it only gives an indication of organic material that is ingested, including food components that are not assimilated (Hughes & Sherr 1983). Moreover, depending on the gut evacuation rates, stomach content analysis only gives an indication of what the animal is feeding on during the analysis period, whereas stable isotopic analysis provides a time integrated diet for that species.

Stable isotopic measurements have been used in various animal ecology studies some of which are: to monitor water-shed level processes such as the input of organic matter into aquatic systems, to describe flow pathways of organic matter in food webs, to follow animal switches from one food chain to another, and to show variation in feeding strategies among individuals (Fry & Sherr 1984, Fry 1991, Deegan & Garritt 1997, Fry 1999). Analysis of the ratios of stable carbon isotopes ($^{13}C/^{12}C$) is a direct way of evaluating pathways of carbon in ecosystems and is especially useful in analysing food web relations in estuaries where C_3 and C_4 plants are important primary food sources (Creach *et al.* 1997, Haines & Montague 1979).

It has been shown that while the stable carbon isotope ratio of a consumer's tissue closely resembles that of its diet, a small but significant increase in the consumer's isotopic ratio relative to the isotopic ratio of the food source occurs (DeNiro & Epstein 1978, Haines & Montague 1979, Fry & Sherr 1984). This ^{13}C enrichment, often predicted at about 1‰ per trophic level increase, is due to the selective loss of ^{12}C during respiration that results in a higher proportion of ^{13}C relative to ^{12}C in the respiring organism's tissues (Rau *et al*. 1983, Fry & Sherr 1984). When the stable carbon isotope ratios of an animal's tissue are compared with those of the dominant primary producers in a system, the source of that animal's diet can be inferred. Assuming that the dominant food sources have distinct isotopic ratios and the isotopic composition of each food source is essentially conserved with each step in the food chain, stable isotope analysis is a valuable tool in the study of estuarine food webs (Haines & Montague 1979). In cases where an animal has more than two isotopically distinct food sources, the resulting carbon isotope data are not easy to interpret, and additional information such as gut content analysis and observation of feeding habits may be required (Haines & Montague 1979).

A number of Eastern Cape studies (e.g. de Villiers 1990, Jerling & Wooldridge 1995, Paterson & Whitfield 1997, Froneman 2001, 2002) have used stable carbon isotope analysis to examine the food webs in South African estuaries. De Villiers (1990) found that in the Kariega Estuary the infaunal bivalve *Solen cylindraceus* utilised a depleted carbon source, most likely terrestrial in origin. Following this study, Paterson & Whitfield (1997) and Froneman (2001) reported the presence of two main carbon pathways, littoral and channel, within the Kariega Estuary. The littoral community included fishes of the family Gobiidae, Mugilidae, Sparidae and most crustaceans that utilised carbon enriched primary carbon sources derived from estuarine macrophytes. The channel pathway comprised mainly zooplanktonic organisms, together with zooplanktivorous and piscivorous fishes, which utilised a depleted carbon source, possibly a mixture of phytoplankton, terrestrial and C_4 plant detritus.

In this chapter the primary sources of carbon utilised by fish communities in two adjacent estuaries with different primary producers are investigated. The Mngazana Estuary has an extensive mangrove forest in the lower and middle reaches, comprising *Avicennia marina*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata*. In addition to the mangroves, salt marsh plants, sedges and eelgrass are also present within the system. In contrast, the Mngazi Estuary has no mangroves but has salt marsh plants, sedges and eelgrass similar to that found in the Mngazana system.

3.2. MATERIALS AND METHODS

Sampling of fish and potential carbon sources

Dominant fish taxa (representing the consumers) and their potential carbon sources (representing the producers) were collected from several sites in the channel and along the banks of each estuary during austral summer (January 2001) and winter (June 2001). An effort was made to analyse as many of the species that occurred in both the Mngazi and Mngazana estuaries as possible. Fish were collected using gill and seine nets and sampling sites were located throughout each estuary. Only one sample was analysed per fish and the number of fish sampled for each species ranged between 2 and 4. Small specimens were frozen whole and in the case of large specimens, dorsal muscle was removed and frozen for later stable isotope analysis. Muscle tissue was selected because it has a carbon signature that is usually representative of the entire fish (Paterson & Whitfield 1997). To remove lipids, which may be depleted in δ^{13}C and thus confound ecological interpretations (Kling *et al*. 1992), all fish samples were washed in a solution of chloroform, methanol and water (ratio 2:1:0.8) adapted from the method of Bligh & Dyer (1959). The fish samples were then dried in the oven at 60^{o}C for 24 hours.

Fresh leaves were collected from living terrestrial plants, mangrove trees (where applicable), salt marsh plants, reeds and eelgrass. Epiphytes were separated from the stems and leaves of eelgrass *Zostera capensis* by carefully scraping the plants and then concentrating these microalgae by centrifugation at 5000 rpm. All sampled vegetation was rinsed in seawater, which had previously been filtered through a 0.2-µm Nucleopore filter. Microphytobenthic samples were collected using a 5 cm diameter corer. Following collection, the top 2 mm of the sediment was removed and frozen for later analysis. In the laboratory, samples were defrosted and the algal mat separated from the detritus by washing in filtered seawater. The sample was then oven dried at 60^{o}C for 24 hours.

Particulate organic matter (POM) was obtained by collecting surface water from the upper, middle and lower reaches of each estuary and then pooled to give a single sample for each estuary. POM was extracted by filtering a 5 l water sample through a 20µm filter onto a pre-combusted GF/F filter, that was subsequently examined under a dissecting microscope (operated at 100x magnification) for the manual removal of potential sources of contamination (e.g. zooplankton). For the determination of the >20 µm POM size fraction, a 5 l water sample was filtered through a 20 µm Nitex mesh. The material retained on the mesh was then collected and placed in a petri dish. All visible zooplankton were removed from the filtrate using a dissecting microscope. The POM samples were then oven dried at 60^{o}C for 24 hours. For the determination of chlorophyll *a* concentration at each station, triplicate 250ml subsurface water samples were filtered through GF/C filters and extracted in 90% acetone for 24 hours in dark. Chlorophyll *a* concentration was then determined flourometrically (Turner 10AU flourometer) before and after acidification (Holm-Hansen & Riemann 1978). Results were expressed as $\mu g l^{-1}$.

Sample preparation

To homogenize, the oven dried samples were ground to a fine powder with a mortar and pestle and then stored in plastic containers for isotopic analysis. Special care was taken not to mix or contaminate any of the samples.

Stable isotope analysis

Following sample combustion using an online Carlo-Erba Preparation Unit, δ^{13}C determination was carried out with a Finnigan-MAT 252 Stable Isotope Mass Spectrometer. Merck gelatine was used as an internal standard, calibrated against several International Atomic Energy Agency reference materials. Stable isotope data are presented as the relative difference between ratios of the sample and the standard. The results were expressed in parts per thousand (‰) deviation from the standard using the following formula:

$$\delta X\ (‰) = [(R_{sample} / R_{standard}) / R_{standard}]\ x\ 1000$$

where X = element in question (carbon) and R = ratio of the heavy over the light isotope ($^{13}C/^{12}C$).

Data analysis

Student Newman-Keuls multiple range testing was performed after a one-way ANOVA was used to determine if there were any significant differences in the isotopic signatures of the dominant consumers in the two estuaries. The analysis was conducted using the statistical computer package, Statgraphics version 5.0 (Statistical Graphics Corporation).

3.3. RESULTS

A multiple range test, performed after the ANOVA indicated that there were no significant differences in the isotopic signatures of primary producers and ichthyofaunal samples collected during January and June ($F = 5.36$, $F = 8.67$, $P > 0.05$ in all cases). As a result, summer and winter samples were pooled for all comparisons between the two estuaries.

MNGAZANA ESTUARY

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Vegetation:

The sampled plants had either enriched (C_4 plants) or depleted (C_3 plants) δ^{13}C values. *Zostera capensis* and its associated epiphytes were enriched and had δ^{13}C values of -12.9‰ and -11.3‰ respectively. These δ^{13}C values are comparable to those of C_4 plants in the literature (Haines & Montague 1979). The mangrove trees *Avicennia marina* (-26.8‰), *Bruguiera gymnorrhiza* (-26.8‰) and *Rhizophora mucronata* (-27.2‰) were depleted, which is typical of C_3 plants (Raven *et al*. 1986). Terrestrial plants had δ^{13}C values ranging between -24.3 and -25.8‰ (Table 3.1) thus indicating a C_3 photosynthetic pathway. Microphytobenthic algae had a δ^{13}C value of -20.3‰.

The different size classes of particulate organic matter (POM) had slightly different δ^{13}C values, -23.9‰ for the <20 µm POM, and -22.5‰ for the >20 µm POM. Analysis of the POM revealed that concentrations of chlorophyll *a* ranged between 4 µg l^{-1} and 8 µg l^{-1}.

Table 3.1. $\delta^{13}C$ values (‰) of dominant primary producers in the Mngazi and Mngazana estuaries.

		Mngazi Estuary		**Mngazana Estuary**	
Plant species	**Habitat**	**Mean $\delta^{13}C$ value**	**Standard Deviation**	**Mean $\delta^{13}C$ value**	**Standard Deviation**
Avicennia marina	Mangrove			-26.8	0.3
Bruguiera gymnorrhiza	Mangrove			-26.8	1.1
Rhizophora mucronata	Mangrove			-27.2	0.9
Zostera capensis	Eelgrass	-12.9	0.5	-12.9	0.5
Zostera epiphytes	Eelgrass	-13.1	0.1	-11.3	0.4
Hibiscus tiliaceus	Terrestrial			-25.8	1.7
Acacia karoo	Terrestrial	-24.3	0.3	-24.3	0.3
Eragrostis spp	Terrestrial	-24.8	0.4	-24.8	0.4
Juncus kraussii	Terrestrial	-23.0	0.7		
Phragmites australis	Terrestrial	-23.8	0.5		
Sarcocornia maritima	Salt marsh	-24.4	1.2	-24.4	1.2
Microphytobenthic algae	Channel	-20.7	0.9	-20.3	0.9
Particulate organic matter					
>20 µm	Channel	-21.5	0.4	-22.5	0.3
<20 µm	Channel	-20.9	1.1	-23.9	1.1

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Ichthyofauna

The fish species analysed formed a continuum of isotopic signatures, with some species and families having general tendencies towards being either depleted or enriched (Figure 3.1). The separation of the various fish species into feeding guilds (Table 3.2) was undertaken following the categorization of Whitfield (1998). Although there was no distinct isotopic grouping within the Mngazana Estuary fish species, detritus feeders belonging to the family Mugilidae were the most enriched taxa, with values ranging from -19.9‰ to -12.9‰. Among the mugilids, *Liza dumerili* was the most enriched with a $\delta^{13}C$ value of -12.9‰ while *Myxus capensis* was the most depleted and had a $\delta^{13}C$ value of -19.9‰. Other mugilids (*Liza macrolepis*, *Mugil cephalus* and *Valamugil buchanani*) had $\delta^{13}C$ values ranging from -16.7‰ to -15.8‰ (Figure 3.1). The planktivorous *Hilsa kelee* (-24.7‰), *Thryssa vitrirostris* (-22.8‰) and *Gilchristella aestuaria* (-22.6‰); the invertebrate feeders *Leiognathus equulus* (-22.1‰) and *Periophthalmus argentilineatus* (-22.9‰), the omnivorous *Rhabdosargus holubi* (-24.7‰) and the piscivorous *Terapon jarbua*(-21.2‰) were the most depleted species (Figure 3.1). The remaining taxa had intermediate δ^{13}C values ranging from -18.5‰ to -20.9‰. These included the piscivorous species *Caranx sexfasciatus*, *Sphyraena jello, Argyrosomus japonicus*, *Elops machnata*, the invertebrate feeders *Acanthopagrus berda, Pomadasys commersonnii*, *Pseudorhombus arsius*, *Favonigobius reichei*, *Glossogobius callidus*, *Oligolepis keiensis, Caffrogobius gilchristi*, *Monodactylus falciformis* and the plankton feeder *Ambassis dussumieri.*

MNGAZI ESTUARY

Vegetation

Among the vegetation types sampled, the eelgrass *Z. capensis* (-12.9‰) and its associated epiphytes (-13.1‰) were the most δ^{13}C enriched. Terrestrial plants had δ^{13}C values ranging from -24.8‰ to -23.0‰ (Table 3.1). The δ^{13}C value of the <20 µm POM was -20.9‰ and the >20 µm POM had a δ^{13}C value of -21.5‰. The δ^{13}C value of microphytobenthic algae was -20.7‰. The chlorophyll *a* concentration in the POM ranged between 5 µg l^{-1} and 7 µg l^{-1}.

Ichthyofauna:

The δ^{13}C values of Mngazi fishes also formed a continuum of isotopic signatures (Figure 3.2). Three species, an invertebrate feeder *Leiognathus equulus* (-21.9‰), a zooplankton feeder *Monodactylus falciformis* (-22.2) and the detritus feeder *Valamugil cunnesius* (-22.7‰) were most depleted. Most detritus feeders belonging to the family Mugilidae were δ^{13}C enriched, e.g. *Valamugil buchanani*, *Mugil cephalus*, *Liza macrolepis* and *Liza dumerili* had values ranging from -16.9‰ to -15.5‰. Most other species had δ^{13}C values ranging from -19.9‰ to -17.3‰ (Figure 3.2). These included the piscivorous species (e.g. *Caranx sexfasciatus*); planktivorous taxa (e.g. *Gilchristella aestuaria* and *Thryssa vitrirostris*) invertebrate feeders (e.g. *Acanthopagrus berda*, and *Pomadasys commersonnii*) and the omnivorous *Rhabdosargus holubi* (Figure 3.2).

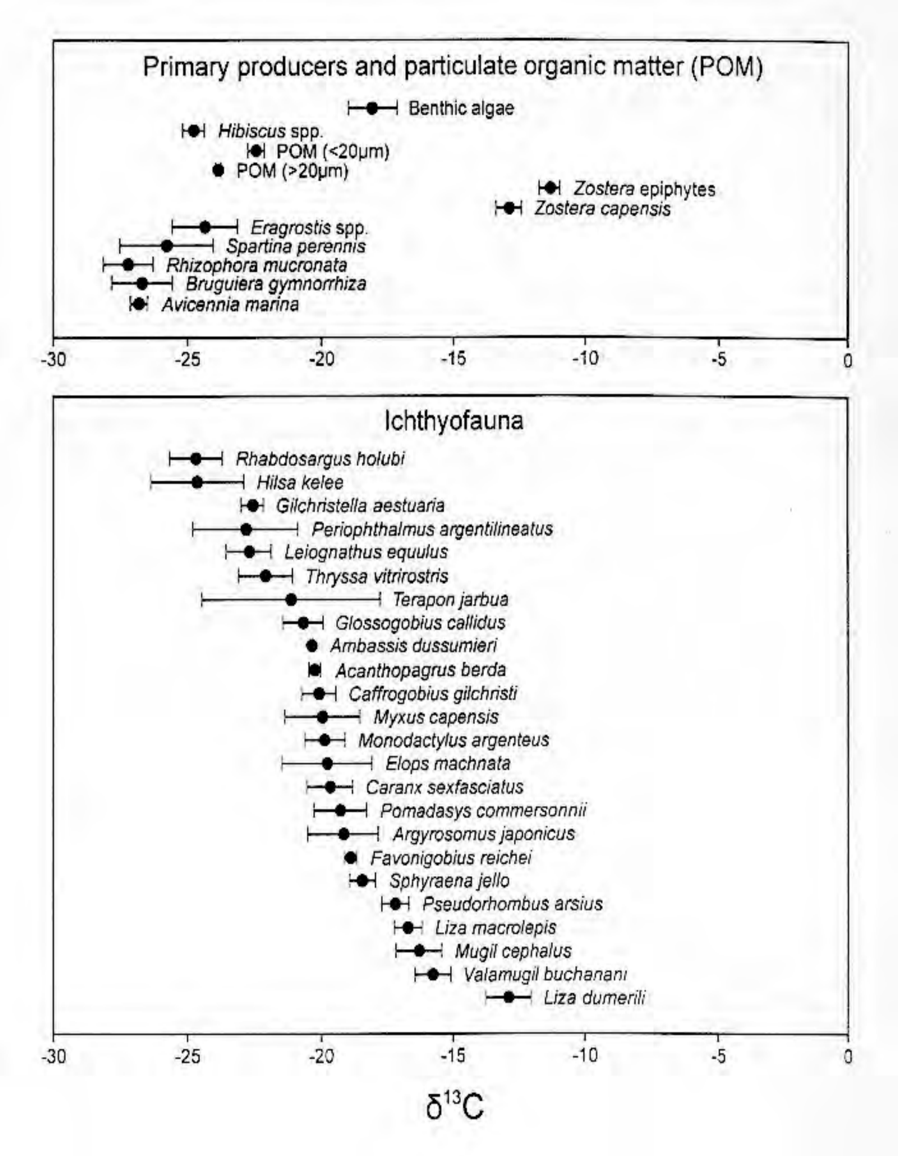

Figure 3.1. The δ^{13}C (‰) means and standard deviations of the dominant primary carbon sources and ichthyofauna in the Mngazana Estuary.

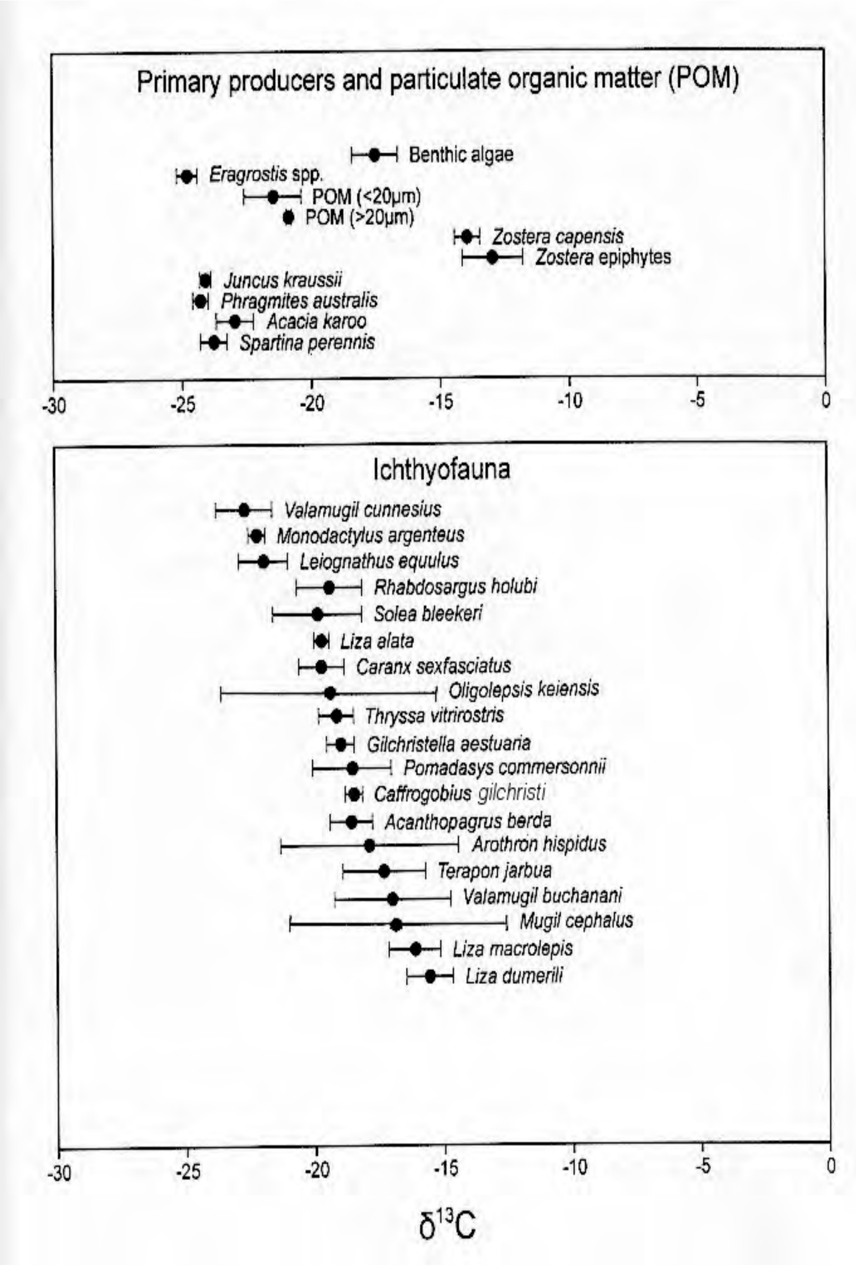

Figure 3.2. The δ^{13}C (‰) means and standard deviations of the dominant primary carbon sources and ichthyofauna in the Mngazi Estuary.

Table 3.2. Fish species, their main food sources and the number of samples taken from the Mngazi and Mngazana estuaries.

				Mngazi Estuary	**Mngazana Estuary**
Family	**Fish species name**	**Dietary preference**	**Life history Category**	**Number of samples**	**Number of samples**
Ambassidae	*Ambassis dussumieri*	Zooplankton	Estuarine		2
Bothidae	*Pseudorhombus arsius*	Invertebrates	Marine		2
Carangidae	*Caranx sexfasciatus*	Fish	Marine	2	5
Clupeidae	*Gilchristella aestuaria*	Zooplankton	Estuarine	2	4
Clupeidae	*Hilsa kelee*	Zooplankton	Marine		2
Elopidae	*Elops machnata*	Fish	Marine		2
Engraulidae	*Thryssa vitrirostris*	Zooplankton	Marine	2	2
Gobiidae	*Caffrogobius gilchristi*	Invertebrates	Estuarine	2	2
Gobiidae	*Oligolepis keiensis*	Invertebrates	Estuarine	3	
Gobiidae	*Favonigobius reichei*	Invertebrates	Estuarine		3
Gobiidae	*Glossogobius callidus*	Invertebrates	Estuarine		5
Gobiidae	*Periophthalmus argentilineatus*	Invertebrates	Estuarine		2
Haemulidae	*Pomadasys commersonnii*	Invertebrates	Marine	6	4
Leiognathidae	*Leiognathus equulus*	Invertebrates	Marine	5	3
Monodactylidae	*Monodactylus falciformis*	Invertebrates	Marine	2	2
Mugilidae	*Liza alata*	Detritus	Marine	2	
Mugilidae	*Liza dumerili*	Detritus	Marine	4	2
Mugilidae	*Liza macrolepis*	Detritus	Marine	4	3
Mugilidae	*Mugil cephalus*	Detritus	Marine	3	2
Mugilidae	*Myxus capensis*	Detritus	Marine		2
Mugilidae	*Valamugil buchanani*	Detritus	Marine	3	2
Mugilidae	*Valamugil cunnesius*	Detritus	Marine	2	
Sciaenidae	*Argyrosomus japonicus*	Fish	Marine		3
Sparidae	*Acanthopagrus berda*	Invertebrates	Marine	2	5
Sparidae	*Rhabdosargus holubi*	Invertebrates & algae	Marine	2	2
Sphyraenidae	*Sphyraena jello*	Fish	Marine		3
Soleidae	*Solea bleekeri*	Invertebrates	Marine	2	
Teraponidae	*Terapon jarbua*	Fish	Marine	3	2
Tetraodontidae	*Arothron hispidus*	Invertebrates	Marine	3	

3.4. DISCUSSION

The stable carbon isotope values of particulate organic matter (POM) from the Mngazi Estuary ranged between -21.5‰ to -20.9‰ while those from the Mngazana Estuary ranged between -23.9‰ and -22.5‰ (Table 3.1). Analysis of chlorophyll *a* indicated that in both systems, phytoplankton biomass attained moderate levels (4 – 8 μg l^{-1}). These data suggest that the differences in POM values obtained in the two systems can be related to the input of carbon from allochthonous and autochthonous sources other than phytoplankton. Analysis of the $\delta^{13}C$ values suggested that the POM in the Mngazana Estuary was close to the range obtained for the mangrove vegetation. This indicates that mangrove derived carbon probably makes a substantial contribution to the POM of this system. In contrast, the absence of a mangrove forest in the Mngazi Estuary suggests that the POM was primarily composed of carbon derived from a combination of microphytobenthic algae and the terrestrial vegetation.

Particulate organic matter is usually composed of phytoplankton and plant detritus, the proportions of which may differ depending on the amount of rainfall. The magnitude of freshwater influx into an estuary affects the nutrient availability and therefore phytoplankton production (Allanson & Read 1995, Froneman 2002). Freshwater deprivation causes low nutrient availability and leads to low phytoplankton density, whereas elevated river inflow results in increased nutrient availability and promotes high phytoplankton production (Allanson & Read 1995). The isotopic values of POM in both the Mngazi and Mngazana estuaries did not indicate temporal variations in the POM composition between January and June during this study (unpublished data). Although records from the Port St Johns lighthouse suggest seasonality in the magnitude of rainfall in this area (Wooldridge 1977), the lack of corresponding temporal variations in the $\delta^{13}C$ values of the POM may be an indication that the summer-winter difference in the freshwater influx into the estuaries was not large enough to result in temporal variations in the composition of POM.

Similarly, there were no significant temporal changes in the $\delta^{13}C$ signatures of the consumers (fish) collected during January and June (unpublished data). Thomas & Cahoon (1993) suggested that seasonal changes in the primary carbon source may not be reflected in animal tissues with a low turnover rate, as these tissues would reflect the time integrated diet of the organism. Hesslein *et al.* (1993) stated that the change in the isotopic composition subsequent to a change in diet is faster in tissues with a high turnover rate (e.g. liver) than those with a low turnover rate (e.g. muscle). Therefore, because the samples used in the isotopic analysis were taken from the dorsal muscle, which has a low turnover rate, temporal changes (if any) in the isotopic signature of the primary food source would not have been reflected in the $\delta^{13}C$ values of consumers.

Using a published review of the literature (Whitfield 1998), fish were separated into three major categories, i.e. detritivores, invertebrate feeders and piscivorous species (Table 3.2). With the exception of *Valamugil cunnesius*, which had an isotopic value of -22.7‰, the Mngazi mugilid species had carbon isotope values ranging from -16.9‰ to -15.5‰ while those from the Mngazana Estuary had $\delta^{13}C$ values ranging from -19.9‰ to -12.9‰ (Figures 3.1 and 3.2). Mugilidae in South African estuaries are known to feed on detritus as well unicellular algae and the meiofauna associated with sand and mud (Masson & Marais 1975, Blaber 1976). The relatively enriched carbon isotope value of most mullet species in both Mngazi and Mngazana suggests a diet that includes relatively enriched carbon sources such as benthic algae and detritus derived from *Zostera* and its epiphytes. Unfortunately, the stable isotope analysis cannot indicate the relative proportions of the different carbon sources that are being utilised. However, Whitfield (1999) suggested that the high incidence of unicellular algae in the diet of mugilids indicates that benthic algae are a favoured food source.

Among the mullet species, *Liza alata* and *Valamugil cunnesius* from the Mngazi system and *Myxus capensis* from the Mngazana Estuary had depleted carbon values (-19.7‰, -22.7‰ and -19.9‰, respectively). The relatively depleted isotopic value of *Valamugil cunnesius* indicates that this species utilised carbon sources that were different from those of the other mullet species. The isotopic signature of this species suggests the assimilation of large proportions of detritus derived from a depleted carbon source such as littoral macrophytes. Both *Liza alata* and *Myxus capensis* had isotopic values that cannot be associated with the sampled primary carbon sources. During this study *Liza alata* specimens were found mainly in the upper reaches of the Mngazi Estuary where eelgrass was absent. Similarly, *Myxus capensis* is a facultative catadromous species whose fry migrate into rivers where they remain for a considerable period (Bok 1984). This species is also known to occur in the upper reaches of some estuaries, particularly in the freshwater dominated regions of these systems (Jubb 1967, Bok 1984). It is therefore possible that the sampled *Myxus capensis* might have spent considerable periods in the freshwater reaches above the Mngazana Estuary, where the potential carbon sources are likely to have been different from those that were sampled in the estuary. It is well documented that the location of an organism in an estuary has a profound effect on the food resource it utilises (Fry & Sher 1984, Paterson & Whitfield 1997). Deegan & Garritt (1997) found that consumers in all regions of Plum Island Sound Estuary, USA, relied mostly on locally produced organic matter. Thomas & Cahoon (1993) also reported within species variation of isotopic signatures in some fishes inhabiting different locations of the coral reefs and attributed this to the availability of different food sources in different locations. The difference in the isotope signatures of *L. alata* and *Myxus capensis* from those of other mullet species in the estuaries may therefore be related to the food resources that were available in that part of the estuary where they spent most of their time prior to capture. More detailed studies on the diet and movements of the two species in these estuaries are needed before this suggestion can be verified.

Within the invertebrate feeding group the benthic invertebrate feeder *L. equulus* (-21.9‰) and the zooplanktivorous *M. falciformis* (-22.2‰) were the most carbon-depleted species in the Mngazi Estuary, while *Hilsa kelee* (-24.7‰), *G. aestuaria* (-22.6‰), *L. equulus* (-22.1‰) and the omnivorous *Rhabdosargus holubi* (-24.7‰) were the most depleted taxa in the Mngazana Estuary. These data indicate that *Zostera* (and its associated epiphytes) and microphytobenthic algae cannot have been their most important carbon source. Carbon signatures from these fish species suggest that these taxa utilised food chains based on large proportions of carbon-depleted sources such as terrestrial vegetation and mangroves or phytoplankton. The terrestrial plants had δ^{13}C signatures ranging from -24.8‰ to -23‰ in the Mngazi Estuary. In the Mngazana Estuary, terrestrial vegetation had δ^{13}C values ranging from -25.8‰ to -24.3‰ and the average δ^{13}C for the mangroves was -26.9‰ (Table 3.1). Allowing for the enrichment values between zero and 1‰ per trophic level (DeNiro & Epstein
1978), the terrestrial vegetation (including mangroves in the case of Mngazana) could be interpreted as the dominant primary carbon source. In contrast, the relatively carbon enriched taxa (e.g. *P. arsius with an isotope value of* -17.2‰) indicate utilisation of a

food chain that included primary carbon sources such as benthic algae and possibly eelgrass.

When the isotope ranges of the invertebrate feeders (including zooplanktivorous fish species) from both the Mngazi and Mngazana estuaries are compared, differences in the available food sources between the two systems become evident. For example, the isotopic values of *A. berda*, *C. gilchristi*, *L. equulus*, *P. commersonnii* and *R. holubi* ranged between -24.7‰ and -19.3‰ in the Mngazana Estuary and between -22.0‰ and -18.4‰ in the Mngazi Estuary (Figure 3.2). Branch & Grindley (1979) found a high diversity of invertebrates (209 species) in the Mngazana Estuary associated with a wide variety of habitats within the system, e.g. mangroves, salt marshes, eelgrass beds, sand banks and rocky shores. The diverse invertebrate prey community available to the fish in this estuary may account for the wide range of δ^{13}C signatures observed among the invertebrate feeders. On the other hand there were <75 species of invertebrates (Branch & Grindley 1979) and fewer habitats in the Mngazi Estuary (no mangrove or rocky shore habitats), hence a narrower range of δ^{13}C value among most fish species feeding on invertebrates.

The piscivorous *T. jarbua* and *C. sexfasciatus* in the Mngazi Estuary had isotopic values of -17.3‰ and -19.7‰ respectively, while the Mngazana piscivores (*C. sexfasciatus, E. machnatha*, *S. jello, A. japonicus* and *T. jarbua*) had δ^{13}C values ranging from -19.8‰ to -18.5‰. These isotopic values from both estuaries indicate that most mullet species did not form a substantial dietary component of these taxa. Analysing the gut contents of piscivorous fishes in Lake St Lucia, Whitfield & Blaber (1978) demonstrated a similar pattern. The most dominant piscivorous species at Lake St Lucia were *A. japonicus* and *E. machnatha* and both preyed extensively on the planktivorous fishes *T. vitrirostris* and *G. aestuaria*. The isotopic signatures of most piscivorous species from the Mngazana Estuary indicated that detritivorous and planktivorous fish species were not their dominant carbon source. Although based on their isotope values, the main carbon source of these species is not clear there is an indication that they might have fed on some invertebrate feeding fishes (Figure 3.1). Similarly, the isotopic signatures of the Mngazi Estuary piscivorous species do not show any clear indication as to which species were their main food source, but they may have assimilated carbon from a variety of fishes including zooplankton and detritus feeders. More information on the normal habitat of piscivorous species as well as habitat overlap between these and their potential prey species is needed in order to pursue this point.

One of the shortcomings of using stable isotopic signatures in the study of food web relations is the difficulty in interpreting isotopic values of fauna where more than two isotopically different food sources are assimilated (Haines & Montague 1979). It is therefore possible that these fish species assimilated a variety of isotopically distinct sources in proportions that cannot be determined using stable carbon isotopes in isolation. Also, the possibility that the piscivorous species of both estuaries derived their carbon mainly from species that were not sampled during this study cannot be excluded. It should be noted that the marine migrant fish species found in the study estuaries (i.e. all piscivores, detritivores and most invertebrate feeders) had spent some time in the marine environment, where they possibly fed on food sources other than those found in estuaries and hence utilised carbon sources that were not sampled. The contribution of the marine based sources to the isotopic signature of the sampled fish species could not be estimated in this study, as the marine food sources were not sampled. The stable carbon isotopes used in this study adequately addressed the primary aim of this research, which was to investigate the origins of carbon utilised by fish in the two estuaries. However, carbon isotopes are generally not good in interpreting trophic dynamics, therefore further research using stable nitrogen and sulphur isotopes might help interpret the trophic structure and trophic pathways within the Mngazi and Mngazana estuaries.

Paterson & Whitfield (1997) and Froneman (2001, 2002) identified two trophic pathways in the Kariega Estuary. The first pathway was based on the carbon-enriched eelgrasses and the salt marsh *Spartina maritima* as the primary carbon source (littoral pathway), while the second one was based on the carbon depleted terrestrial plant debris, C_4 estuarine macrophytes and phytoplankton (channel pathway). The two carbon-depleted invertebrate feeders *L. equulus* and *M. falciformis* from the Mngazi Estuary probably had phytoplankton and terrestrial vegetation as their primary carbon sources and conformed to the channel trophic pathway. The other fish taxa did not conform to any of the suggested pathways but instead represented a mixture of trophic pathways. Mixing of trophic pathways has been reported elsewhere in an estuary, e.g. in Plum Island Sound, Massachusetts USA (Deegan & Garritt 1997). The layout of vegetation in the Kariega is different from that in the Mngazi in that the former system has large intertidal areas partially separated from the channel by a band of eelgrass bed (Ter Morshuizen & Whitfield 1994). The Mngazi Estuary, on the other hand, has limited intertidal areas and only a few patches of sparse eelgrass in the lower reaches. The small intertidal area in the Mngazi and lack of separation from the channel zone is a possible reason for the mixing of the available primary carbon sources, hence the lack of a distinction between littoral and channel pathways. This results in a continuum of isotopic signatures with general tendencies towards certain sources of organic matter rather than a tight clustering around a particular organic source.

In general, the food web of the Mngazi Estuary appeared to be supported by a carbon source more enriched than that of the Mngazana Estuary (Figures 3.1 and 3.2). The most plausible source of carbon in the Mngazana Estuary was that derived from the extensive mangrove forest, which was more depleted than the adjacent terrestrial vegetation. Several authors have investigated the contribution of mangrove detritus as a primary carbon source of consumers in estuaries. Loneragan *et al.* (1997) and Chong *et al.* (2001) found that the contribution of mangrove detritus as a primary carbon source of juvenile prawns in estuaries was limited to the mangrove fringe and decreased in an offshore direction. Other studies indicated that mangrove derived detritus was not an important carbon source of estuarine filter feeders (Fry & Smith 2002) and fiddler crabs (France 1998). Zooplankton selected phytoplankton over the mangrove detritus component of suspended organic matter in Gautami Godavari Estuary and adjacent Kakinada Bay, India (Bouillon *et al.* 2001). The results of this study indicated that mangroves made an important contribution as a primary carbon source of the fishes. Although mangrove trees were not the dominant carbon source for any of the sampled fishes in this study, they still play an important role in trapping and stabilising sediments as highlighted by Newell *et al.* (1995).

CHAPTER 4: GENERAL DISCUSSION

It is well documented that the fish community structure in estuaries reflects the physical and chemical characteristics, as well as the biological interactions, within these systems. Some of the factors that have been found to influence the species composition and diversity (number of species) of fishes in estuaries include biogeographic position (e.g. Shao *et al.* 1997, Harrison 2003), mouth status (e.g. Bennett 1989, Potter *et al.* 1993), estuary size (e.g. Whitfield 1983), habitat diversity (Whitfield 1986, Jaureguizar 2003), turbidity (e.g. Cyrus & Babler 1987a, 1987b; Castillo-Rivera 2002) and salinity (e.g. Griffiths 2001, Whitfield 1998).

The main hypotheses tested in this study included: (1) that estuary mouth status influences fish community structure in estuaries, such that there will be differences between the fish communities within permanently open estuaries and those in estuaries with mouths that sometimes close; (2) littoral vegetation plays a major role in the carbon cycling in estuaries; (3) mangroves are an important carbon source for fishes in estuaries, such that the isotopic values of consumers in a mangrove estuary (e.g. Mngazana) will be different from those of consumers in a non-mangrove estuary (e.g. Mngazi); (4) biogeography is a primary determinant of fish species composition in estuaries.

Since the majority of fish species inhabiting estuaries in South Africa and elsewhere in the world are marine taxa (Kennish 1986, Day 1981, Whitfield 1994) that spend part of their lives in these systems, and because of the close proximity of the Mngazi and Mngazana estuary mouths, a degree of similarity between the structures of the fish communities in these estuaries was expected. Although both systems derive their fish species from the same coastal marine stock, dissimilarities between the estuaries could arise from differences in their mouth status and the resultant hydrodynamics. Differences in hydrodynamics may have contributed to differences in the larval fish species diversity in four estuaries on the west coast of Taiwan (Tzeng *et al.* 2002). Similarly, Vorwerk *et al* (2003) found that mouth status was the single most important factor determining the community structure of fishes in estuaries on the Ciskei coast. The wide, deep and permanently open mouth is likely to be main reason for the higher recorded species diversity in the Mngazana Estuary when compared with the intermittently closed Mngazi Estuary. Similarly, the permanently open Knysna Estuary had more species than the neighbouring seasonally closed Swartvlei Estuary (Whitfield & Kok 1992).

The proportion of resident estuarine fishes has been found to increase with a decrease in the degree of connection between the estuary and the adjacent marine environment (Bennett 1989). Kok & Whitfield (1986) suggested that the numerical dominance of estuarine species in temporarily closed estuaries might be due to the increase in total foraging area following the inundation of intertidal habitats, which increases the size of nursery areas and the availability of invertebrate food sources. The Mngazi Estuary, with its more limited connection to the marine environment, had 18% more estuarine fishes (in terms of CPUE) than the neighbouring Mngazana Estuary (Tables 2.4 and 2.5). The greater success of estuarine species such as *G. aestuaria* in the Mngazi Estuary, when compared with Mngazana, can be attributed to factors such the weakness of the tidal action due to the narrow mouth opening. Reduced tidal exchange improves the survival of *G. aestuaria* larval stages that might otherwise be lost to the marine environment (Strydom *et al*. 2002). The narrow, shallow mouth would also limit the exchange of large piscivorous marine species, which are likely to enter the estuary during high tide and retreat back to the sea with the receding tide (Blaber *et al*. 1989). In addition, the submergence of intertidal vegetation would offer added cover to the estuarine species, which are normally small in size, thereby reducing predation by piscivorous fish and birds. The lower relative abundance of estuarine species in the Mngazana Estuary can therefore be attributed to the deeper, wider mouth, as well as the strong tidal exchange between the estuary and adjacent marine environment.

Because of the characteristic salinity fluctuations in the upper reaches of estuaries, this is a physiologically stressful environment to most marine and freshwater fishes inhabiting this zone. According to Skelton (1993) the Cape Region (which includes the Mngazi and Mngazana systems) is characterised by low fish species diversity, e.g. the Kei River contains only two freshwater taxa. A total of three freshwater species was captured from each of the Mngazi and Mngazana estuaries. This low representation of fish species in the upper reaches of both study estuaries (Chapter 2) can be attributed to the stressful salinity conditions that marine fishes are subjected to in this region and the low diversity of freshwater species from which potential recruits can be drawn. While in both estuaries the upper reaches had the least number of species, the number and composition of species found in the middle and lower reaches was similar. This situation is different to that found in many Australian estuaries where there were large differences in fish species composition in the different estuarine regions (Potter & Hyndes 1999, Thiel & Potter 2001, Roy *et al*. 2001). Thiel & Potter (2001) attributed the strong zonation to these Australian estuaries having three morphologically different regions, which result in major differences in the available habitats. In contrast to the situation in Australia, differences in the physico-chemical properties of the estuarine regions in the study systems were not as pronounced (Figures 2.1 and 2.2).

The South African coastline covers a range of climatic and oceanic conditions that influence the faunal communities found in estuaries of the subcontinent. The effect of the warm Agulhas Current along the east coast of South Africa, as well as the upwelling phenomena on the south and southwest coasts, have been identified as major factors influencing marine and estuarine temperatures and consequently the ichthyofauna of this region (Maree *et al.* 2000). In the Transkei region of the east coast of South Africa the Agulhas Current is situated close to the coast. Because of exchanges between the estuarine and marine environments, the influence of this current on fish species composition would be more pronounced in estuaries with permanently open mouths than in intermittently closed estuaries. Consequently, it was not surprising that the permanently open Mngazana Estuary had a higher proportion of tropical species than the Mngazi Estuary with its more limited contact with the marine environment (Chapter 2).

The Mngazi and Mngazana estuaries had higher species diversity compared with similar estuaries located further south. For example, the southwestern Cape permanently open Palmiet and the predominantly open Kleinmond estuaries (Bennett 1989) had fewer species than the Mngazi and Mngazana estuaries (Chapter 2). This result reinforces the accepted finding that species diversity decreases from KwaZulu-Natal around the Eastern and Western Cape to the Atlantic west coast (Day *et al.* 1981, Whitfield 1994), following the decrease in average sea temperatures. The upwelling events that frequently occur along the southeast and southern Cape coasts, together with the increasing offshore movement of the Agulhas Current in the Algoa Bay region, results in a temperature decline that may be a barrier to the westward distribution of tropical species. In a similar manner, the cool Benguela Current has been identified as a barrier to the distribution of tropical west African species into southwest coast estuaries (Harrison 2003). The subtraction of tropical species, which according to Day *et al.* (1981) constitute the bulk of estuarine ichthyofauna in southern Africa, is the primary reason for the decline in fish species diversity from the northeast to the southwest (Blaber 1981).

According to Harrison (2002), the study estuaries fall within the subtropical region, close to the warm temperate boundary situated at the Mdumbi Estuary (31°55'50"S; 29°12'58"E). The proximity of the biogeographical location of Mngazi and Mngazana estuaries to the warm temperate/subtropical boundary was mirrored by the presence of both temperate and tropical species (Chapter 2). In a survey of Transkei estuaries (excluding the Mngazi and Mngazana estuaries) conducted by Plumstead *et al.* (1991), the estuaries between the Mbashe and Mntafufu systems (i.e. within the subtropical region) were dominated by tropical species. This study has also shown that tropical taxa were the dominant species in the Mngazi and Mngazana estuaries. Plumstead *et al.* (1991) found that many tropical species such as *Valamugil seheli, V. robustus, Crenimugil crenilabus* and *Pomadasys kaakan* were rarely caught in southern Transkei estuaries. The scarcity of these species in southern Transkei could be linked to the transitional nature of this area, which represents the southern limit of these species distribution. The results from the Mngazi and Mngazana estuaries support this finding, and except for *V. robustus*, these species were either not found (*V. seheli, C. crenilabus)* or were found in very low numbers (*P. kaakan*). Other tropical species become progressively more abundant from the Kei Estuary northwards, including *Hilsa kelee* and *Thryssa vitrirostris* (Plumstead *et al.* 1991), both of which were found in large numbers in the study estuaries (Chapter 2).

Harrison (2003) determined that along the coast of South Africa, subtropical estuaries were dominated by fish of tropical origin and warm temperate systems by endemic species. Further analysis of these data revealed biogeographic differences in the contributions of estuary association categories to the species composition of fishes in estuaries. The transitional nature of the biogeographic position of the study sites was emphasized by the contributions of estuarine and tropical species to the overall fish assemblage (Figure 4.1). The percent contribution of estuarine species (Categories Ia and Ib) was highest in the cool temperate region, gradually decreasing to a minimum in the subtropical region. In contrast, the percent contribution of marine species (Categories II and III) was lowest in the cool temperate estuaries and higher in both warm temperate and subtropical estuaries. Stragglers (Categories IV and V) contributed the least in all three biogeographic regions (Figure 4.1). These differences may be related to the variable physiological effects that water temperature has on the various life-history categories, especially those species that occupy both the marine and estuarine environment at different stages of their life cycle. Estuarine resident species that are able to complete their entire life cycle within an estuary are generally most abundant in the cool temperate region, and this may be related to their avoidance of the upwelling events associated with the marine environment. In contrast, marine species in the cool temperate region cannot avoid upwelling events, and would therefore be subjected to the adverse effects of such events.

The abundance and diversity of fishes generally increases from a minimum in cool temperate regions to a maximum in tropical regions (Day 1981). Biological factors such as increased competition for resources as the number of species and their densities increase towards the tropics could also limit the distribution of estuarine species, as there is an overlap in the food sources that are utilised by both estuarine and marine fishes (Whitfield 1998). The increase in the number of piscivorous fishes from the cool temperate to the subtropical estuaries (Harrison 2003) may increase predation pressure on the estuarine species thereby contributing to the observed decrease in the number of estuarine species in the north-easterly direction. Further research is required before any conclusions can be reached on this aspect.

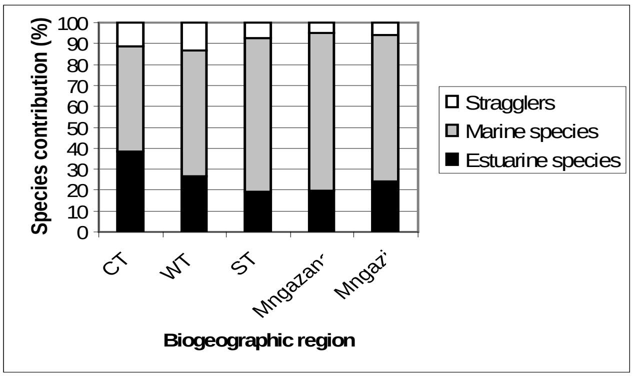

Figure 4.1. Fish species composition (%) based on life-history categories for each taxa in cool temperate (CT), warm temperate (WT) and subtropical (ST) estuaries (data from Harrison 2002), compared with species collected in the Mngazi and Mngazana estuaries during this study. Representative estuaries were selected from the cool temperate (Orange, Olifants, Berg), warm temperate (Knysna, Kromme, Kariega) and subtropical (Mntafufu, Mkomazi, Mlalazi) regions.

Although the ichthyofaunal sampling was only done in January and June and therefore does not constitute the full range of seasons, for simplicity, January will be termed summer and June will be referred to as winter and the temporal changes in the community structure between January and June will be referred to as seasonal variations. Seasonal changes in species composition and abundance have been related to factors such as seasonal temperature changes and spawning migrations (Kennish 1986, Marais 1983). The results of this study indicated differences in the proportions of temperate species during summer and winter (2001) in the Mngazana Estuary, with some species of temperate origin (e.g. *Lichia amia, Caffrogobius gilchristi, Caffrogobius natalensis, Psammogobius knysnaensis* and *Solea bleekeri*) only appearing during winter, while the contribution of tropical species remained the same. These results support the findings of Branch & Grindley (1979) who suggested that seasonal variations in fish species composition were related to tropical species moving south in summer when the waters are warmer and temperate species extending their ranges northwards in winter. Reduced numbers of *L. amia* in several south coast (warm temperate) estuaries during winter have been recorded (Marais & Baird 1980, Marais 1983), while a winter increase in abundance of this species in KwaZulu-Natal estuaries has been reported (Marais 1983).

The lack of changes in the proportion of tropical species during both summer and winter in the Mngazana Estuary (Figure 4.1) when compared with changes in the seasonal species composition recorded by Branch & Grindley (1979) is noteworthy. The increase in the overall proportion of tropical species during both summer and winter, and the decrease in temperate species recorded during this study, relative to the findings of Branch & Grindley (1979), may be an effect of global warming. Higher average water temperatures consistent with increased atmospheric temperature would favour tropical species, while limiting the northward penetration of temperate species during winter. Several authors have reported ecosystem effects in the marine, estuarine and terrestrial environments that have been associated with increasing atmospheric temperatures. The recorded increase in water temperatures of the North Atlantic Sea has been paralleled by a decline in cod stocks (O'Brien *et al*. 2000). Beaugrand *et al*. (2002) recorded a significant poleward movement of warm-water copepod species, coupled with a decrease in the number of cold-water species in the North Atlantic and European seas. An increase in the relative abundance of fish species with warm water affinities coupled with a decrease in the relative abundance of species with cooler water affinities was also recorded in the Tagur Estuary in Portugal (Cabral *et al*. 2001) and this was associated with increasing average water temperatures in this estuary.

Global warming effects on aquatic ecosystems, such as those reported in the above northern hemisphere temperate regions, have not been documented for southern Africa. This may be related to the fact that temperature is not as important a determinant of fish community structure in the subtropical and temperate regions of South Africa as it is in cold temperate regions of Europe and North America. Other expected effects of global warming that may have major ecosystem effects include changes in distributional overlaps of some predators and prey (Murawski 1993) and changes in the timing of ecological events which might result in a mismatch of larvae and their food supply (Blaxter 1992).

Unlike the Mngazana, the Mngazi Estuary displayed an increase in the proportion of tropical species and a decrease in temperate species during summer while temperate species increased and tropical species decreased during winter. The reasons for the observed differences in the seasonal variations of temperate and tropical species between the Mngazi and Mngazana estuaries are unclear, but the differences in the degree of connection to the marine environment possibly played a role. The warm Agulhas Current flows close to the shore in the Port St Johns area (Lutjeharms 1998), which includes the study sites. In this area the Agulhas Current water temperatures varies little between summer and winter months, with an average of 23°C during summer (December, January, February) and 20°C during winter months (June, July, August) (Christensen 1980). This current brings warm water to the estuaries thus moderating the effect of the decreased atmospheric and riverine temperatures during winter. Because of the more limited marine influence on the Mngazi Estuary, the riverine and atmospheric conditions (rather than the sea) would have had a greater impact on environmental conditions pertaining to this estuary, probably resulting in greater seasonal water temperature fluctuations than the more marine dominated Mngazana system. Due to the limited moderating effect of the marine environment in the Mngazi Estuary, water temperatures would be warmer in summer and cooler in winter than would be in the Mngazana Estuary and this potentially contributed to the heightened differences in the proportions of tropical and temperate species in the former during the summer and winter sampling occasions. Further research is, however, required before any conclusions can be reached on this issue.

In both estuaries, the $\delta^{13}C$ data suggested that fringing vegetation (including mangroves) was an important constituent of particulate organic matter (POM) found in these systems. This detritus was a primary food source for the fish taxa, either directly or indirectly depending on the species level in the food chain (Chapter 3). Other studies have indicated that mangroves do not contribute significantly as primary sources of carbon for a number of different estuarine taxa such as filter feeders (Fry and Smith 2002), fiddler crabs (France 1998) and zooplankton (Bouillon *et al.* 2001). Although this $\delta^{13}C$ study indicated similarities between the primary carbon sources utilised by fishes in the Mngazi and Mngazana estuaries, the isotopic values of invertebrate feeder species that were present in both estuaries varied more widely in the Mngazana Estuary when compared with the Mngazi Estuary (Chapter 3). The differences in isotopic range within the invertebrate feeders the two estuaries probably reflects the presence of more habitats and invertebrate species in the Mngazana Estuary than the Mngazi system (Branch & Grindley 1979). Most mugilid species had $\delta^{13}C$ values that suggested assimilation of enriched primary carbon sources such as benthic algae and eelgrass. This result supports previous studies that showed that mullets ingest benthic microalgae as well as eelgrass derived detritus and meiofauna (Masson & Marais 1975, Blaber 1976). The importance of benthic algae as a source of organic matter in estuaries has also been highlighted by Fry & Sher (1984).

Contrary to some studies (e.g. Paterson & Whitfield 1997, Vizzini *et al.* 2002), the isotopic values of fishes during this study formed a continuum, with some species tending towards being more depleted or enriched along the carbon isotope spectrum. Both Paterson & Whitfield (1997) and Vizzini *et al.* (2002) identified benthic/littoral and pelagic/channel carbon pathways in their study estuaries, and found that phytoplankton was an important component of the pelagic/channel pathway. Although phytoplankton was a component of POM (Chapter 3), the results of this study indicate that the contribution from this source was not substantial in the two estuaries. In contrast to phytoplankton, benthic algae and macrophytes were an important source of organic matter that was utilised directly and indirectly by fishes in both the Mngazi and Mngazana estuaries.

This study has succeeded in highlighting similarities and differences between fish communities of the Mngazi and Mngazana estuaries and put forward possible reasons for the structuring of these communities. Aspects of the structure of these fish communities that need further research include seasonality, trophic dynamics and the effects of global warming.

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